Comprehensive Sabine Watershed Management Plan

December 1999

Prepared for
Sabine River Authority of Texas in Conjunction with the Texas Water Development Board

Contract
#97-483-214

SRA96425

STATE OF TEXAS
THOMAS C. GOOCH
50668
LICENSED
PROFESSIONAL ENGINEER

12/8/99

Thomas C. Gooch

Thomas C. Gooch, P.E.
Freese and Nichols, Inc.

Jeff Taylor

M. Jeffrey Taylor
Brown and Root, Inc.

Freese and Nichols, Inc.
4055 International Plaza
Suite 200
Fort Worth, TX 76109
817/735-7300

In association with:
Brown and Root, Inc.
and
LBG-Guyton Associates

TABLE OF CONTENTS
COMPREHENSIVE SABINE WATERSHED MANAGEMENT PLAN

APPENDICES

FIGURES

TABLES

EXECUTIVE SUMMARY

In October 1996, the Sabine River Authority authorized Freese and Nichols, Brown and Root, and LBG-Guyton to conduct the Comprehensive Sabine Watershed Management Plan. This plan was performed in conjunction with the Texas Water Development Board. The purpose of this plan is to update the 1985 *Update of the Master Plan for the Sabine River*. Significant changes have taken place since 1985 that necessitated an update of SRA's overall plan for the Basin. This plan takes an overall look at Basin development including such issues as water need, water supply, the environment, conservation, economic development, and natural resources among others.

The first Master Plan for SRA was in 1955. It was basically a plan for reservoir development. Lake Cherokee was the only reservoir in the Basin at that time. The plan listed thirteen potential reservoirs. In 1962, SRA prepared a *Supplement to the Master Plan*, which revised the hydrologic analyses, yield determinations, and development plan for the Basin. In 1985 the *Update of the Master Plan for the Sabine River* was performed. By the time of the 1985 Master Plan Update, six of the original 13 reservoirs had been built. The 1985 Plan further recommended that four new reservoirs be developed prior to the year 2030. Those four reservoirs were Waters Bluff, Big Sandy, Bon Wier, and Big Cow Reservoirs. As stated above, significant changes have developed since 1985 that necessitate an update of that plan. Information from these previous plans as well as other published studies were used in this Comprehensive Plan. A complete list of references used in this study is included in Appendix A of the main report.

It is important to note that the Senate Bill One Regional Planning process, which was initiated during the course of this plan, has become the mechanism for water planning throughout the State. Any future projects that come from this comprehensive plan should be incorporated into the Senate Bill One Planning process to ensure that the projects become part of the Texas Water Plan.

In this Comprehensive Sabine Watershed Management Plan, the Sabine Basin is divided into two distinct geographic regions: the Upper Basin and the Lower Basin. The Upper Basin begins at the upstream end of the Basin and extents down to the headwaters of Toledo Bend

Reservoir in Panola County. The Lower Basin extends from the headwaters of Toledo Bend Reservoir to Sabine Lake at the Gulf of Mexico.

Development Plan and Recommendations

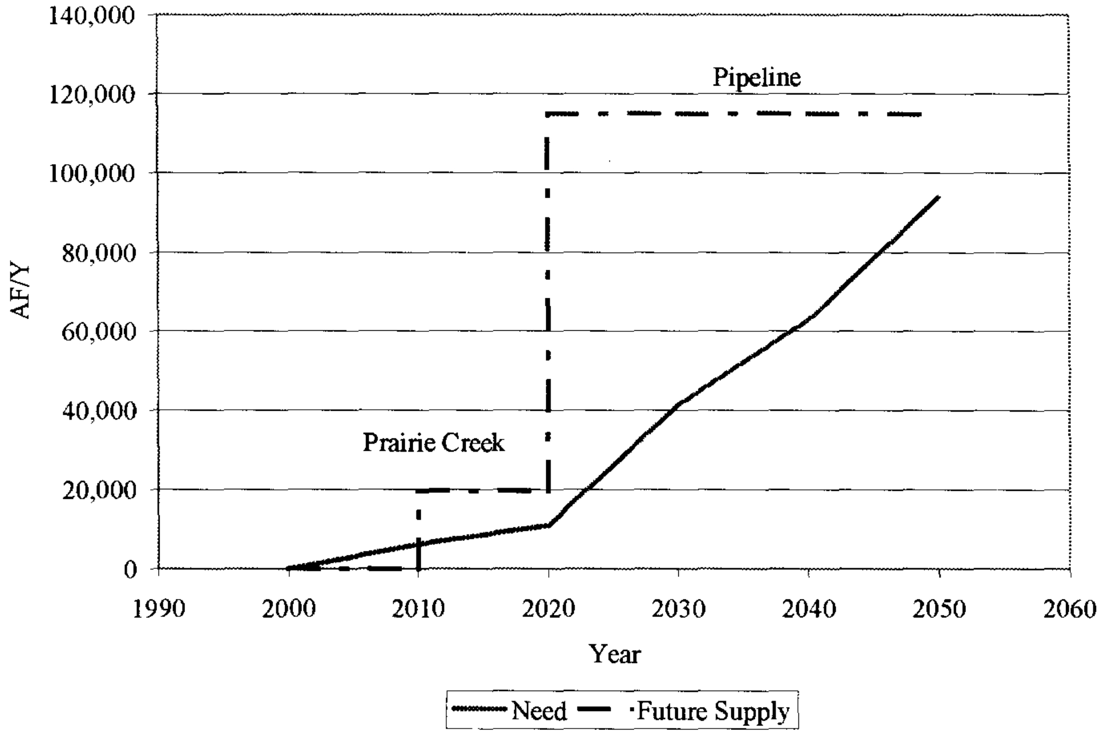
The Texas Water Development Board (TWDB) Consensus Planning population and water use projections were used as a basis for the determining the water needs in the Basin. Based on these projections, the Upper Basin water use will increase from 197,000 acre-feet per year in 1990 to 457,000 acre-feet per year in 2050. The Lower Basin water use will increase from 79,000 acre-feet per year in 1990 to 164,000 acre-feet per year in 2050. These water use projections do not include any use for instream flows and bay and estuary inflow needs, as those have not yet been determined by the state agencies.

Based on the detailed comparison of water needs and available supply, it was determined at this time no new supplies need to be developed in the Lower Basin. It was also determined that in the Upper Basin approximately 93,000 acre-feet per year of additional supply is needed by the year 2050. Potential sources for future water supply include new surface water reservoirs, diversions from the Sabine River, a transmission pipeline from Toledo Bend Reservoir, importation from outside the Basin, and some limited new ground water resources.

The most viable surface water project is a staged development of Prairie Creek Reservoir. This reservoir site was selected based on its location, cost analysis and assessment of developmental concerns. Its firm yield should provide approximately enough supply to meet projected 2023 demands. When the yield of Prairie Creek Reservoir is fully used, there are two options for further supply. One option is diverting water from the Sabine River to supplement the yield of Prairie Creek Reservoir. Diversions would provide some additional supply but would not meet all the projected needs. The other option, as shown in the Figure ES.1, would be to build a pipeline from Toledo Bend Reservoir to Prairie Creek Reservoir. As needs increase and larger demands develop, approaching the limit of the Prairie Creek supply, this pipeline should be constructed. This pipeline/reservoir system would be able to provide for all the projected additional demands in the Upper Basin through 2050. This option has become particularly attractive since SRA is now building a pipeline along the approximate route of this pipeline about half way to Prairie Creek Reservoir to serve an industrial customer. This represents a substantial cost savings to SRA for a future extension of this pipeline route to Prairie

Creek Reservoir. It would decrease the cost of this option even below the amount presented in this report.

Figure ES.1: Recommended Water Resource Development



Issues and recommendations identified in this plan are summarized below.

- SRA should continue to pursue negotiations with the City of Dallas to allow for selling the water in Dallas's contract that must remain in the Sabine Basin.
- SRA should begin the process of permitting Prairie Creek Reservoir. A new reservoir typically takes 10 to 15 years to permit and construct. Therefore, if Prairie Creek Reservoir is planned to meet the needs in the Upper Basin by 2010, the permitting process should be started by year 2000. Should significant obstacles arise to the development of Prairie Creek Reservoir, SRA should pursue the development of the State Highway 322 Stage II reservoir. SRA should talk to TXU Electric regarding their plans for the mining operations at the reservoir site.

- Prior to year 2010, SRA should re-evaluate the water use demand projections (the Senate Bill One projections that are accepted by TWDB) to assess changes in growth and future needs.
- SRA should review the results of the Water Availability Model (WAM) of the Sabine River when completed by TNRCC. This model will indicate if there is additional supply available from the Sabine River for future diversions or insufficient water for existing contracts.
- Based on the results of the re-evaluated demand projections and the WAM, SRA should evaluate the need, timing, and sizing of a transmission pipeline from Toledo Bend Reservoir with terminal storage at Prairie Creek. SRA should pursue the design, permitting and construction of the pipeline several years prior to the expected shortage.
- SRA should pursue discussions with various customers regarding reducing their contracted amount. If a portion of the entity's water contract is released, it could be used for water supply needs elsewhere in the Basin.
- SRA should initiate discussions with Wood County regarding the possibility of converting the Wood County Lakes to water supply. There is a potential 20,000 acre-feet per year of firm yield from these four lakes. However, this would impact the current recreational value of these reservoirs.
- SRA should encourage the Cities of Kilgore and Canton to work with the TWDB regarding the possibility of implementing ASR at their existing well fields to better utilize the surface water supplies during drought and high demand periods.

Other recommendations from this comprehensive report include the following:

- SRA should continue evaluating potential environmental mitigation areas for future water development projects. This will enable SRA to pursue surface water projects that require mitigation lands.
- Due to the uncertainty surrounding the current Bottomland Hardwoods status in the Sabine Basin and their importance to reservoir development, we recommend that an updated statewide study of Bottomland Hardwoods be conducted. SRA should request that the TWDB and/or the TNRCC conduct such a study.

- SRA should review its current contracting procedures to determine if modifications would result in more accurate allocations of firm yield to its customers. Currently, there are a number of large water contracts in the Upper Basin that are not being fully utilized.
- SRA should conduct volumetric surveys of their existing reservoirs to verify sedimentation rates. If the sedimentation rates are significantly different from those used in this plan, SRA should re-evaluate the firm yields of the affected reservoirs. The projected firm yield of Lake Tawakoni and Lake Fork in the year 2050 is approximately 18,100 acre-feet per year less than the current contracted amounts. This amount is not reflected in the total 93,000 acre-feet per year of projected water needs in the Upper Basin.
- SRA should continue their public participation and information programs to its customers and water and wastewater providers. Specific recommendations for expanding awareness of water resource management to water and wastewater providers are included in Section 9.3 of the main report. Recommendations for public participation are outlined in Section 12.2 of the main report and in a separate technical memorandum.
- SRA should implement an economic development program for traditional economic development utilizing local, regional, and state resources throughout the Sabine Basin. Further, this effort should be expanded to include eco-tourism to fully take advantage of the wealth of natural resources in the Basin.
- SRA should continue their current water quality monitoring program to assess water quality in the Basin. We recommend that SRA expand the special studies program to include more high flow or storm sampling studies for non-point source documentation, and SRA should pursue working with the TNRCC to develop regional tolerance values for bioassessment data.
- SRA should provide a technical assistance program to support water and wastewater providers in the Basin with information such as EPA and TNRCC regulations. Provide recommendations on treatment options to help small water supply entities comply with regulations. Host and/or facilitate any available TWDB and TNRCC seminars or workshops regarding water or wastewater treatment. Facilitate the

TNRCC plant optimization program within the Basin. If necessary, hire local consultants on an as needed basis to help with this technical assistance program.

- Train entities within the Sabine Basin that collect water quality data in approved data collection and analysis methods so that this information can be used in the Clean Rivers Program and SRA's Information System and GIS database.
- Host and/or facilitate TWDB drought management and contingency planning seminars to assist all of the water suppliers in the region with their plans.
- Study further the opportunity of implementing regional water and wastewater treatment facilities.
- Use GIS and other data analysis methods to continue monitoring for water quality problems that may be related to wastewater treatment effluent and septic systems, non-point sources, oil and brine spills, construction activities, and specific anthropogenic pollutants.

1.0 INTRODUCTION

In November of 1996, the Sabine River Authority of Texas authorized Freese and Nichols, Inc., to prepare a regional water management plan for the Sabine Basin that would address water supply issues through the year 2050. This project was partially funded by the Texas Water Development Board (TWDB). Brown and Root, Inc. and LBG-Guyton were subconsultants to Freese and Nichols on this project. This plan was intended to provide an assessment of the current water resources within the Basin, identify future water needs and provide a plan to address these needs. The contractual scope of work identified twenty tasks relating to water management within the Basin. These tasks, along with the primary responsible party are listed below.

• Task 1: Update General Basin Information	Brown & Root
• Task 2: Sabine Watershed Hydrology	Brown & Root
• Task 3: Ground Water Evaluations	LBG-Guyton
• Task 4: Water Rights	Freese & Nichols
• Task 5: Update Surface Water Information	Freese & Nichols
• Task 6: Population Projections and Water Use	Brown & Root
• Task 7: Water Treatment Needs *	Freese & Nichols
• Task 8: Wastewater Treatment Needs *	Freese & Nichols
• Task 9: Water Conservation	Brown & Root
• Task 10: Water Quality Program	Freese & Nichols
• Task 11: Mineral Resources Evaluation	Brown & Root
• Task 12: Environmental Considerations	Freese & Nichols
• Task 13: Public Participation	Brown & Root
• Task 14: Lake Sedimentation	Freese & Nichols
• Task 15: Aquifer Storage and Recovery *	LBG-Guyton
• Task 16: Information Resource Issues	Brown & Root
• Task 17: Surface Water Project Issues	Freese & Nichols
• Task 18: Other Water-Related Issues	Brown & Root
• Task 19: Preparation of the Management Plan	Freese & Nichols
• Task 20: Mitigation Banking	Freese & Nichols

* Tasks 7, 8 and 15 were funded by the TWDB.

This Comprehensive Sabine Watershed Management Plan is a compilation of the information and data assembled for the above listed tasks. Detailed discussions of the methodology and findings are presented in Task Memoranda, which were submitted to SRA as separate documents. This report contains an executive summary, the main report and appendices, and is generally organized in the following order: 1) an identification of existing conditions, 2) projected water demands, 3) existing water supplies, 4) identification of future needs or available supply, 5) potential future water supply, 6) other Basin issues (water and wastewater needs, environmental issues, etc.) and 7) recommended water resource management plan. A list of reports and information used in developing this report is included in Appendix A.

1.1 Background

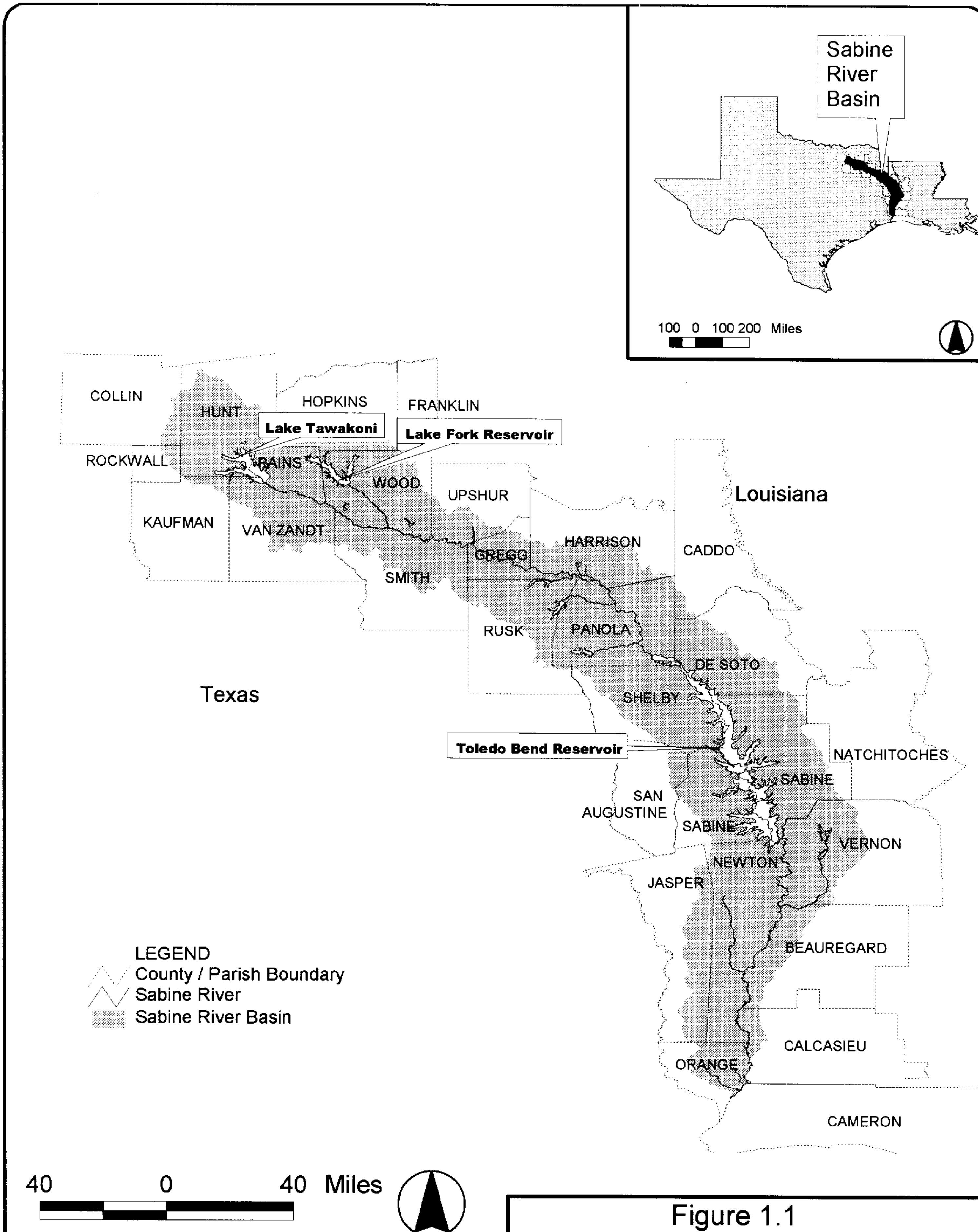
The Sabine River originates in Texas northeast of Dallas and flows southeast towards Logansport, Louisiana, then south to Sabine Lake. The crescent-shaped Basin, shown on Figure 1.1, is 48 miles across at its widest point and over 300 miles in length from its headwaters to its mouth at Sabine Lake. All or part of twenty-one Texas counties and seven Louisiana parishes are in the Sabine Basin. The total drainage area of the Basin is 9,756 square miles, with 7,396 square miles (76 percent) in Texas and 2,360 square miles (24 percent) in Louisiana. Table 1.1 lists the Texas Counties in the Sabine Basin.

The Sabine River Authority of Texas, the Sabine River Authority of Louisiana, and the Sabine River Compact Administration all have responsibilities relating to the waters of the Sabine Basin.

The Sabine River Authority of Texas

The Sabine River Authority was created by the Legislature in 1949 as an official agency of the State of Texas. The SRA was created as a conservation and reclamation district with responsibilities to control, store, preserve, and distribute the waters of the Sabine River and its tributary streams for useful proposes.

The SRA of Texas is governed by a nine-member Board of Directors, who serve six-year terms, with three members being appointed by the Governor of Texas every two years. Directors are required to reside within a county situated wholly or partially within the watershed of the Sabine River and are vested with the management and control of the affairs of the Authority.



Source: Texas Natural Resources Information System
www.tnris.state.tx.us/gispage.html
Environmental Systems Research Institute Data and Maps, Volume 1, 1996.

Figure 1.1
Sabine Basin Map

Comprehensive Sabine
Watershed Management Plan

The Authority, as an agency of the State, receives no appropriations and is not empowered to levy or collect any kind of taxes. Operating funds are primarily derived from the sale of raw and treated water, hydro-electric power, water quality services, and recreational and land use permit fees.

Table 1.1: Texas Counties in the Sabine Basin

Upper Basin	Percent of County in Basin	Lower Basin	Percent of County in Basin
Collin	6	Shelby	79
Rockwall	19	San Augustine	8
Hunt	69	Sabine	87
Kaufman	4	Jasper	55
Van Zandt	44	Newton	100
Rains	100	Orange	56
Hopkins	30		
Wood	97		
Smith	45		
Franklin	<5		
Upshur	27		
Gregg	90		
Rusk	49		
Harrison	42		
Panola	100		

The General Manager's office of SRA is responsible for the implementation of Board policy, project development, operations, management, accounting, and personnel management. The General Manager's office has two major branches: development and operations. The Development Branch evaluates existing water quantity and quality conditions throughout the river Basin by performing planning studies, monitoring and implementing water quality and pollution control activities, performing basin-wide resource management and new project development. A large portion of this work is accomplished through SRA's Environmental Services Division, which operates a water quality and biomonitoring laboratory as well as the Upper Basin Field Office and Lower Basin Field Office. The Development Branch is also responsible for economic development activities, public participation in SRA programs, and SRA's extensive Information System, GIS, and website. The Operations Branch is responsible for managing SRA-owned facilities. These facilities include Lake Fork Dam and Reservoir, Iron Bridge Dam and Lake Tawakoni, Toledo Bend Dam and Reservoir, and the SRA Canal System. (SRA Texas jointly with SRA Louisiana owns, operates, and maintains Toledo Bend Dam and Reservoir.)

The Sabine River Authority, State of Louisiana

The Sabine River Authority, State of Louisiana (SRA Louisiana) was created in 1950 for the purpose of conservation and reclamation of water within the Sabine watershed in Louisiana. The Board of Commissioners for SRA Louisiana is composed of 13 members appointed by the Governor of Louisiana, with one acting as chairman.

SRA Louisiana has the authority to conserve, store, control, preserve, and distribute the waters of the Sabine watershed in Louisiana. It also has the authority to provide works of public improvement for flood control, soil conservation, water supply to municipalities, navigation of the Sabine River, and hydroelectric generating facilities.

SRA Louisiana has three offices: an administrative office; an engineering office; and the Sabine River Diversion Canal office. SRA Louisiana's Administrative Office is responsible for water sales, recreational site construction and maintenance, shoreline management, and sewage regulation and permitting for all of SRA Louisiana. The Engineering Office at Toledo Bend administers all engineering, maintenance, and operational aspects of the waters in Toledo Bend Reservoir for SRA Louisiana. The Sabine River Diversion Office is responsible for managing the canal diversion system.

The Sabine River Compact

The Sabine River Compact was signed by representatives of the State of Texas and Louisiana, and the United States on January 26, 1953, and subsequently was ratified by the legislatures of the Sates and approved by the Congress of the United States. The major purposes of the Compact are to provide for the equitable apportionment between the States of Louisiana and Texas of the waters of the Sabine River and its tributaries; and, to establish a basis for cooperative planning and action by the States for the construction, operation and maintenance of projects for water conservation and utilization on the reach of the Sabine River common to both

States, and for the apportionment of the benefits therefrom. As used in the Compact, the word "Stateline" means the point on the Sabine River where its waters in downstream flow first touch the States of both Louisiana and Texas. The essentials of water apportionment provisions of the Compact are as follows:

- Texas retains free and unrestricted use of the water of the Sabine River and its tributaries above the Stateline, subject only to the provisions that the minimum flow of 36 cubic feet per second must be maintained at the Stateline.
- Any reservoir constructed in the watershed above the Stateline subsequent to January 1, 1953, will be liable for its pro rata share of the guaranteed minimum flow.
- Texas may either use the yield of these Upper reservoirs above the Stateline or allow it to flow downstream in the Stateline reach to a desired point of removal without loss of ownership.
- All free water (free water means all waters other than stored water) in the Stateline reach, without reference to origin will be divided equally between the two States.
- Neither State may contract a dam on the Stateline reach without the consent of the other State.
- Water stored in reservoirs constructed by the States in the Stateline reach shall be shared by each State in proportion to its contribution to the cost of storage.
- Should either State construct a reservoir on a stream tributary to the Stateline reach of the Sabine River, that State is entitled to the yield of the reservoir, but its share of the flow of the Sabine River is reduced by the reduction in flow resulting from the operation of the reservoir.
- Water consumed for domestic and stock water purposed is excluded from the apportionment under the Compact.

1.2 Sabine Basin Hydrology

Diverse climatologic, topographic, and geologic features that generally trend from north to south across the Sabine Basin characterize its hydrology. Climatologic factors such as temperature, rainfall, and humidity directly affect the rate at which water enters and leaves the river system. Topography and geologic factors define the river/stream system within the Basin, and can affect runoff, evaporation, sedimentation rates, reservoir storage capacity, and water quality.

Due to the natural diversity within the Basin, the hydrology of the northern region is significantly different from the southern region. These distinct regions are commonly referred to as the "Upper Basin" in the north and the "Lower Basin" in the south. The division between the two areas is the headwaters of Toledo Bend Reservoir. The Upper Basin is characterized by cool winters, hot summers, and seasonal rainfall patterns. The Lower Basin has a coastal climate with mild winters, high annual rainfall, and moderate to high humidity.

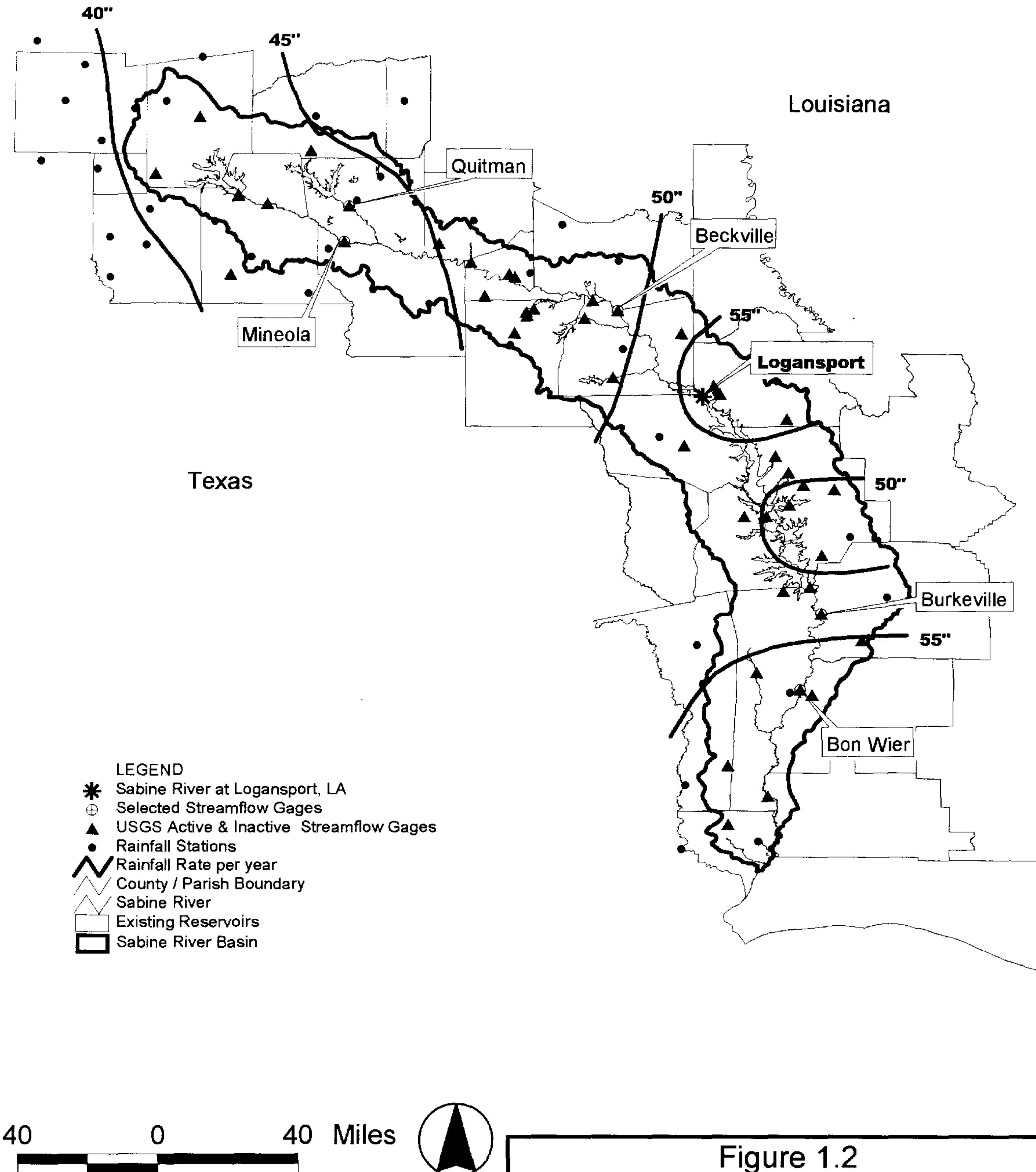
The average annual precipitation over the Sabine Basin ranges from a low of 40 inches in the far northern portion of the Upper Basin to 59 inches near the Gulf Coast, as illustrated on Figure 1.2. Generally, the heaviest rainfall occurs in the late spring, with the mid-summer months being the driest. The drier air and hot summers in the Upper Basin result in higher rates of evaporation than the Lower Basin. Average annual net reservoir evaporation rates range from a low of 8 inches per year at the Toledo Bend Dam to 32.5 inches per year at Lake Tawakoni. High evaporation and reduced rainfall and runoff can lead to drought conditions. Since 1900 several droughts have occurred in the Sabine Basin. Even with the recent drought periods, the droughts of the 1950s and 1960s still appear to be the most severe of meteorological record.

The local topography is characterized by a gentle slope north to south with elevations ranging from 700 feet above mean sea level at the Basin's headwaters to sea level in the coastal region. Land surfaces in the Upper Basin are rolling to hilly with streams in shallow valleys. The Lower Basin is generally flat with a fairly uniform slope.

Soils in the Basin fall into three main types: Blackland Prairie, East Texas Timberland, and Coastal Prairie. The Blackland Prairie group is located in the uppermost part of the Basin, and is comprised of various clayey soils. Due to their sloping nature and clay texture, these soils are susceptible to erosion. Documented sediment production rates for Blackland Prairie are three to five times greater than the other soil types in the Basin. The East Texas Timberland series soils are primarily light-colored sandy loam, and cover nearly 90 percent of the Basin. The light sandy texture of these soils makes them susceptible to heavy erosion when the natural vegetation is removed. Reforestation and reseeding efforts can reduce erosion in this region. The Coastal Prairie soils, located along the Gulf Coast, are primarily dark gray to black clays. This region, with its flat topography, poor drainage and grassy vegetation, has the lowest erosion and sedimentation rates in the Basin.

Streamflow in the Sabine Basin is measured by the United States Geological Survey (USGS) at continuous recording streamflow-gaging stations. There are currently 20 gages in the Basin. Sixteen of these stations are located in Texas and four are located in Louisiana. Of the 20 gages, five were selected as representative of discharge patterns in the Basin based on their location, period of record, and proximity to a rainfall monitoring station. The selected gages are Quitman, Mineola, Beckville, Burkeville and Bon Wier, and are shown on Figure 1.2.

The historical data from these flow gages indicate that the average annual streamflow varies from 426 cubic feet per second (cfs) at the Quitman gage on Lake Fork Creek in the Upper Basin, to 6,853 cfs at the Bon Wier gage in the Lower Basin. As shown on Figure 1.3, average monthly streamflows generally increase from November to May, then decrease from June to October. This follows typical rainfall patterns in the Basin. The largest streamflow discharges have occurred in the Lower Sabine River. Over 130,000 cfs of streamflow was recorded at the Ruliff gage in 1884. The second largest discharge of 117,000 cfs occurred on February 1, 1999, at the Burkeville gage. The third largest discharge event on record occurred in 1989, with a recorded flow of 116,000 cfs also at the Burkeville gage. Such extreme hydrologic flood conditions are less common in the Upper Basin.

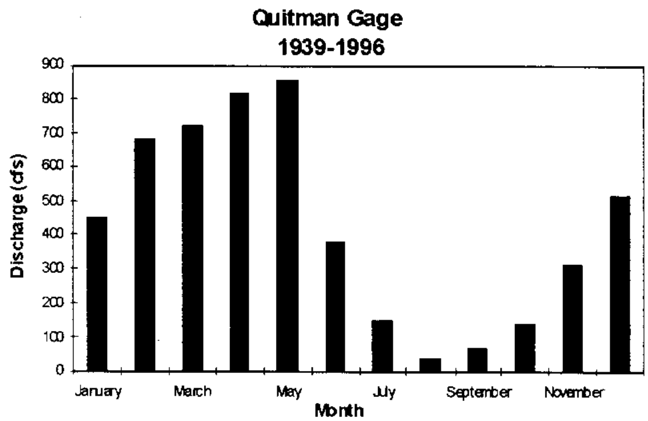


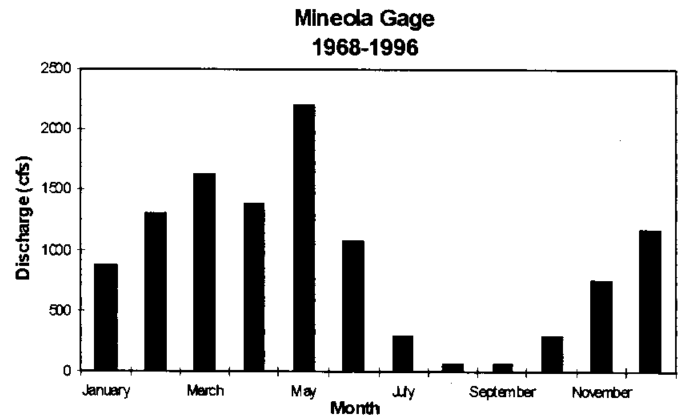
Source: National Oceanic and Atmosheric Administration (NOAA)
www.ncdc.noaa.gov/data/coop-precip/texas.txt

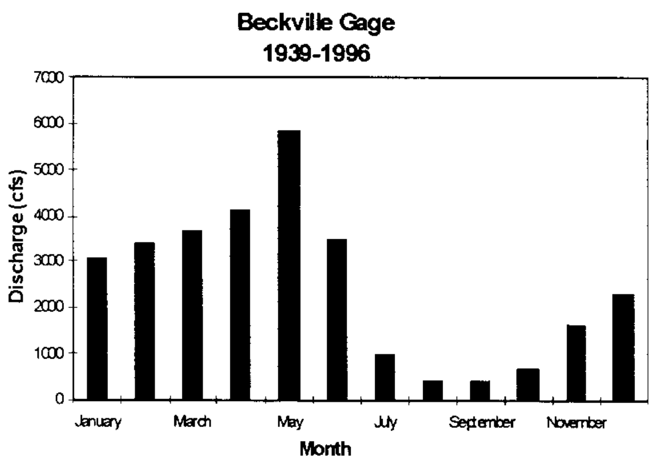
Figure 1.2
Rainfall Isoclines

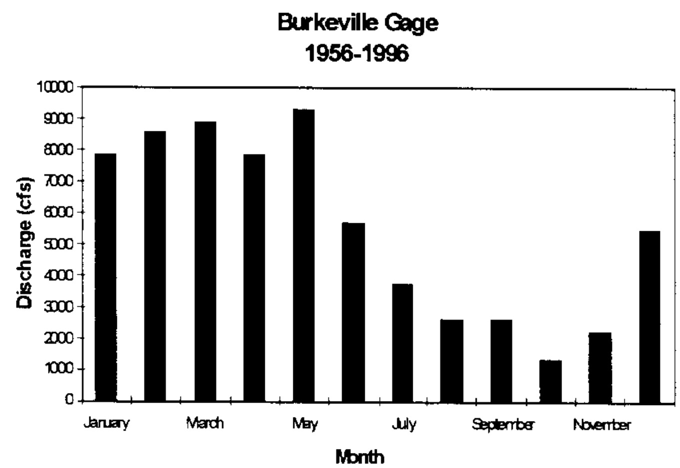
Comprehensive Sabine
Watershed Management Plan

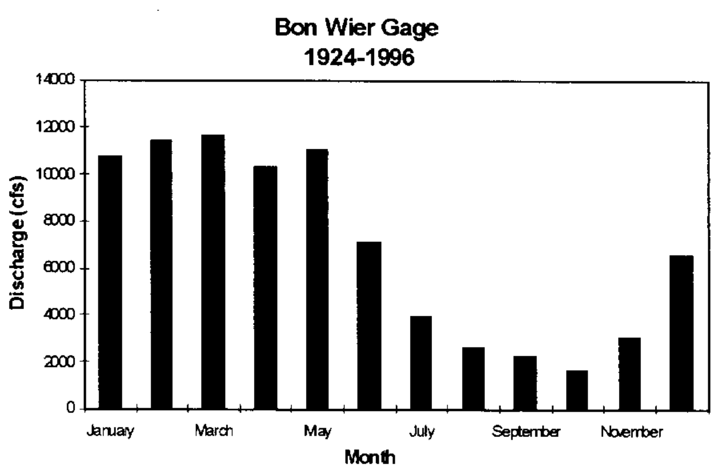
Figure 1.3: Average Monthly Streamflow Discharges











1.3 Water Rights

In Texas, surface water is public property, and the state confers the right to impound and to use surface water. In most instances state law requires a water right for the use of surface water in Texas. The various types of water right documents are known as certificates of adjudication, permits, term permits, and temporary permits.

As discussed in Section 1.2, the Sabine Basin consists of the Upper Basin and the Lower Basin. The Upper Basin can be further divided into three distinct areas: a) the area between the headwaters of Toledo Bend Reservoir and Lake Fork and Iron Bridge Dams; b) the area upstream of Lake Fork Dam; and c) the area upstream of Iron Bridge Dam. (Iron Bridge Dam is located at Lake Tawakoni.) By far the greatest number of water rights within the Basin are located between Toledo Bend reservoir and Lake Fork and Iron Bridge Dams. There are 163 water rights located in this area totaling 178,140 acre-feet per year. In the Lower Basin, there are only 15 water rights, but they total almost 900,000 acre-feet per year. Most of the rights in the Lower Basin are currently being used for industrial and irrigation purposes because municipal water use in the area is generally from ground water sources. A summary of the water rights by area is presented in Table 1.2. Details of the individual water rights are included in Appendix B.

Table 1.2: Summary of Water Rights in the Sabine Basin

Area	No. of permits	Annual Permitted Use (ac-ft/yr)							
		Mun	Mun/Ind	Ind	Irr	Mining	Other	Total	Out of Basin Use[3]
Lower Basin[1]	15	101,460	100,400	600,235[2]	96,817	0	0	898,912	
Lake Fork & Iron Bridge to Toledo Bend	163	109,254	0	62,068	5,456	701	661	178,140	
Above Lake Fork Dam	13	169,160	0	19,500	506	0	0	189,166	120,000
Above Iron Bridge Dam	5	242,259	0	0	250	0	0	242,509	190,480
Total – Sabine Basin	**196**	**622,133**	**100,400**	**681,803**	**103,029**	**701**	**661**	**1,775,727**	**310,480**

1. There is one hydroelectric right, permitted at 21,000 cfs.
2. E.I. DuPont de Nemours Company's right for 267,000 AF/Y of brackish water is in the Lower Basin, but is not included in this total because the brackish water is not a useable source of supply.
3. Permitted to City of Dallas for Out of Basin Use.

Mun – Municipal　　Mun/Ind – Municipal/Industrial　　Ind – Industrial
Irr – Irrigation　　Other – Recreation or Miscellaneous

Review of the historical use of water rights in the Sabine Basin indicates there may potentially be water available from existing unused or underutilized rights. There is a significant amount of permitted surface water that is not currently being used in the Lower Basin. At this time there is no shortage in the Lower Basin that needs to be met by this permitted but unused water or by additional water via a new water right.

The area between the headwaters of Toledo Bend Reservoir and Lake Fork and Iron Bridge Dams is currently the largest demand center in the Basin. It includes the Longview/Marshall/Kilgore area. Based on historical use, there appears to be several large water rights in this area that are only being partially utilized. However, at this time, most of this water is being reserved for the future use of the right holders and will not be made available for other users.

The area upstream of Lake Fork and Iron Bridge Dams is an area of fairly significant demand, including the City of Greenville and a number of rural water supply corporations. The historical records show that the use from Lake Tawakoni is steadily increasing. Historical use from Lake Fork has been less than 10 percent of the permitted amount; but essentially the entire permitted amount has been contracted. SRA has a joint use permit for Lake Tawakoni and Lake Fork. This permit enables SRA to provide water to Lake Fork and Tawakoni customers from either lake, which provides flexibility and efficiency in operating the system. Most of the entities with contracts in the lakes have secured this water for future demands. There is some potential for a limited amount of water becoming available from the two lakes. This is discussed further in Section 3.2 of this report.

Another potential source of water lies in the Louisiana portion of the Sabine Basin. There are three categories of water rights in Louisiana: absolute ownership, riparian, and state ownership. Ground water is considered part of the land and is owned outright under the Doctrine of Absolute Ownership. Surface waters are in the public domain and are "owned" by the State except where riparian rights were established before 1910. The lack of clear delineation between the rights of the public, state, and landowners makes ownership of surface water a complicated issue. The overlapping nature of these rights continues due to lack of legislation and legal precedents regarding them.

Louisiana's abundant supply of water has resulted in limited development of regulatory authority regarding surface water rights, sales or transfers. Water supply transfers between

Louisiana and other states are not excluded by State statute. Interstate transfers of Louisiana's waters may be possible through negotiated agreements with the state government. SRA Louisiana currently allows sales of its water interstate through Logansport, Louisiana to Joaquin, Texas. The location of Logansport is shown on Figure 1.2.

1.4 Mineral Resource Evaluation

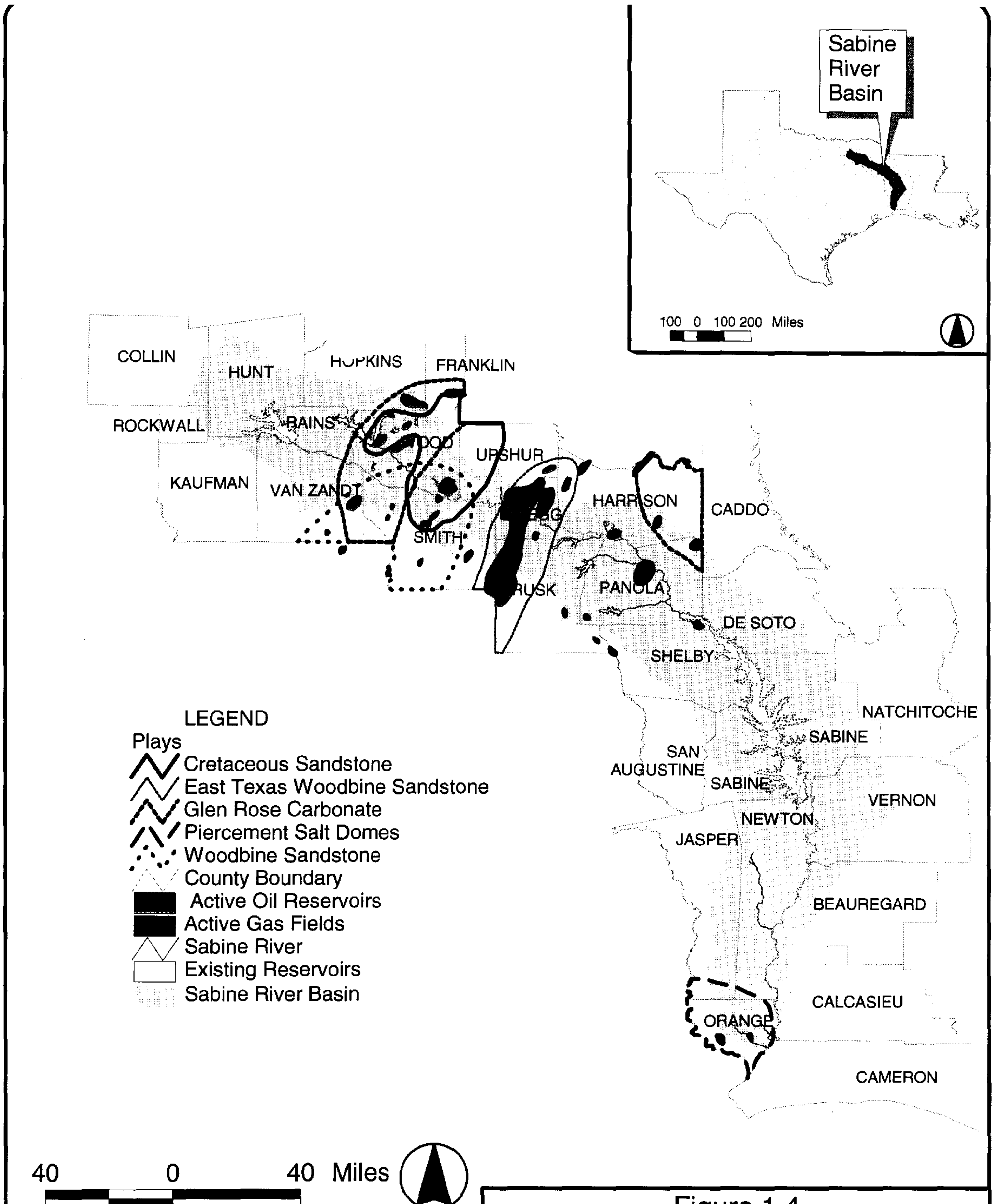
Mineral resources in the Sabine Basin include energy resources of oil, natural gas and lignite, and the industrial mineral resources of limestone, clay, sand and gravel, salt and sulfur. Historically, these resources have had an important role in the area's economy and growth. However, development of these resources also has the potential to impact future water supply projects and water quality within the Basin. An overview of the current mineral resource developments in the Sabine Basin was conducted to examine possible impacts and locations of on-going mining activities.

Oil and gas are a major energy resource in the Sabine Basin. Proven fields, such as East Texas Oilfield in Rusk and Gregg counties, continue to produce a large percentage of the Basin's total production. Overall, production in the Sabine Basin has declined over the past decade as prices of crude have fallen and proven reserves have been depleted. In 1997, there were ten of the 21 counties producing oil and gas, with the largest production in Gregg, Harrison, Rusk and Upshur counties. The generalized areas of reserves currently under development are shown on Figure 1.4.

The second major energy resource found in the Sabine Basin is lignite. Lignite, a low-grade coal, is present in both near-surface and deep-basin sediments. The near-surface deposits are most commonly developed due to more economical mining methods. There are five permitted lignite mines currently in operation in the Basin. The total 1996 production from these mines was 27.6 million tons, 51 percent of the state's total production. The locations of the active mines are shown on Figure 1.5.

Industrial minerals occurring in the Sabine Basin include limestone, clay, salt, sulfur, sand and gravel. These minerals are used as bulk products for construction materials, raw materials for ceramics, chemicals and fertilizers, refractors and specialty-grade rock and mineral products. As shown on Figure 1.6, there are significant deposits and active mining of these minerals throughout the Basin.

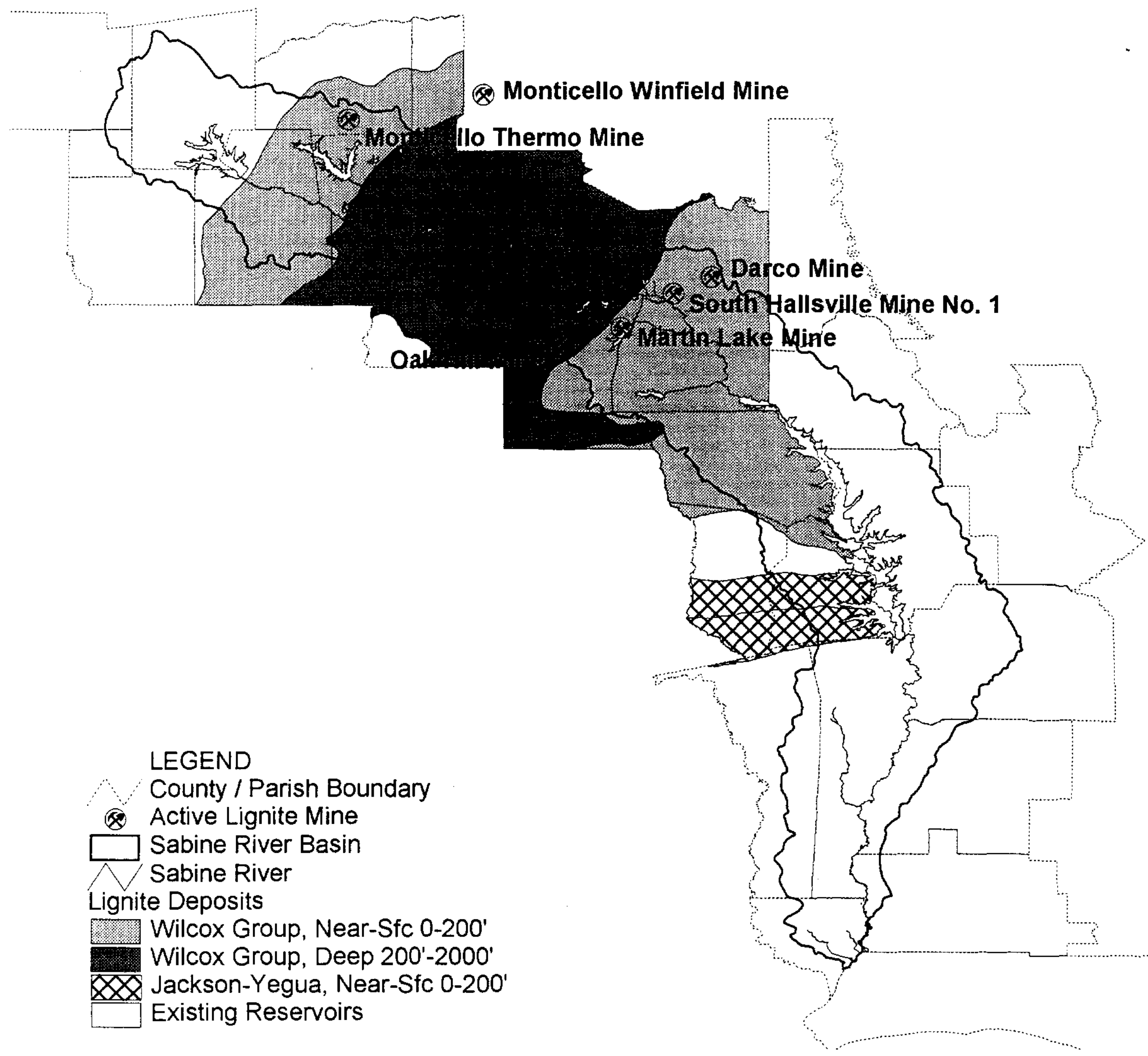
Consideration of mineral development should be given when planning the location of new water resource projects, such as reservoirs. Proper siting of water resource development projects reduces the risk of surface water contamination from contact with exposed minerals and mineral formations, and also reduces the cost of conflict mitigation. Potential impacts of mineral development on proposed reservoir sites are discussed in Section 7 of this report.

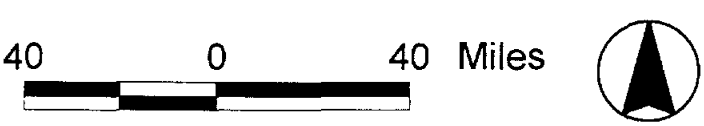


Source: Bureau of Economic Geology
Mineral Resources of Texas, 1979, and
Atlas of Major Texas Oil Reserves, 1983.

Figure 1.4
Oil and Gas Reservoirs

Comprehensive Sabine
Watershed Management Plan





Source: Bureau of Economic Geology
Mineral Resources Circular, No.76, 1985.

Figure 1.5
Lignite Mining

Comprehensive Sabine
Watershed Management Plan

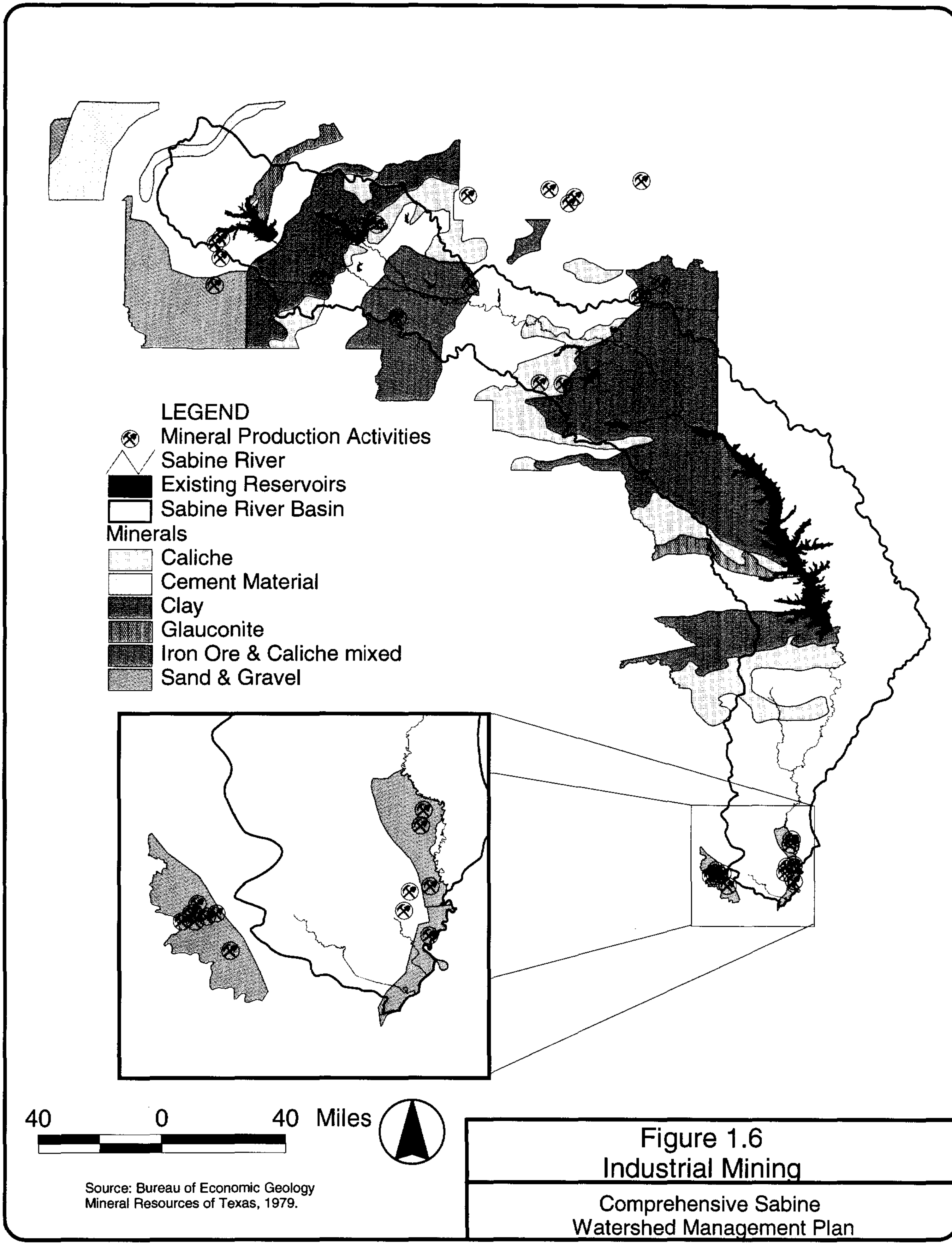


Figure 1.6
Industrial Mining

Comprehensive Sabine
Watershed Management Plan

2.0 WATER NEEDS

Water resource planning requires reliable forecasts of population and water demand. Increasing populations translate into increased water demand for municipal, residential and commercial uses. Community growth, the growth of local commerce and industry and the development of new industries all increase demand for water. Projections of the Sabine Basin's population growth and increased water demands for the planning period, 2000 through 2050, are needed to determine the extent of future water supply requirements within the Basin.

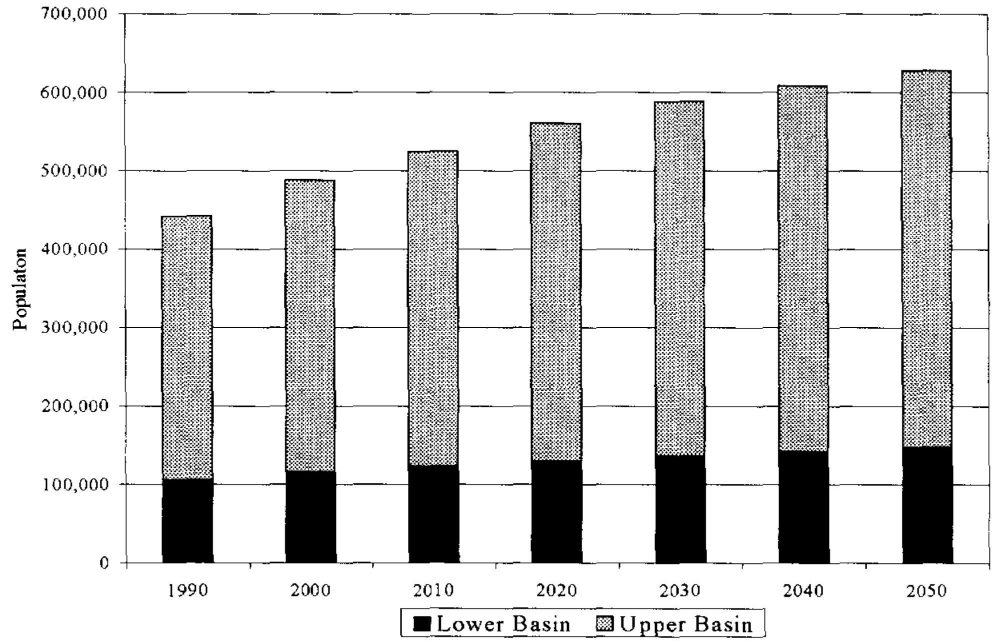
The Texas Water Development Board (TWDB), Texas Natural Resource Conservation Commission (TNRCC) and the Texas Parks and Wildlife Department (TPWD) have jointly developed a consensus-based planning approach for state-wide projections of population and water demands. These projections, termed the Consensus Planning Projections, forecast different water use scenarios by decade, and, as required by the TWDB, were used as the basis for water supply planning in this Management Plan.

2.1 Population Projections

Population projections developed through the Consensus Planning process are based on 1990 U.S. Census data. The 1990 population of the Sabine Basin was 442,358, with the Upper Basin accounting for 76 percent of the total population. Longview is the largest city in the Basin with a 1990 population over 70,000. Orange, Texas, is the only city located totally within the Lower Basin with a 1990 population greater than 5,000.

Future growth within the Sabine Basin is forecast at the county level using a standard demographic model. Population within the counties is allocated by cities (for cities over 1,000 in population). The remaining population is grouped in the "County Other" category. The demographic model generates four scenarios based on varying rates of migration: 0.0 Migration, 0.5 Migration, 1.0 Migration, and the "Most Likely" Scenario. For the Sabine Basin, the highest population growth occurs under the "most likely" scenario. This represents the most conservative conditions and therefore was used for planning purposes. Figure 2.1 illustrates the "most likely" population projections and indicates the Upper and Lower Basin share.

Figure 2.1: Projected "Most Likely" Population in the Sabine Basin



The "most likely" scenario predicts:

- The Sabine River Basin population will increase 42 percent from 1990 to a total projected population of 627,800 in 2050.
- The distributions of population between the upper and lower portions of the Basin will remain relatively stable.
- The counties near the Dallas-Fort Worth Metroplex will experience rapid rates of growth consistent with Metroplex development rates.
- Leading population growth in the Lower Basin is Orange County with a projected increase of 51 percent over the 60-year period.

2.2 Water Use

The TWDB defines six water use classifications for statewide water planning purposes: municipal, manufacturing, irrigation, livestock, steam power generation, and mining. Population, weather conditions and water conservation measures in force in a community largely determine municipal water use. Manufacturing, irrigation, livestock, steam power generation, and mining water uses are determined by broader economic and technological factors.

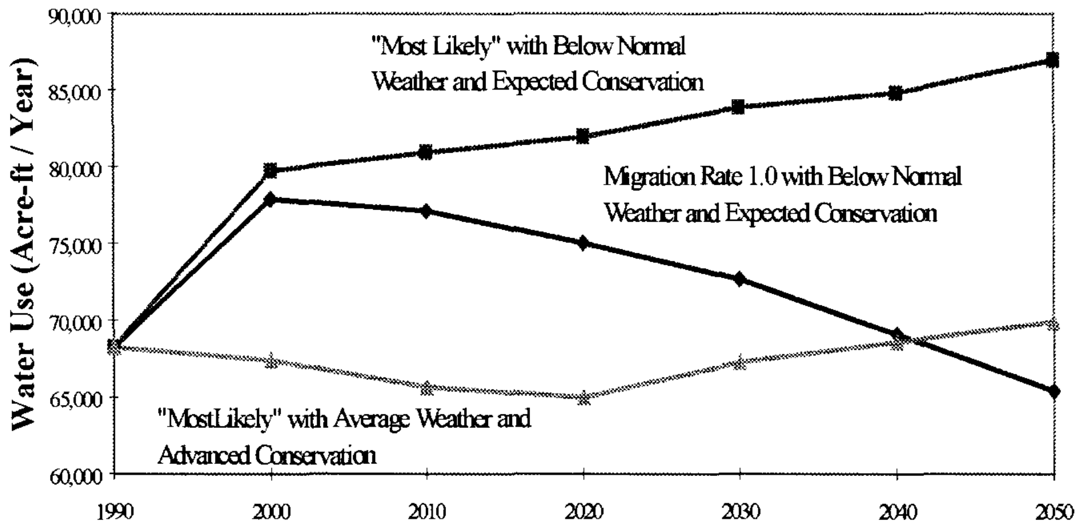
The TWDB prepared projected water requirements, by use type, for each decade from 2000 through 2050 as part of the *1996 Consensus-Based Update to the Texas Water Plan.* TWDB developed several scenarios for most water use types based upon specific population projections and water use assumptions. The "Most Likely" scenario projections were used for municipal, irrigation, livestock, power and mining water use categories. The projections selected for manufacturing water use represent the higher demand series, "Low Oil Price without Conservation".

Municipal Water Demands

City-specific municipal water use projections are based on a historical per capita water use rate multiplied by projected future population estimates. These estimates are adjusted to reflect the impact of climate and conservation activities on water demands in each community through different water use scenarios. To assess the effects of climatic conditions, two weather-related scenarios are developed: average rainfall patterns and below normal rainfall patterns. Adjustments to water use projections for conservation efforts are identified by three levels of conservation savings: plumbing code only, expected, and advanced. In addition, the different population projections are included in generating the range of municipal water use scenarios.

The TWDB's "most likely" municipal water use projections assume a per capita water use rate adjusted for below normal rainfall conditions and expected conservation savings. The municipal water use estimates are calculated by applying this rate to the "most likely" population scenario for each city with a population of 1,000 or more and for the "county other" category. This scenario generally represents the highest demand condition among the projections. To confirm this assumption for the Sabine Basin, the differences in municipal water required for three scenarios were evaluated. As shown on Figure 2.2, the "most likely" scenario with below normal weather and expected conservation, yields the highest water demand each decade over the next 50 years. Since this scenario represents the most conservative conditions and plans for providing water supply during drought conditions (below normal weather), it was used to predict municipal water use requirements for the Basin.

Figure 2.2: Sabine Basin Municipal Water Requirements by Scenario



Manufacturing Water Demands

Manufacturing water use forecasts are developed through national and statewide growth outlooks for various industry categories, regional and county shares of manufacturing output, historical water use records, and industry-specific water use efficiencies. Projections are based on two assumptions regarding industry growth; the expansion of existing capacity and new manufacturing locations, and the historical relationship between the price of oil and industrial activity continuing over the next 50 years. The TWDB prepared seven scenarios reflecting these assumptions: Baseline Oil Prices, with and without conservation, Low Oil Prices, with and without conservation, High Oil Prices, with and without conservation, and No Growth. The "Low Oil Prices without conservation" scenario projects the highest manufacturing demands for the Basin and was used to identify future water requirements in the Sabine Basin. For planning purposes, this is consistent with other demand scenarios chosen for the Management Plan and it recognizes the relative size and importance of manufacturing water use in the Basin.

Irrigation Water Demand

The TWDB irrigation water demand projections are based on crop-specific prices, yields, production costs, water costs, acres under production, irrigation systems and improvements in water use efficiency and Federal farm policy. TWDB's "most likely" scenario, which was used in this Plan, assumes changes in crop yields with prices, production costs and Federal farm payments remaining at current levels. It also assumes the adoption of advanced irrigation technology that will achieve very efficient water use. For the East Texas Region, this is generally not a good assumption. Much of the irrigation water use in southeast Texas is for rice farming. New technology and advances in agriculture are now allowing rice farmers to produce two crops per year on their land, which actually *increases* the water use. However, because TWDB required that Consensus Planning data be used in this study, the "most likely" scenario was used.

Steam Power Water Demand

Steam power electric generation water use projections were based on power generation demands and estimates of the water needed to produce the required power use capacity. Future demand is estimated using information on historical water use patterns by power generating plants, planned plant expansions, ownership of fuel sources used for generation, plant operating characteristics, and the impacts of energy conservation on demand. TWDB developed two projection series reflecting "high" and "low" water use scenarios.

In this study, the “high” use series was used for steam electric water use projections. This series assumes 1) the use of existing plant technology with no change in electric power generation capacity and 2) a water use rate equal to the average water use between 1988 and 1991.

Livestock Water Demand

Livestock water use is calculated by multiplying the projected number of livestock by the water consumption per unit of livestock. Water use for livestock is assumed to remain constant after the year 2000.

Mining Water Demand

The mining industry uses water for processing, leaching to extract ores, dust control and reclamation. Water use for mining makes up only about one percent of the overall usage of water in Texas. Therefore, a single series of projections was produced by TWDB. However, in the Sabine Basin mining represents a larger percentage of the total water demand.

2.3 Projected Water Demands

The water demands for the Sabine Basin are projected to increase approximately 124 percent from 1990 to 2050. The largest increases in water demands are attributed to growth in manufacturing, mining and power generation. The distribution between Upper and Lower Basin total demands varies only slightly over the 50-year planning period, with the Upper Basin demands representing 71 to 76 percent of the total. The increases in the Upper Basin are driven by water supply for manufacturing demands in Harrison County, increased mining demands in Wood and Panola counties, and power production in Gregg and Harrison counties. Through the public participation process for this study, there were some concerns raised over the high demand projections for manufacturing in Harrison County. For this reason, this plan recommends a staged water development program that has the flexibility to provide water supply as the demand occurs, without investing large amounts of capital for demand that may not ever materialize. The Lower Basin demands increase at a consistent rate over the planning period, with the largest increases occurring in Orange County. The distribution of water demands by use type for the entire Basin in 2050 is shown on Figure 2.3. The water use requirements by decade are shown on Figure 2.4.

Figure 2.3: Sabine Basin Projected 2050 Water Demand

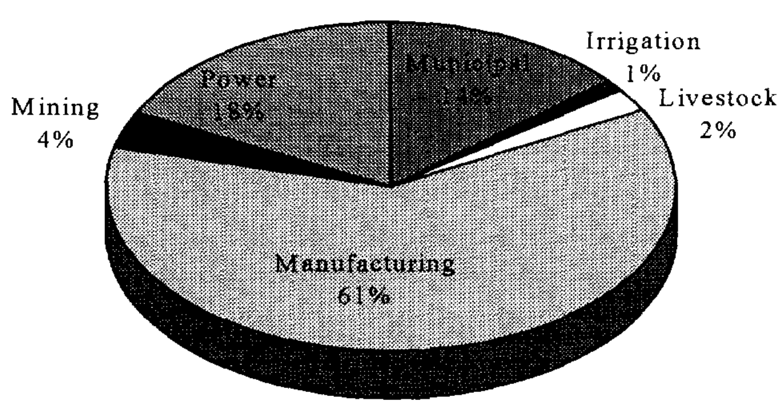
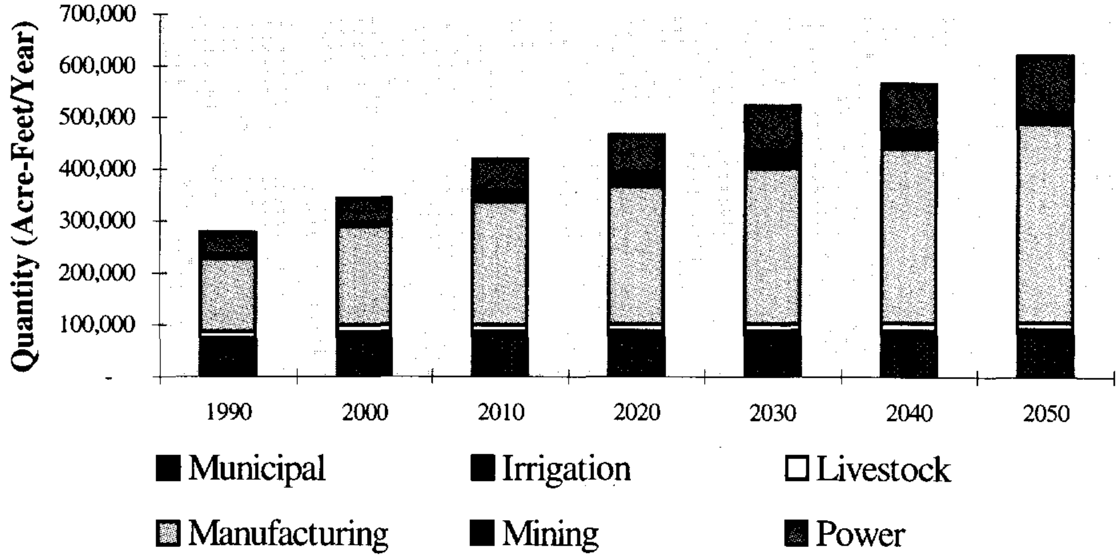


Figure 2.4: Water Use Requirements by Decade



The projected demands identified for the Upper and Lower Basins by water use type are presented in Tables 2.1 and 2.2. County level data for all projection scenarios and use type are included in Appendix C of this report.

Table 2.1: Sabine Upper Basin Water Demand by Use Type (acre-feet)

Decade	*Municipal*	*Irrigation*	*Livestock*	*Manufacturing*	*Mining*	*Power*	*Total*
1990	52,791	715	10,353	90,334	8,736	34,488	197,417
2000	62,533	714	11,327	133,808	7,920	38,300	254,602
2010	63,537	714	11,327	171,121	22,021	50,500	319,220
2020	64,558	714	11,327	192,241	27,431	55,500	351,771
2030	66,045	714	11,327	216,228	35,290	65,500	395,104
2040	66,750	714	11,327	242,239	34,513	65,500	421,043
2050	68,368	714	11,327	275,411	22,743	79,000	457,563

Table 2.2: Sabine Lower Basin Water Demand by Use Type (acre-feet)

Decade	*Municipal*	*Irrigation*	*Livestock*	*Manufacturing*	*Mining*	*Power*	*Total*
1990	15,438	5,568	2,386	50,487	28	5,574	79,481
2000	17,198	5,556	2,311	57,148	33	6,000	88,246
2010	17,390	5,241	2,311	64,826	33	10,000	99,801
2020	17,390	5,241	2,311	73,461	34	15,000	113,437
2030	17,795	5,167	2,311	82,942	35	20,000	128,250
2040	18,043	5,094	2,311	94,787	36	25,000	145,271
2050	18,592	5,024	2,311	107,997	37	30,000	163,961

3.0 EXISTING SURFACE WATER SUPPLIES

The existing surface water resources in the Sabine Basin include water supply reservoirs, recreational lakes, a canal distribution system, and the Sabine River and its tributaries. There are nine water supply reservoirs and four recreational lakes (the Wood County Lakes) in the Texas portion of the Sabine Basin. Two additional lakes are located in the Louisiana portion of the Basin. SRA owns and operates Lake Fork and Lake Tawakoni in the Upper Basin, and the jointly owns and operates Toledo Bend Reservoir with Sabine River Authority, State of Louisiana. These three reservoirs provide over 90 percent of the total permitted surface water supply in the Basin. SRA also owns and operates a canal system located in the Lower Basin. The locations of the existing reservoirs for the Upper and Lower Basins are shown on Figures 3.1 and 3.2, respectively.

3.1 Sedimentation

Sedimentation does not appear to be a serious problem throughout the Sabine Basin. The measured suspended sediment load indicated by the published records is relatively low. The total silt load, including bed load, at the Logansport gage station (in the middle of the Basin) averaged 0.20 acre-foot per square mile per year over a 34-year period. The low erosion throughout the Basin is associated with the East Texas Timberlands and Coastal Prairie soils within the Basin. Lake Tawakoni is the only reservoir located in the Blackland Prairie land resource area. This area typically has sediment production rates three to five times greater than those for the East Texas Timberlands or Coastal Prairie areas. Recent hydrographic studies conducted by TWDB for Lake Tawakoni and Lake Cherokee indicated average sedimentation rates of 1.72 and 0.97 acre-feet per year per square mile of watershed drainage area, respectively. When taking into account only the contributing land in the drainage area (excluding the lake area), the sedimentation rates are 1.86 and 1.01 acre-feet per year per square mile of drainage area. These rates are higher than previously published siltation rates for the reservoirs.

The disagreement between the predicted and measured rates of silt accumulation may be attributed to possible inaccuracies in calculating the original capacities of the lakes. The methodology used when the lakes were constructed was generally less exact than the system now used by the TWDB, and this could account for at least part of the difference. It is also possible that the siltation rates previously projected are low.

This uncertainty can be resolved through additional volumetric surveys with techniques comparable to those now being used by TWBD. For purposes of this study, the future capacities of Lake Tawakoni and Lake Cherokee were estimated based on the latest siltation rates. The capacities of the other lakes were based on the rates published in *Inventory and Use of Sedimentation Data in Texas* (Texas Board of Water Engineers, 1959). The average sedimentation rates and estimated future capacities for the Sabine Basin reservoirs are presented in Table 3.1.

Table 3.1: Estimated Sedimentation Rates and Future Capacities of Reservoirs

Reservoir	Drainage Area (sq. miles)	Sedimentation Rate	Year Began Filling	Capacities (ac-ft)		
		(ac-ft/yr/sq. mi)		Initial	2000	2050
Lake Tawakoni	756	1.86	1960	936,200	884,200	819,200
Lake Fork	493	0.30	1979	675,800	673,000	666,300
Toledo Bend	7,178	0.12	1966	4,447,000	4,412,300	4,361,300
Wood Co. Lakes			1962			
Quitman	31	0.50		7,440	6,900	6,100
Holbrook	15	0.60		7,990	7,700	7,200
Hawkins	30	0.50		11,890	11,300	10,600
Winnsboro	27	0.50		8,100	7,600	7,000
Lake Gladewater	35	0.50	1952	6,950	6,100	5,300
Lake Cherokee	158	1.01	1948	49,295	40,800	32,700
Martin Lake	130	0.40	1974	77,500	76,200	73,800
Lake Murvaul	115	0.40	1957	45,840	44,000	41,800
Brandy Branch	4	1.00	1982	29,513	29,500	29,400
Lake Vernon	112	0.40	1963	57,000	55,400	52,200
Anacoco Lake	209	0.40	1951	24,000	22,100	20,200

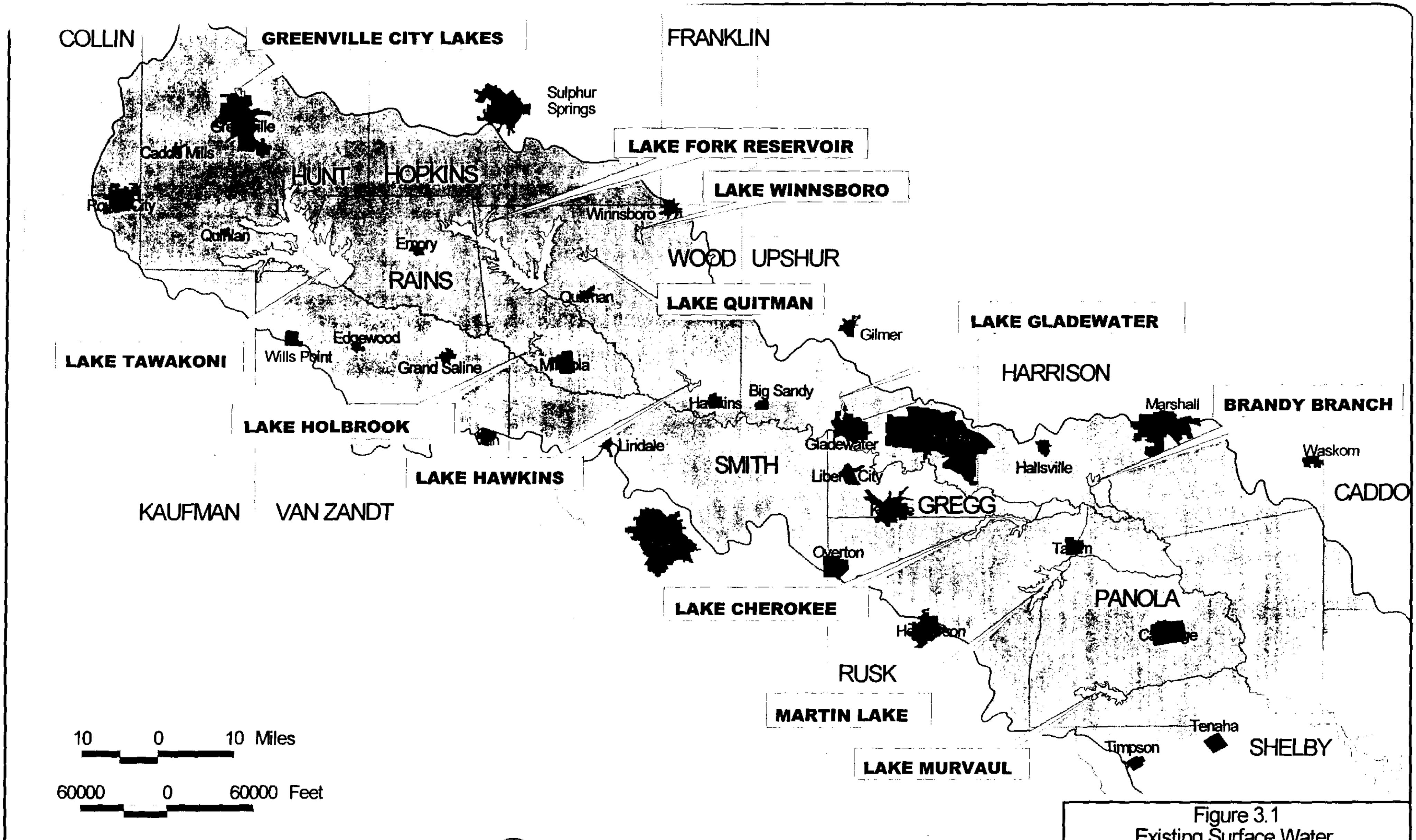
3.2 Existing Lakes and Reservoirs

A review of existing water supply reservoirs was conducted, and their hydrologic characteristics are summarized in Table 3.2. The current and projected yields of most of the reservoirs were updated based on estimated or actual (if available) sedimentation. Contracted amounts for each reservoir were inventoried to assess potential available supply. A brief description of each reservoir follows.

3.2.1 SRA Reservoirs and Canal System

Lake Tawakoni

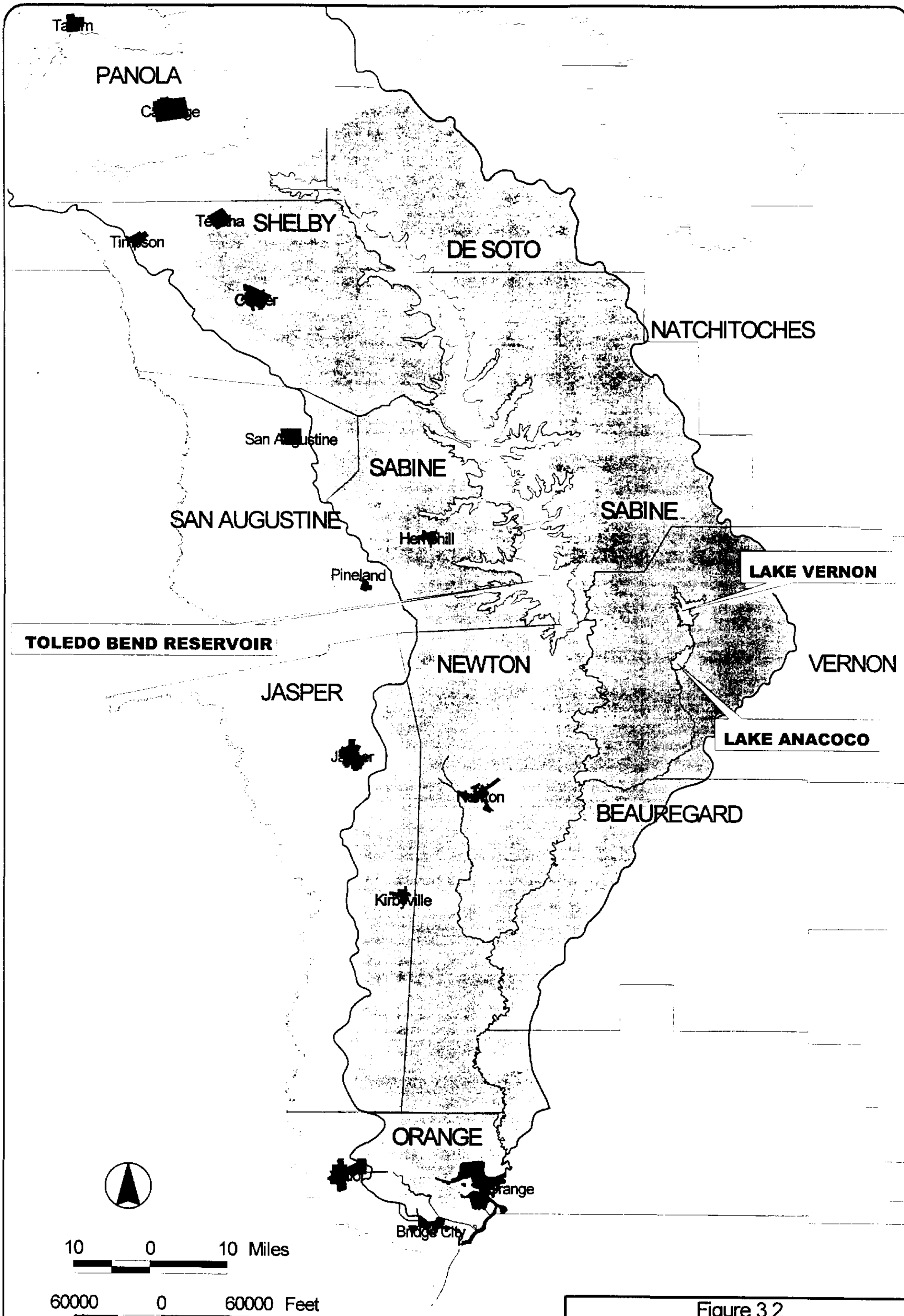
Lake Tawakoni, impounded by Iron Bridge Dam, is used for municipal water supply. It is located on the Sabine River in Rains, Van Zandt, and Hunt Counties, nine miles northeast of Wills Point, Texas. According to the 1997 TWDB hydrographic survey, the reservoir has a surface area of 37,879 acres and a capacity of 888,137 acre-feet at the conservation level of 437.5 feet mean seal level (msl). The SRA permit for Lake Tawakoni is for 238,100 acre-feet per year for municipal use. The City of Dallas is entitled to 80 percent of Tawakoni's yield. The remaining permitted amount is fully contracted by SRA to local municipal users. Although SRA has had several requests for additional supply from Lake Tawakoni, this reservoir does not have any water available for meeting



Source: Environmental Systems Research Institute Data and Maps, Volume One, 1996.

Figure 3.1
Existing Surface Water
Reservoirs - Upper Basin

Comprehensive Sabine
Watershed Management Plan



Source: Environmental Systems Research Institute Data and Maps, Volume 1, 1996.

Figure 3.2
Existing Surface Water Reservoirs - Lower Basin

Comprehensive Sabine Watershed Management Plan

Table 3.2: Summary of Existing Reservoirs and Lakes in the Sabine Basin

Reservoir	Location (counties)	Stream	Drainage Area (SM)	Conservation Pool			Permitted Use (ac-ft/yr)	Yield Estimate (ac-ft/yr)	
				Surface Area (Acres)[1]	Capacity (ac-ft)[1]	Elev (msl)		1997	2050
Lake Tawakoni	Rains/Van Zandt/Hunt	Sabine River	756	37,879	888,137	437.5	238,100	230,891	221,459
Lake Fork	Wood/Rains/ Hopkins	Lake Fork Creek	493	27,690	675,800	403	188,600	187,962	187,031
Toledo Bend	Newton/ Shelby/Sabine	Sabine River	7,178	181,600	4,477,000	172.0	750,000	1,043,300[2]	1,043,300
Greenville City Lakes[3]	Hunt	Cowleech Fork	Not applicable	505	6,969	537	4,159	1,200 (2,800)	1,200 (2,800)
Quitman Holbrook Hawkins Winnsboro	Wood	Dry Creek Keys Creek Little Sandy Big Sandy	31 15 30 27	814 653 776 806	7,440 7,990 11,890 8,100	395.0 372.0 343.75 419.0	0 0 0 0	3,710 3,285 8,035 5,760	NA
Lake Gladewater	Upshur	Glade Creek	35	800	6,950	300.0	1,679[4] (3,358)	6,900	NA
Lake Cherokee	Rusk/Gregg	Cherokee Bayou	158	3,083	41,506	280	62,400[5]	39,400	NA
Martin Lake	Rusk/Panola	Martin Creek	130	5,101	77,500	306	25,000	25,000[6]	25,000
Lake Murvaul	Panola	Murvaul Bayou	115	3,820	45,840	265.3	22,400	27,787	27,050
Brandy Branch	Harrison	Brandy Branch	4	1,242	29,513	340	11,000	11,000[7]	18,000[7]
Lake Vernon	Vernon Parish, LA	Anacoco Bayou	112	4,250	57,000	245	0	61,655	NA
Anacoco Lake	Vernon Parish, LA	Anacoco Bayou	209	2,600	24,000	194	0	28,025	NA

1. Area and capacity reported are original area and capacity, except for Lake Tawakoni and Lake Cherokee. For these two reservoirs the values are from the latest sediment survey.
2. Texas' portion of Toledo Bend's yield. Total yield from this reservoir is 2,086,600 ac-ft/yr.
3. Greenville City Lakes are a series of off-channel reservoirs that are used to impound diversions from Cowleech Fork Sabine River. Operational modifications could increase the firm yield to 2,800 ac-ft/yr.
4. Current permit amount. City of Gladewater has applied for an increase in their permit to 3,358 ac-ft/yr.
5. Permitted amount is based on the construction of two reservoirs. Only one reservoir was completed.
6. The firm yield is higher than this, but the reservoir cannot be operated at firm yield due to power plant operation requirements.
7. Natural yield is minimal. 11,000 ac-ft/yr is currently being imported from Cypress Basin. This amount may eventually increase to 18,000 ac-ft/yr.

the needs of new customers or the additional needs of existing customers. Based on results from the 1997 hydrographic survey, the firm yield of the lake is estimated to be 230,891 acre-feet per year.

In 1997, the Texas Water Development Board completed a volumetric survey of Lake Tawakoni for SRA, which provided updated area-capacity data and sedimentation rates. The reservoir yield was evaluated using the new area-capacity data, evaporation data from the 1985 Master Plan, and runoff data from the 1985 Master Plan that was adjusted for impacts of the full use of upstream water rights. Upstream return flows, which are not included in this yield analysis, are approximately 3,800 acre-feet per year. Based on this data, the current firm yield of Lake Tawakoni is estimated to be 230,891 acre-feet per year. When the 1997 area-capacity data was projected out at the historical rate of sedimentation, the 2050 yield is estimated at 221,459 acre-feet per year.

The SRA has a Joint Use Permit for Lake Tawakoni and Lake Fork which allows them to serve any of the customers from either of the lakes so long as use does not exceed the total permitted use amount. This allows customers who are closer to one lake, but have a contract to use the other, to use the closer lake for its supply and cut down on transmission costs. When actual use approaches the permitted amount, a pipeline connecting the two reservoirs will have to be constructed to maintain the current flexibility in operating the reservoirs jointly.

Lake Fork Reservoir

Lake Fork is located on the Lake Fork Creek in Wood, Rains, and Hopkins Counties, five miles west of Quitman, Texas. Lake Fork Reservoir has a surface area of 27,690 acres and a storage capacity of 675,800 acre-feet at the conservation level of 403 msl. The SRA holds a permit for 188,660 acre-feet per year for municipal and industrial water supply. The City of Dallas has a contract with SRA for 131,860 acre-feet per year, which is 70% of Lake Fork's permitted amount. However, 11,860 acre-feet per year of Dallas' contracted amount cannot be transferred out of the Sabine Basin. This water will be used to meet local demands when Dallas establishes a price under which SRA can sell this water. Almost the entire remaining amount in Lake Fork is committed through contracts or options. The current yield is estimated at 187,962 acre-feet per year. The 2050 yield is estimated at 187,031 acre-feet per year.

Toledo Bend Reservoir

Toledo Bend Reservoir is used for municipal, industrial, irrigation and hydropower purposes. The reservoir is located on the Sabine River in Sabine, Newton and Shelby Counties in Texas, and Sabine and Desoto Parishes, Louisiana. Toledo Bend Reservoir has a storage capacity of 4,477,000 acre-feet and a surface area of 181,600 acres at the conservation level of

172.0 feet msl. The SRA holds a water right for 750,000 acre-feet per year. Texas' full yield in the lake is 1,043,300 acre-feet per year, so there is an additional 293,300 acre-feet per year of unpermitted yield. SRA has attempted unsuccessfully to obtain a permit for this unpermitted yield. Currently SRA has contracted only 2,119 acre-feet per year to local municipal users and 17,922 acre-feet per year to an industrial customer. The rest of the right and additional yield is available for future. Over the past 29 years Hydropower operation at Toledo Bend Dam has provide an average of over 240,000 megawatt-hours per year. This renewable energy source has saved approximately 13 million barrels of oil, worth about $200 million.

SRA Canal Division

SRA has a right to divert 100,400 acre-feet per year for municipal and industrial purposes and 46,700 acre-feet per year for irrigation purposes through its SRA canal supply system. The water is diverted from the Sabine River in southern Orange County through an intake channel to the SRA pump station. From there it is lifted into the SRA Canal which travels through Orange County and delivers water to SRA's customers. A study conducted for SRA in 1995 showed that the conveyance limit of the canal system is 309 million gallons a day, or 346,000 acre-feet per year (Brown & Root, 1987). The canal has an average top width of 40 feet and average bottom width of 20 feet. The top of the canal is at 26 feet msl at the pumping station. SRA has a permit to divert 100,400 acre-feet per year for municipal and industrial use and 46,700 acre-feet per year for irrigation use. Out of its municipal and industrial permit, SRA has committed 60,000 acre-feet per year.

3.2.2 Other Sabine Basin Lakes and Reservoirs

Greenville City Lakes

The City of Greenville owns and operates six off-channel storage reservoirs for a portion of its municipal water supply. Presently only Reservoirs 4, 5 and 6 are used for water supply. Reservoirs 4 and 6 also serve as cooling water basins for the City's power plant. The City's diversion point is located on the Cowleech Fork Sabine River between U.S. Highway 69 and Sate Highway 34. The water flows by gravity from the diversion point into the interconnected reservoirs. The City's water right allows a total impoundment of 6,969 acre-feet and diversion and use of 4,159 acre-feet per year. Based on a recent evaluation of the Greenville Lakes by Freese and Nichols, the estimated firm yield of the reservoirs under current operating conditions is 1,200 acre-feet per year. Minor modifications to the operation of the system would increase the firm yield to 2,800 acre-feet per year. The reservoirs have a combined surface area of 505 acres.

Greenville has historically used most of their permitted use from these reservoirs each year, and the City is currently studying the options to increase the yield of its reservoirs, including the possibility of building an additional off-channel reservoir for additional supply.

Wood County Lakes (Quitman, Holbrook, Hawkins, and Winnsboro)

The four Wood County Lakes were built in 1962 by Wood County for the purposes of recreation and flood control. The reservoirs are owned and operated by Wood County. The capacities and surface areas of the reservoirs are listed in Table 3.2. Yield estimates were calculated for this study by updating the information from the 1985 Master Plan. The results indicate that as much as 20,000 acre-feet per year of firm yield may be available from these lakes for water supply if the permits were amended to include consumptive water use. It is unlikely that these recreational lakes would be operated at firm yield due to the decreased aesthetic and recreational benefits associated with significant lake level fluctuations. However, these reservoirs, if converted to water supply, could be very beneficial in meeting the local needs that cannot be met by Lake Fork.

Lake Gladewater

Lake Gladewater was completed in 1952 and is owned and operated by the City of Gladewater. It is located in the northwest part of the City of Gladewater in Upshur County. At the conservation level of 300 feet msl, it has a storage capacity of 6,950 acre-feet and an area of 800 acres. The City holds a water right for 1,679 acre-feet per year for municipal water use. Previous yield studies as well as the yield estimates done for this study, indicate the yield of the lake is around 6,900 acre-feet per year. The City has recently submitted an official request to TNRCC to increase their permitted amount to 3,358 acre-feet per year. If this increase is granted, approximately 3,500 acre-feet per year of firm yield would be unpermitted. However, it is unlikely that the City of Gladewater would allow the lake to be operated at its full yield because it would decrease the aesthetic value of the property around the lake, which the City leases to homeowners.

Lake Cherokee

Lake Cherokee is privately owned and operated by Cherokee Water Company, which is comprised of 1,500 stockholders, each of whom pay a yearly rental for one parcel of waterfront land. Many of the stockholders live on these waterfront parcels. The dam is located on Cherokee Bayou about six miles upstream of the mouth. The reservoir is in both Rusk and Gregg Counties and is 12 miles southeast of Longview. According to the 1997 hydrographic survey by TWDB, Lake Cherokee has a capacity of 41,506 acre-feet and an area of 3,083 acres at the conservation level of 280 msl. The original water right permit was granted based on the construction of two reservoirs, but only one was actually built. Therefore the 62,400 acre-feet per year right far exceeds the actual yield of the existing lake. Cherokee Water Company has contracts totaling 18,000 acre-feet per year for municipal and industrial purposes.

In December 1997, HDR Engineering performed a study of Lake Cherokee using the 1997 TWDB volumetric survey. HDR determined the firm yield of the lake is 39,400 acre-feet per year. However, the firm yield is based on emptying the lake during a critical drought, and the owner of the lake, Cherokee Water Company, is opposed to any operational changes that would increase lake level fluctuations. Based on the company's preferred operating condition of limiting drawdown to 4.5 feet, HDR concluded there is no additional supply available from Lake Cherokee beyond the currently contracted amount of 18,000 acre-feet per year.

Martin Lake

Martin Lake was constructed in 1974 and is owned and operated by Texas Utilities Electric Company (TU Electric) for the purpose of cooling at a steam electric power plant. The reservoir is located in Rusk and Panola Counties on Martin Creek. It has a capacity of 77,500 acre-feet and an area of 5,101 acres at the conservation level of 306 feet msl. TU Electric holds the right to divert and consumptively use 6,250 acre-feet per year for each 750-megawatt power unit. At the time the permit was granted there were to be three power units installed with the fourth planned for some time in the future. At this time, it is unclear if or when the fourth will be built. TU is currently in the process of requesting a change to the permit that will give them the right to 25,000 acre-feet per year regardless of how many power units are present. Yield studies on Martin Lake indicate the firm yield is greater than the 25,000 acre-feet per year permit. However, TU must maintain a certain lake level for their pumps to operate, and cannot operate the lake at its firm yield. Due to these constraints, there would not be any additional supply available from Martin Lake for the needs of the Sabine Basin.

Brandy Branch

Brandy Branch Reservoir was built in 1982. It is owned and operated by Southwestern Electric Power Company (SWEPCO) to provide cooling for SWEPCO's Pirkey Power Plant. It is located on Brandy Branch in Harrison County about 10 miles southwest of Marshall, Texas. It has an area of 1,242 acres at the conservation elevation 340 feet msl. The reservoir has a very small drainage area (four square miles) and thus has very little natural inflow. The inflow to the reservoir is supplemented by the interbasin transfer of 11,000 acre-feet per year from the Cypress Basin. SWEPCO buys this water from Northeast Texas Municipal Water District out of Lake O' the Pines. The water right for Brandy Branch allows for the impoundment of a 29,513 acre-foot reservoir and consumptive use of 11,000 acre-feet per year. There is an option to increase the interBasin transfer and the consumptive use to 18,000 acre-feet per year. All of this water would be used for solely for the power plant, therefore, no additional supply is available from Brandy Branch for the needs of the Sabine Basin.

Lake Murvaul

Lake Murvaul was completed in 1958 and is owned and operated by Panola County Fresh Water Supply District Number One, which has a water right to divert and use 22,400 acre-feet per year from the lake. The reservoir is located entirely in Panola County and is about 10 miles southeast of Carthage, Texas. Lake Murvaul has a capacity of 45,840 acre-feet and an area of 3,820 acres at the conservation level of 265.3 feet msl. The District has a contract with the City of Carthage that grants to the City the exclusive right to withdraw water from the lake. The District is prohibited from selling water to any other entity without express consent from the City, and then the water can be sold only to entities within Panola County. The City's contract allows them to withdraw 13,440 acre-feet per year. This amount will supply the projected peak-day needs of Carthage through year 2030. The remainder of the permitted amount (8,960 acre-feet per year) could be used to meet other needs within Panola County.

3.2.3 Louisiana Lakes and Reservoirs

The Sabine River Authority, State of Louisiana (SRA Louisiana) has jurisdiction over water resources in the Louisiana portion of the Sabine Basin. This includes the Louisiana share of Toledo Bend Reservoir, two additional reservoirs and a canal diversion system.

SRA Louisiana Canal Division

The Louisiana Sabine River Diversion Canal System provides water for local industries and irrigators in southwestern Louisiana. It is located about four miles south of Starks, Louisiana on the Old Sabine River. The system consists of approximately 40 miles of conveyance facilities. The diversion system's primary users are industries in the Lake Charles area and farms and private users along the canal route. In fiscal year 1995-1996, the Louisiana Canal System used a total of 52,309 acre-feet of water.

Lakes Vernon and Anacoco

Lake Vernon and Anacoco Lake are located in Vernon Parish on Anacoco Bayou, a tributary of the Sabine River. Lake Vernon is located upstream of Louisiana State Highway 8, and its outflow flows down Anacoco Bayou to Anacoco Lake. Currently, both lakes are managed by the Anacoco Prairie Game and Fish Commission and maintained by the Louisiana Department of Transportation and Development.

Lake Vernon was constructed in 1963 for recreation and industrial water supply. It has a capacity of 57,000 acre-feet and an area of 4,250 acres at the conservation level of 245 feet msl. The lake is used for boating, fishing, and hunting. There are no existing diversions from Lake Vernon, but new industrial development in Leesville may eventually require water from the lake.

Anacoco Lake is downstream of the mouth of Prairie Creek on Anacoco Bayou and has a drainage area of 209 square miles. The Louisiana Department of Wildlife and Fisheries built this lake in 1951 for recreational use. The lake has a storage capacity of 24,000 acre-feet and an area of 2,600 acres at the conservation level of 194 feet msl. Anacoco Lake remains a recreational lake with fishing and boating activities. Historically, during low flows in the Sabine River, a local industry has withdrawn water from Anacoco Lake. Currently there are no diversions from the lake and none planned.

3.3 Committed Supplies

As shown on Table 3.3, the surface water supplies located in the Upper Basin are nearly fully committed, while there is ample supply available in the Lower Basin. Of the two reservoirs operated by SRA in the Upper Basin (Lake Tawakoni and Lake Fork), there is only a small amount of uncommitted supply, and this does not account for reduced yields in the lakes due to sedimentation. If the sedimentation rate continues as projected, by year 2050 the yield of the Lake Tawakoni-Lake Fork system may actually be 18,100 acre-feet per year less than the current contracted amount. The only other reservoir in the Upper Basin with available supply within its existing permit is Lake Murvaul. All of the yield from Lake Murvaul is committed to the needs of Panola County and cannot be used for needs in other areas. Lake Gladewater has some available supply based on its yield calculation. However, the City of Gladewater will probably not allow use of the full reservoir yield if it adversely affects lake property owners. A possible future water supply source is the Wood County Lakes. If these lakes were to be converted to water supply reservoirs, there is a potential supply of 20,000 acre-feet per year. Due to the recreational nature of these lakes it is unlikely that Wood County would agree to operate the lakes at full yield for water supply purposes.

In the Lower Basin there is an abundant supply. Toledo Bend Reservoir alone has over 747,000 acre-feet per year of uncommitted supply within its existing permit. There is an additional 293,300 acre-feet per year of potential supply available through the unpermitted yield of the reservoir. The SRA Canal system also provides a source of additional supply in the Lower Basin.

Table 3.3: Committed Surface Water Supply - Texas Sabine Basin

Existing Water Supply	Permitted Amt (ac-ft/yr)	Total Committed Amount (ac-ft/yr)	1997 Available Supply (ac-ft/yr) Permit	Additional Yield
Upper Basin:				
Lake Tawakoni	238,100	238,402	0	0
Lake Fork Reservoir	188,660	188,190	169[1]	0
Greenville Lakes	4,159	4,159	0	0
Wood Co. Lakes	0	0	0	20,790
Lake Gladewater	3,358[2]	3,358	0	3,542
Lake Cherokee	62,400[3]	18,000	0	0
Martin Lake	25,000	25,000	0	NA
Brandy Branch	11,000	11,000	0	0[4]
Lake Murvaul	22,400	13,440	8,960[5]	4,650[5]
Run of River				
Longview	20,547	20,547	0	NA
Eastman Chemical	134,500	134,500	0	NA
Other	13,374	13,374	0	NA
Total (Upper Basin)	723,438	669,410	9,129	28,982
Lower Basin:				
Toledo Bend	750,000	20,041	729,959	293,300[6]
SRA Canal System	147,100	59,532	87,568	0
Total (Lower Basin)	897,100	79,573	817,527	293,300

1. This is the available supply above the joint permit with Lake Tawakoni, but does not include 11,860 acre-feet from Dallas' contracted amount.
2. Gladewater currently has a permit for 1,680 ac-ft/yr. They have applied for an increase in their permit to 3,358 ac-ft/yr.
3. The permitted amount was based on the construction of two reservoirs. Lake Cherokee has an estimated yield of 39,400 ac-ft/yr. Operators of Lake Cherokee indicate there is no additional supply above the contracted 18,000 ac-ft/yr.
4. SWEPCO has a contract with NTMWD to increase the amount of water imported from Lake O' the Pines to 18,000 ac-ft/yr, if needed. However, this water is solely for the power plant operation and will not be used for water supply purposes.
5. Water from Lake Murvaul must remain in Panola County and is not available for needs outside the county.
6. SRA has been unsuccessful in previous attempts to obtain a permit for this additional yield.

3.4 Contracting Issues

Historical records of water use in the Upper Basin indicate there are several currently underutilized water rights in this area. Generally, this water is being reserved for the future use of the right holders and cannot be considered as available supply. While there may be special situations where the right holder may no longer need the full amount of their existing water right and would release a portion for other uses, the present water rights system used in Texas encourages water users to secure contracts or options for all possible future needs. Releasing some water contracts may jeopardize the holder's ability to re-contract for this water at a later date.

The standard procedure for contracting water is to set an amount that the customer will take on an annual basis. If the reservoir is a customer's secondary source of supply, then generally the contracted amount is not needed every year. A change in this procedure could allow the customer to designate how much it would need over a period of several years. This approach will generally lead to a smaller allocation of firm yield under the terms of the agreement, leaving as much as possible of the yield available for other uses. This concept would work only in cases where SRA reservoirs were a customer's secondary source of supply. This method of contracting is not consistent with the current way TNRCC normally operates, and may take considerable time and effort to work out with TNRCC.

Another option to make water available would be for SRA to renegotiate a contract before its expiration date if the customer requests it, is not using the water, and does not plan to use the water in the future. Any water released through this means could be available to other entities that have already made requests for the water.

A more questionable option for making more water available is similar to TNRCC's short-term permits. The idea is to make water available that is contracted but not currently being used. This unused water could be "subcontracted" to other entities for use in the short-term until the time when the first entity needs the water. Many of the entities who have contracts with SRA from Lake Fork or Tawakoni Reservoir have intended that water for future use as far as 20 years from now. That water could be used by other entities in the interim period. SRA could facilitate this "subcontracting", and all parties would have to agree to the terms of the contracts. One important consideration for this option would be the ability to terminate these short-term contracts at the end of their terms. If an entity is completely dependent upon the source of supply, it would be difficult for the SRA to terminate the supply to that entity and return it to the original contracted customer, even though the contract was specified as a short-term contract.

4.0 EXISTING GROUND WATER SUPPLIES

Significant quantities of variable quality ground water occur throughout most of the Sabine Basin. Much of the recoverable ground water within the Basin has already been developed and is considered "existing supply". The vast majority of ground water in East Texas is contained in two major aquifers: the Carrizo-Wilcox aquifer and the Gulf Coast series of aquifers including the Catahoula, Jasper, Evangeline, and Chicot. Additional quantities of ground water can be obtained from lower yielding minor aquifers including the Nacatoch, Queen City, Sparta, and Yegua. General locations of these aquifers are shown on Figure 4.1. Outcrop locations for these aquifers are shown on Figure 4.2. For the purposed of this study, outcrop locations were considered equivalent to recharge zones.

Currently there are 182 entities in the Sabine Basin that use ground water for all or a portion of their water supply. As shown on Table 4.1, most of these users are rural water supply corporations. Very few cities and even fewer industries rely on ground water due to limitations in quantity and quality. Based on the water use projections, much of the growth in demands is expected to occur in the larger cities and manufacturing sector. Large demands most likely cannot be met by local ground water sources. Also, much of the ground water that is available for future development is not near the location of need or is not of adequate quality. Therefore, ground water is considered a limited option for future water supply. This is discussed further in Section 8.0.

Table 4.1: Existing Ground Water Users

Entity	Upper Basin	Lower Basin
Cities > 5,000	3	2
Cities < 5,000	18	6
Water Supply Corporations	87	31
Other (resorts, camps, schools)	23	12
Total	**131**	**51**

Ground water occurs in several distinct geologic formations, or aquifers, that generally extend in bands perpendicular to the axis of the river. Differences in thickness and permeability

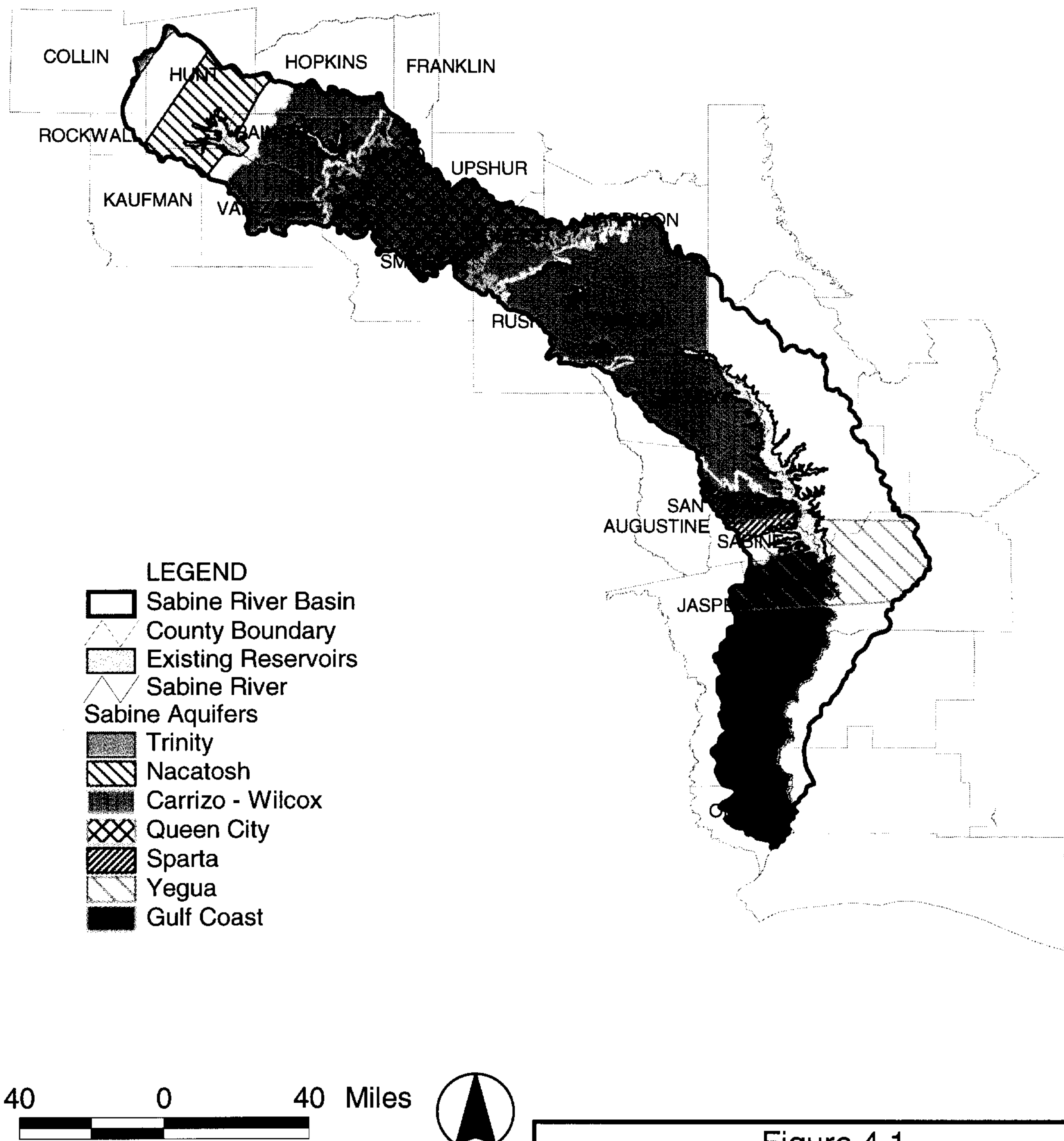
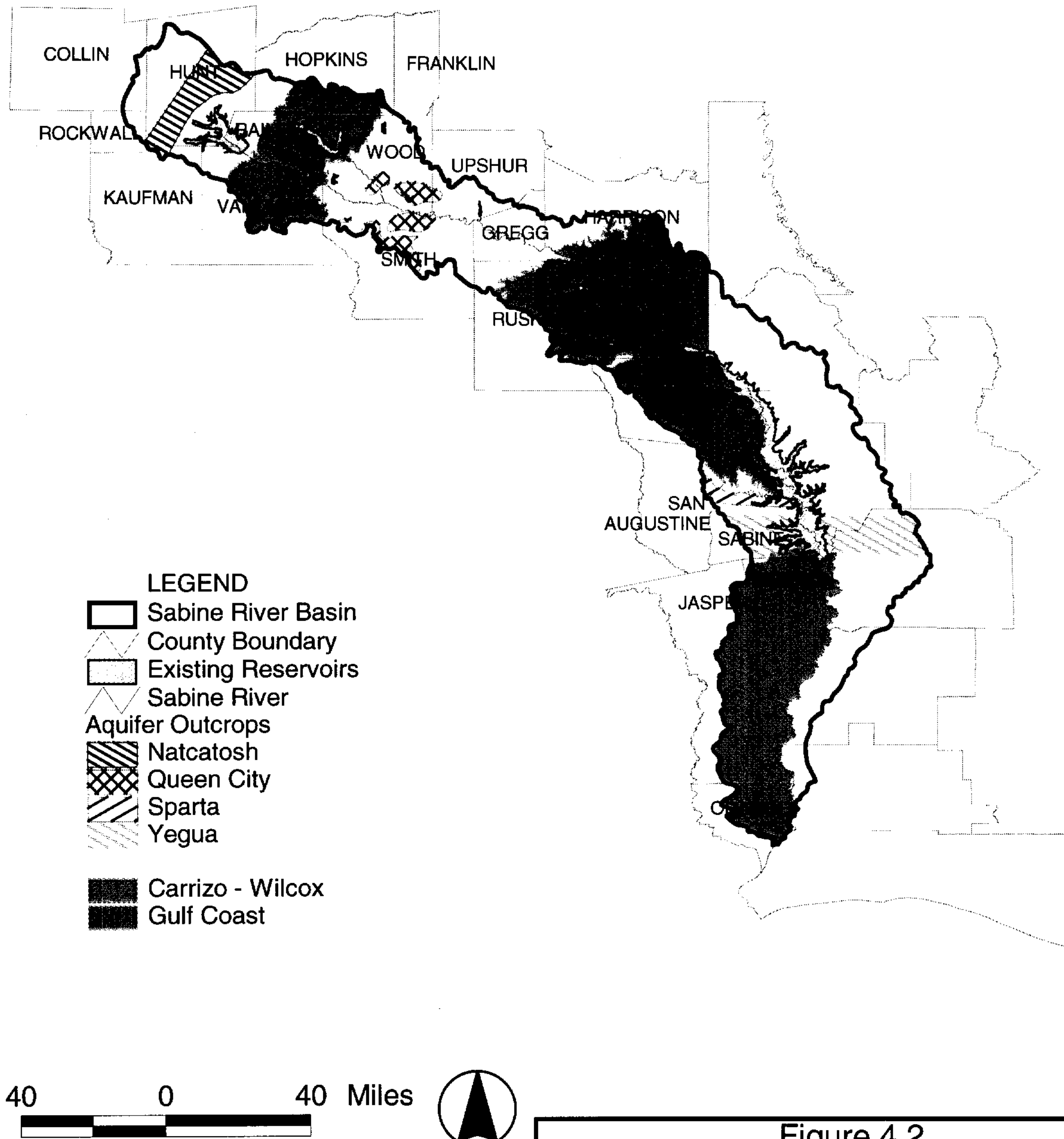


Figure 4.1
Aquifer Locations

Comprehensive Sabine
Watershed Management Plan

Source: Texas Natural Resources Information System
www.tnris.state.tx.us/gispage.html



Source: Texas Natural Resources Information System
www.tnris.state.tx.us/gispage.html

Figure 4.2
Aquifer Outcrop Locations

Comprehensive Sabine
Watershed Management Plan

result in the variable ability of each aquifer to produce water. Some aquifers produce only enough to supply individual households while others may produce hundreds of gallons per minute to large capacity wells. This combination of permeability and thickness is referred to as the aquifer's transmissivity, and plays an important role in how much water can be extracted from the aquifer. The higher the transmissivity, the greater amount of water can be produced. The chemical quality of the water in each aquifer also differs throughout their extent. Quality differences are the result of the solubility of the minerals present in the formation and the length of time that water is in contact with the minerals. It is the productivity and quality of the ground water supply that ultimately determines the type and suitability of use.

4.1 Aquifer Descriptions

Major Aquifers

Carrizo-Wilcox Aquifer

The Carrizo-Wilcox is the most extensive and productive aquifer in the Sabine Basin, extending from Van Zandt County in the Upper Basin to Sabine County in the Lower Basin. This aquifer is composed of two separate and distinct geologic units, the Wilcox Group and the Carrizo Formation. Since these two units are hydrologically connected over much of their extent, they are considered one aquifer. The Carrizo consists of massive sand beds and ranges in total thickness from 40 to 180 feet. The underlying Wilcox Group ranges in total thickness from 1,000 to 2,400 feet, and is characterized by interbedded sand, clay and shale.

Transmissivity of the aquifer ranges from approximately 600 gallons per day per foot (gpd/ft) to as much as 70,000 gpd/ft, depending on the location. In general, higher transmissivities are located in the productive Carrizo zones. Ground water velocities in the Carrizo-Wilcox are about 10 feet per year. Properly constructed wells in the Carrizo-Wilcox can produce as much as 800 gallons per minute (gpm) in many areas. The overall rate of recharge to the Carrizo-Wilcox is estimated to be approximately one percent of the average annual rainfall over the outcrop area, which corresponds to between 40,000 and 50,000 acre-feet per year. About half of the water recharged within this area moves to the adjoining Neches River Basin.

Within the Sabine Basin, only a few areas have seen significant water level declines in the Carrizo-Wilcox over time. In some areas just outside the Basin large declines have been observed in localized areas. Water level declines of 300 to 400 feet have been reported in the

Tyler and Lufkin-Nacogdoches areas since 1940. However, the increased use of surface water has reduced and even reversed the water level declines in many areas. The largest declines observed in the Sabine Basin have occurred in Smith County, showing greater than 100 feet of decline from 1960 to the present. Other wells in Smith County completed in the Carizzo-Wilcox showed relatively stable water levels, indicating that these observed declines are localized occurrences near heavy ground water pumping centers. Declines ranging from 50 to 75 feet have been reported for some wells in Gregg, parts of Rusk, and Wood Counties. Smaller declines have been observed in Hopkins, Rains and parts of Rusk Counties. For all cases there were many other wells that did not show any water level declines. Based on these data, the declines observed in the Carrizo-Wilcox in the Sabine Basin are not large, and are only significant near large well fields and pumping centers.

Water from the Carrizo-Wilcox aquifer generally meets drinking-water standards throughout most of its extent. However, in some areas elevated levels of dissolved solids and high acidity pose a problem. Quality deteriorates with depth naturally, especially in the Wilcox. Total dissolved solids increase rapidly in the artesian downdip direction and exceed 3,000 mg/l in southern Sabine County. In the outcrop areas, shallow water sands are susceptible to contamination from surface activities, and may contain high levels of nitrate.

Gulf Coast Aquifer

The Gulf Coast aquifer system occurs throughout much of the Lower Basin of the Sabine River in Newton, Jasper, and Orange counties. Formations comprising the aquifer system consist of interbedded clays, silts, sands, and gravels, all of which are hydrologically connected to form a large, leaky aquifer system. This system is comprised of four aquifers that include, from deepest to shallowest: the Catahoula, the Jasper, the Evangeline, and the Chicot.

The Catahoula sandstone is primarily composed of interbedded and interlensing sand and clay. The Catahoula can yield moderate to large quantities of water in southeast Sabine County. Productivity from the aquifer decreases to the west. Aquifer tests on Catahoula wells indicate a transmissivity of about 19,000 gpd/ft.

The Jasper aquifer is primarily interbedded sands and clays. It ranges in thickness from 200 to 3,200 feet. Fresh water is available from this aquifer from the outcrop to between 50 and 75 miles downdip. This aquifer furnishes water for the towns of Jasper and Newton, as well as other towns within the Sabine Basin. In southeast Texas, the Jasper is little used, but is capable of producing more than 3,000 gpm from properly constructed wells. Transmissivities in the Jasper range from less than 19,000 gpd/ft in the outcrop area to 260,000 gpd/ft east of the Sabine River.

The Evangeline aquifer includes all sediments between the Berkville aquiclude and the Chicot aquifer, and has a high sand to clay ratio. Fresh water is found to depths of 1,500 feet below sea level; the downdip limit of fresh water is in Orange County. Transmissivities are between 16,000 and 111,000 gpd/ft, averaging about 62,000 gpd/ft. The thickness of the Evangeline in Jasper and Newton counties is about 300 feet and the thickness increases rapidly downdip.

The Chicot aquifer is the uppermost formation and has a greater sand to clay ratio than the Evangeline. Transmissivities range from 90,000 to 500,000 gpd/ft, which are the greatest of the four formations. The thickness of the Chicot in the Jasper and Newton county area is about 225 feet, and as with the Evangeline and other Gulf Coast formations, it increases in thickness rapidly in the downdip direction.

Recharge to the Gulf Coast aquifer system is derived from precipitation that falls on the formation outcrops of each of the four individual aquifers. Approximately four percent of the approximately 54 inches of average annual rainfall infiltrates downward into the aquifers, while another one inch per year enters the outcrop and is discharged to streams. Due to the leaky artesian nature of the system an undetermined amount of interformational leakage occurs between the aquifers.

Water level declines in the Gulf Coast aquifer vary with formation and location. For the deepest formations, the Catahoula and Jasper, there are limited data on the water levels. Data available since 1980 for the Jasper indicate that water levels have remained essentially stable. In the Evangeline aquifer, years of heavy pumping have produced significant water-level declines for the past 50 years. Since 1967, the water level declines have decreased due to the increased use of surface water in the region to meet demands. Declines in the Chicot aquifer are generally less than have been observed in the Evangeline. The largest amount of decline in the Chicot has occurred in Orange County. Recent data show significant recovery in water levels since the mid-1970s. In some cases the water levels returned to the same level as in the early 1940s.

Water quality is generally good in the shallower portions of the Gulf Coast aquifer, and generally declines at greater depths. Overall, there is little difference among the chemical compositions of ground waters from the different aquifers that comprise the Gulf Coast aquifer. These aquifers are characterized by ground waters with wide, overlapping ranges of chemical compositions.

Minor Aquifers

Nacatoch Aquifer

The Nacatoch is the westernmost significant aquifer in the Sabine Basin occupying primarily the southeastern half of Hunt County and overlapping into the Basin's portion of Hopkins, Kaufman, and Rains counties. It consists of 200 to 300 feet of sand bed sequences separated by impermeable layers of mudstone or clay. Net sand thickness is greatest (100 to 120 feet) near the outcrop and thins in a southeasterly direction to a minimum of about 40 feet. Pumping tests conducted on City of Commerce municipal wells in Hunt and Delta counties demonstrated well yields in excess of 200 gallons per minute and an average transmissivity of 2,506 gpd/ft. These wells are located where the aquifer is most productive and are not representative of other areas of the aquifer. Within the Sabine Basin, Nacatoch well yields are generally less than 100 gpm and extended pumping will likely result in local water-level declines. Prior to 1980, the City of Commerce and local industries relied heavily on the Nacatosh for water supply, but major water level declines forced the city to abandon its ground water use in favor of surface water sources.

Recharge to the Nacatoch aquifer is limited because only about one-third to one-sixth of the Nacatoch outcrop contains permeable sand beds. In a regional aquifer study conducted by the TWDB, recharge is estimated to equate to one-half of one percent of the annual rainfall falling on the rechargeable outcrop area. Limiting factors to recharge are listed as low hydraulic conductivity of the soil cover and poor transmissivity of the formation.

Nacatoch water quality is generally alkaline, with an average pH of 8.4. Water is generally suitable for domestic and livestock use but is unsuitable for irrigation due to its high sodium adsorption ratio and high residual sodium carbonate characteristic. Water with total dissolved solids less than 1,000 mg/l in the Nacatosh is restricted to the outcrop and a small downdip area in Hopkins County.

Queen City Aquifer

The Queen City aquifer primarily occurs in Smith, Upshur, Wood, and Gregg counties where it supplies small to moderate quantities of water to wells. The formation consists of inter-fingering beds of sand, silt, clay, and minor amounts of lignite, and increases in thickness toward the center of its extent, reaching a maximum of approximately 600 feet in northern Smith County. Transmissivities of the Queen City typically range from 3,000 to 12,000 gpd/ft.

The Queen City is generally unconfined and recharges rapidly. Water levels respond quickly to rainfall fluctuations, and based on the limited data available, the Queen City aquifer is not showing any regional declines in water levels. The annual effective recharge to the Queen City aquifer within the Sabine Basin is estimated to be close to 138,000 acre-feet. This is a significant amount of water and exceeds the total amount of estimated annual effective recharge for any of the other aquifers in the study area. However, most of this water is discharged to springs and seeps that form the base flow of area streams and rivers.

The water quality in the Queen City aquifer is generally good, well within safe drinking water standard limits. The ground water tends to be slightly acidic, with an average pH of 6.6. The median nitrate concentration in this aquifer is 1.5 mg/l with a reported high concentration in excess of 100 mg/l. As with all of the East Texas and coastal aquifers, water quality deteriorates in the down dip direction.

Sparta Aquifer

The Sparta aquifer crops out over approximately 119 square miles in Smith, Wood, and Upshur counties and attains a thickness of up to 270 feet. The formation also crops out over 45 square miles, in an east-west trending belt in Sabine County. The Sparta aquifer consists of loosely consolidated fine to medium grained sands interbedded with clay and shale, with as much as 60 to 70 percent water-bearing sand. Typically Sparta transmissivities range from 1,000 to 5,000 gpd/ft. Most Sparta wells yield less than 100 gpm of fresh to slightly saline water.

Loose sandy soils on the outcrop contribute to a high recharge potential estimated to be at least 5 percent of the average annual rainfall. Water levels are relatively shallow in outcrop areas and respond rapidly to fluctuating precipitation conditions. Well data show fairly stable water levels. Some wells do show lowering of water levels, probably due to low permeabilities and high pumpage.

Water in the outcrop areas is generally of excellent quality although high iron concentrations and acidity cause problem in isolated areas. High iron content commonly appears in wells that are completed in sand beds at the base of the formation. The aquifer water quality deteriorates rapidly with depth in the downdip direction, towards the south and east. Nitrate concentrations are often high in areas where the water table is shallow, with a maximum concentration of 75 mg/l.

Yegua Aquifer

Within the Sabine Basin, the extent of the Yegua aquifer is limited to the southern half of Sabine County. The Yegua consists of alternating beds of sand, silt, and clay, the aquifer is capable of producing as much as 1,000 gpm. Water-bearing sand thickness ranges up to 350 feet with a significantly thick sand bed occurring at the base of the formation. Well tests have indicated transmissivities of 18,000 gpd/ft.

Loose sandy soils over the outcrop area provide for reasonably good recharge to the aquifer. Water quality in the Yegua aquifer in the Sabine Basin is generally good in the outcrop area and for a short distance downdip. Elevated levels of nitrate, especially in shallow wells, are a local problem. The Yegua is used almost exclusively for rural domestic and livestock supply with a total demand of about 10 acre-feet per year.

4.2 Aquifer Demands and Ground Water Availability

Approximately 48,000 acre-feet per year of ground water is projected by TWDB in the development of the 1997 State Water Plan to be used within the Sabine Basin by the year 2000. Table 4.2 presents the 1996 historical ground water use and the year 2000 projected use by county. The distribution of the projected ground water use by type is shown on Table 4.3. As shown on these tables, the Carrizo-Wilcox aquifer is the most heavily developed aquifer in the Basin, with water being used in 13 counties. Usage of the Carrizo-Wilcox is heaviest in Smith County and slightly less in Panola, Rusk, Van Zandt, and Wood counties. Municipal use (including rural domestic use) accounts for nearly 75 percent of the total Carrizo-Wilcox ground water use within the Basin.

The Gulf Coast aquifer is the other major water supply aquifer in the Sabine Basin.

Approximately 84 percent of the ground water pumped from the Gulf Coast aquifer is used for public supply, with Orange County accounting for 72 percent of that municipal demand. The City of Orange is the largest user of the aquifer with an annual demand of over 4,000 acre-feet per year. Approximately 2,200 acre-feet per year of Gulf Coast aquifer ground water is used for irrigation in Newton County, and minor amounts are also used in all counties for manufacturing, mining, and livestock.

The four lower yielding aquifers, Nacatoch, Queen City, Sparta and Yegua, provide less than one tenth of the total projected ground water use in the year 2000. Ground water from the Nacatoch aquifer is currently used primarily for rural domestic supply and to a much lesser extent for minor irrigation use. Prior to around 1980, the City of Commerce and local industries relied heavily on the Nacatoch. However, major water-level declines in the aquifer forced the city to abandon its ground water use in favor of surface water sources. The Queen City aquifer is the largest producer of the lower yielding aquifers. Most pumpage from the Queen City aquifer is for rural domestic and livestock supply and mining in Wood County. Only the community of Big Sandy in Upshur County uses water from the Queen City for municipal supply at a rate of about 220 acre-feet per year. Due to their limited extents, the Sparta and Yegua aquifers provide water for only 17 acre-feet per year of demand, which is used mostly for rural domestic and livestock supply. There are no municipal wells reported pumping from these aquifers.

A few wells in the Basin have been completed in aquifers listed as "other" in Table 4.2. These specific aquifers were not identified due to their relative insignificance within the Basin. A minor amount of ground water is produced from the Trinity aquifer in Collin and Rockwall counties. In Harrison and Sabine counties, the aquifer terminology of Cypress Springs and Cain River have been used in older reports to depict aquifer units that are currently incorporated in aquifer units used in this report. Ground water associated with the Cypress Springs and Cain River are likewise incorporated into the current aquifer usage. These "other" ground water sources provide approximately 470 acre-feet per year in the Sabine Basin.

Table 4.2: Ground Water Demand by County

County	1996 Pumpage	Projected Year 2000 Pumpage (ac-ft/yr)[1]							
		Carrizo-Wilcox	Gulf Coast	Nacatoch	Queen City	Sparta	Yegua	Other[2]	Total
Upper Basin:									
Collin	195							11	11
Rockwall	148							50	50
Hunt	812			352					352
Kaufman	194			5					5
Van Zandt	3,476	3,714							3,714
Rains	562	114							114
Hopkins	1,791	557		319					876
Wood	5,574	3,950			2,601				6,551
Smith	4,734	4,567			491				5,058
Franklin									
Upshur	1,502	955			295				1,250
Gregg	2,930	1,126			400			410	1,936
Rusk	3,720	3,256			137				3,393
Harrison	1,348	2,606							2,606
Panola	5,225	3,661							3,661
Total Upper Basin	**32,211**	**24,506**	**0**	**676**	**3,924**	**0**	**0**	**471**	**29,577**
Lower Basin:									
Shelby	2,290	2,793							2,793
San Augustine	88	103							103
Sabine	113	351				7	10		368
Jasper	1,820		1,838						1,838
Newton	3,048		4,144						4,144
Orange	12,739		9,243						9,243
Total Lower Basin	**20,098**	**3,247**	**15,225**	**0**	**0**	**7**	**10**	**0**	**18,489**

1. Projected ground water use in year 2000 reported in 1997 State Water Plan.
2. Other aquifers include limited portions of the Trinity, Cypress Springs and Cain River that are located within the Sabine River.

Table 4.3: Ground Water Demand by Use Type – Year 2000

	Aquifer Demand (ac-ft/yr)					
Aquifer	**Municipal**	**Manufacturing**	**Mining**	**Irrigation**	**Livestock**	**Total**
Carrizo-Wilcox	20,657	793	3,349	122	2,832	**27,753**
Gulf Coast	12,740	122	33	2,200	130	**15,225**
Nacatoch	319	200	46	106	5	**676**
Queen City	2,096		1,223	226	379	**3,924**
Sparta	7					**7**
Yegua	10					**10**
Other	460				11	**471**
Total	**36,289**	**1,115**	**4,651**	**2,654**	**3,357**	**48,066**

4.2.1 Ground Water Availability

Ground water availability can be estimated using several different methods, which have varying results. The TWDB developed a ground water model for a large area that included the upper portions of the Sabine Basin. To determine water availability to meet future needs, the model was run assuming all future demand was met by ground water. This resulted in large availability numbers for counties where large demands were projected (e.g., Harrison County was projected to have an annual ground water availability of 183,500 acre-feet per year). These high availability estimates include both effective recharge and the removal of ground water from storage. While the TWDB model does demonstrate that there is a significant amount of water contained in the Carrizo-Wilcox aquifer, the model was not run to simulate levels of pumpage that might be considered based on reasonable and practical economic assumptions.

Another method to estimate the ground water availability uses the annual effective recharge for each aquifer. This methodology is the most conservative since these availability estimates do not include the removal of water from storage. This approach allows for the assessment of long-term availability of the aquifer without incurring large water level declines.

For this Plan, the estimated ground water availability in the Sabine Basin is based on a modified water budget approach. The components of the budget consist of input to the aquifer system as recharge, water held in storage within the aquifer, and output or withdrawal from the aquifer as pumpage and spring flow. Annual effective recharge for the aquifers within the Sabine Basin were derived from estimates based on TWDB aquifer analyses and include consideration of input to the aquifer from both precipitation and seepage from streams. Water in storage is based on estimates of saturated thickness and storage coefficient of the aquifer medium. Total discharge from the aquifer includes pumpage and water that is naturally rejected from underground in the form of spring flow.

In quantifying availability, consideration was made concerning the historical use of each aquifer in each county. If water level records suggested a relatively static condition, then annual effective recharge was considered an appropriate availability estimate. However, if the aquifer in a particular county had been or is expected to be heavily used and recharge alone is insufficient to meet forecasted demands, then recharge along with a specified depletion of storage was assigned as availability. The availability estimates for the Gulf Coast, Sparta and Yegua aquifers are based solely on annual effective recharge, while estimates for the Carrizo-Wilcox, Queen City and Nacatoch aquifers include, for some counties, the depletion of a specified amount of water in storage.

Estimated ground water availability from the Carrizo-Wilcox aquifer in the Sabine Basin is based on the annual effective recharge throughout the aquifer extent, and also includes a three-percent per year depletion of storage in most counties. Nacatoch aquifer availability consists of effective recharge in outcrop counties and a combination of recharge and/or storage depletion in the downdip counties of Hopkins and Rains.

Water availability from the Queen City aquifer is limited to effective recharge in Harrison and Rusk counties where recharge is less relative to other counties. In the other counties, effective recharge estimates are significantly higher (Table 4.5) and do not realistically equate to availability. For these counties availability is based on recoverability estimates for the portion of the aquifer with sufficient saturated thickness to support well yields of 200 gpm or more. Availability was estimated by establishing a conceptual well field over the designated area with wells spaced one mile apart and allowed to withdraw water at a rate of 12 hours per day for 365 days. This method allowed for a much more reasonable availability estimate in Gregg, Smith, Upshur and Wood counties. The total amount of water that is determined to be available from the Queen City aquifer in the Sabine Basin is about 32,000 acre-feet per year.

A total of 138,492 acre-feet of ground water per year are estimated to be available in the Sabine Basin. Summaries of these estimates by county and aquifer are shown in Tables 4.4 and 4.5. Of the six primary aquifers in the basin, the Gulf Coast (53,003 acre-feet), the Carrizo-Wilcox (44,820 acre-feet) and the Queen City (32,012 acre-feet) contain 94 percent of the total annual available ground water.

Since there is ample surface water supply already developed in the lower basin, it is unlikely that future well fields in the Gulf Coast aquifer will be developed for regional supply. Ninety seven percent of the calculated availability from the Carrizo-Wilcox is located in the upper basin. The Queen City aquifer, located totally in the upper basin, has the greatest annual water recharge at 137,800 acre-feet per year. However, as previously discussed, much of the water is released from the aquifer to local streams and springs. Proper development of well fields could reduce the amount of lost recharge, but probably could never capture the recharge quantity indicated in Tables 4.4 and 4.5.

Table 4.4 Ground Water Availability by Aquifer

Aquifer	Year 2000 Projected Pumpage	Effective Recharge (ac-ft/yr)	Annual Availability (ac-ft/yr)
Upper Basin:			
Carrizo-Wilcox	24,506	40,040	40,766
Nacatosh	676	222	234
Queen City	3,924	137,800	32,012
Other	61	0	26
Total Upper Basin	**29,167**	**178,062**	**73,038**
Lower Basin:			
Carrizo-Wilcox	3,247	3,960	4,054
Gulf Coast	15,225	53,003	53,003
Sparta	7	7,400	7,400
Yegua	10	997	997
Total Lower Basin	**18,489**	**65,360**	**65,454**

Table 4.5: Ground Water Availability by County

County	Aquifer	Year 2000 Projected Pumpage	Effective Recharge (ac-ft/yr)	Annual Availability (ac-ft/yr)
Upper Basin:				
Collin	Other	11	0	26
Rockwall	Other	50	0	0
Hunt	Nacatoch	352	198	198
Kaufman	Nacatoch	5	5	5
Van Zandt	Carrizo-Wilcox	3,714	2,803	2,892
Rains	Carrizo-Wilcox	114	1,202	1,202
	Nacatoch	0	0	2
Hopkins	Carrizo-Wilcox	557	2,002	2,066
	Nacatoch	319	19	29
Wood	Carrizo-Wilcox	3,950	7,207	7,437
	Queen City	2,601	53,742	10,920
Smith	Carrizo-Wilcox	4,567	4,404	4,404
	Queen City	491	46,852	9,100
Franklin	None	0	0	0
Upshur	Carrizo-Wilcox	955	2,002	2,066
	Queen City	295	22,048	4,550
Gregg	Carrizo-Wilcox	1,126	2,402	2,402
	Queen City	400	9,646	1,930
Rusk	Carrizo-Wilcox	3,256	4,004	4,130
	Queen City	137	2,756	2,756
Harrison	Carrizo-Wilcox	2,606	4,805	4,958
	Queen City	0	2,756	2,756
Panola	Carrizo-Wilcox	3,661	9,209	9,209
Total Upper Basin		**29,167**	**178,062**	**73,038**
Lower Basin:				
Shelby	Carrizo-Wilcox	2,793	1,030	1,030
San Augustine	Carrizo-Wilcox	103	198	204
	Sparta	0	888	888
Sabine	Carrizo-Wilcox	351	2,732	2,820
	Yegua	10	997	997
	Sparta	7	6,512	6,512
Jasper	Gulf Coast	1,838	10,134	10,134
Newton	Gulf Coast	4,144	28,765	28,765
Orange	Gulf Coast	9,243	14,104	14,104
Total Lower Basin		**18,489**	**65,360**	**65,454**

4.2.2 Current Ground Water Problems

Through the course of this planning effort, visits were made to major water users and providers throughout the Basin. During these visits, it was discovered that a number of entities, particularly in the Upper Basin, were experiencing difficulty with their current ground water systems. Table 4.6 lists those entities and associated ground water problems.

Table 4.6: Identified Ground Water Problems – Upper Basin

Entity	County	Aquifer	Problem
White Oak	Gregg		No good quality ground water available. Currently on surface water.
East Mountain	Upshur	Carrizo-Wilcox	Saline ground water
Elderville WSC	Gregg, Rusk	Carrizo-Wilcox	Decreasing ground water quality and quantity
Tryon Road WSC	Gregg	Carrizo-Wilcox	Decreasing ground water quality and quantity
Gum Springs WSC	Harrison	Carrizo-Wilcox	Decreasing ground water quality and quantity
Hallsville	Harrison	Carrizo-Wilcox	Decreasing ground water quality and quantity
MacBee WSC	Van Zandt	Carrizo-Wilcox	Iron and manganese levels limit portion of service area
Bright Star-Salem WSC	Wood, Rains	Carrizo-Wilcox	Decreasing ground water quality; have requested surface water from SRA.
Combined Consumers WSC	Hunt	Nacatosh	Last well went out of service in May 1997. High iron and sodium concentrations for municipal use.
City of Quinlan	Hunt	Nacatosh	Water quality issues. TNRCC has advised the City to slowly discontinue ground water use.
North of Quinlan	Hunt	Nacatosh	Ground water quality deteriorates going north from Quinlan.

There appears to be a pattern of decreasing water quality and in some cases water quantity. This could possibly be attributed to over pumping of the water supply wells, which would cause water level declines and allow poorer quality water to enter the wells.

5.0 COMPARISON OF EXISTING SUPPLY AND PROJECTED DEMAND

To adequately manage the water resources in the Sabine Basin and plan for future growth, there needs to be an understanding of the existing water supply, projected demand, and anticipated need. The existing supply consists of water supply reservoirs, diversions from the Sabine River and it tributaries, ground water, and imports from outside the Basin. Projected water demands are the expected water use requirements developed from the TWDB's 1996 Consensus Projections as discussed in Section 2.0. The anticipated need is based on the difference between the supply and the demand.

The Sabine Basin has a vast resource of existing water supply in the Toledo Bend Reservoir. However, this supply is not easily accessible to other areas with need such as the Upper Basin. Therefore, the comparison of existing supply and demand was evaluated on a county by county basis. Supplies from surface water reservoirs, river diversions, and importation were attributed to different counties based on the existing water rights and contracts. Unpermitted additional yield of existing reservoirs was considered unassigned supply in the county of the reservoir. Ground water supply was estimated from the year 2000 ground water projections, since these projections better reflect existing ground water resources that are currently used or planned for future supply. The projected water demands for each decade are identified for the Basin and county by the TWDB. Further discussion of potential ground water resources is included in Section 8.0.

The total water supply was assumed to meet only the need of the county, unless there was unassigned supply available in the county. This was because it was assumed that a water right holder would be reluctant to reduce its existing contracted supply. Also, water supply sources such as Lake Murvaul have stipulations that the water can only be used for county needs. A summary of the supply, demand and projected need is presented in Table 5.1. Details of the distribution of water supply within the Basin are included in Appendix E.

Table 5.1: Comparison of Existing Supply and Demands

	SUPPLY (acre-feet/year)					DEMAND (acre-feet/year)						2050	
County	**Surface**	**Groundwtr**	**Imports**	**Exports**	**Total**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**Difference**	**Available**
Upper Basin													
Collin		11	2,638		2,649	523	415	754	1,269	2,032	2,638	11	
Rockwall		50	3,705		3,755	1,030	1,306	1,760	2,373	3,110	3,705	50	
Hunt	252,970	352	1,323	211,202	43,443	12,233	11,578	11,554	11,684	11,603	11,816	31,627	11,860
Kaufman	1,120	5			1,125	225	241	258	276	287	295	830	
Van Zandt	10,256	3,714		300	13,670	5,997	5,979	5,982	5,918	5,768	5,753	7,917	
Rains	4,271	114			4,385	2,037	2,097	2,135	2,183	2,207	2,299	2,086	
Hopkins	95	876			971	3,202	3,186	3,155	3,128	3,090	3,069	-2,098	-2,098
Wood	130,542	6,551		120,280	16,813	9,609	32,668	32,373	31,977	30,548	26,172	-9,359	-9,359
Smith	2,362	5,058			7,420	5,141	5,076	4,985	4,859	4,740	4,578	2,842	
Franklin			28		28	20	22	23	26	27	28	0	
Upshur	5,569	1,250			6,819	2,313	2,348	2,372	2,406	2,421	2,459	4,360	
Gregg	59,102	1,936	20,000		81,038	40,695	43,334	45,887	48,891	51,959	56,457	24,581	
Rusk	36,596	3,393		1,008	38,981	34,491	39,250	44,101	49,216	49,251	49,304	-10,323	-10,323
Harrison	145,293	2,606	34,000		181,899	127,443	162,637	181,332	207,615	230,577	265,858	-83,959	-83,959
Panola	28,173	3,661			31,834	9,643	9,083	15,100	23,283	23,423	23,132	8,702	
Total	676,349	29,577	61,694	332,790	434,830	254,602	319,220	351,771	395,104	421,043	457,563		-93,879
Lower Basin													
Shelby	1,460	2,793	3,800		6,593	6,271	6,570	6,908	7,371	7,832	8,380	-1,787	
San Augustine		103			103	185	180	176	174	172	172	-69	
Sabine		368			368	1,264	1,264	1,254	1,250	1,249	1,271	-903	
Jasper		1,838			1,838	1,854	1,839	1,810	1,833	1,854	1,893	-55	
Newton	750,285	4,144			754,429	4,201	4,200	4,160	4,133	4,058	4,047	750,382	
Orange	156,605	9,243		9,438	156,410	74,471	85,748	99,129	113,489	130,106	148,198	8,212	
Total	908,350	18,489	3,800	9,438	919,741	88,246	99,801	113,437	128,250	145,271	163,961	755,780	755,780

1. Upper Basin surplus was determined from the need by county (negative surplus) and **unassigned** surplus supply that could be used in other counties.
2. It was assumed that the surplus in Gregg, Panola, Smith, Upshur and Van Zandt counties are not available for supply outside the respective county.

The supply/demand analyses addresses the projected TWDB needs only and does not include demands for environmental flows. Based on this analysis, the results indicate that in the year 2050 the Lower Basin has an available future supply of over **755,700** AF/Y, and the Upper Basin has an expected need of approximately 94,000 AF/Y. This need is largely assigned to three counties: Harrison, Rusk and Wood. The projected need in Harrison County is attributed to manufacturing growth; the need in Rusk County is primarily for power; and Wood County's increased water requirement is largely due to mining and power. Hopkins County indicates a need of nearly 2,100 AF/Y, which is attributed to livestock demands. The unassigned 11,860 AF/Y in Hunt County is the portion of Dallas's contract in Lake Tawakoni that must remain in the Sabine Basin. This water does not have to remain in Hunt County, and is available for use where needed in the Upper Basin.

As shown on Table 5.1, the projected need in these counties will occur sometime after year 2000 and before 2030. The projected need in Wood County shows a sudden increase in water requirements by 2010 due to power and mining. Since there are no known plans for power or mining in this county in the immediate future, this need probably will not occur until after 2010. Harrison County does not show a need until after 2020. Summaries of the projected need in the Upper Basin and projected surplus in the Lower Basin by decade are presented on Figures 5.1 and 5.2, respectively.

Figure 5.1: Projected Need for New Supply – Upper Basin

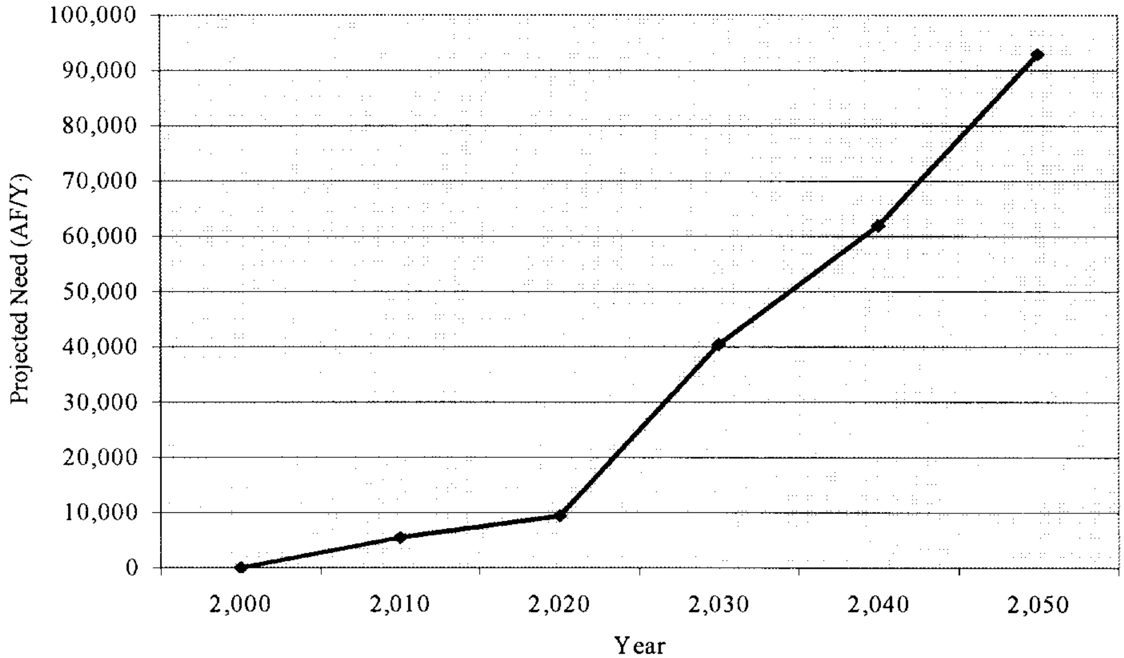
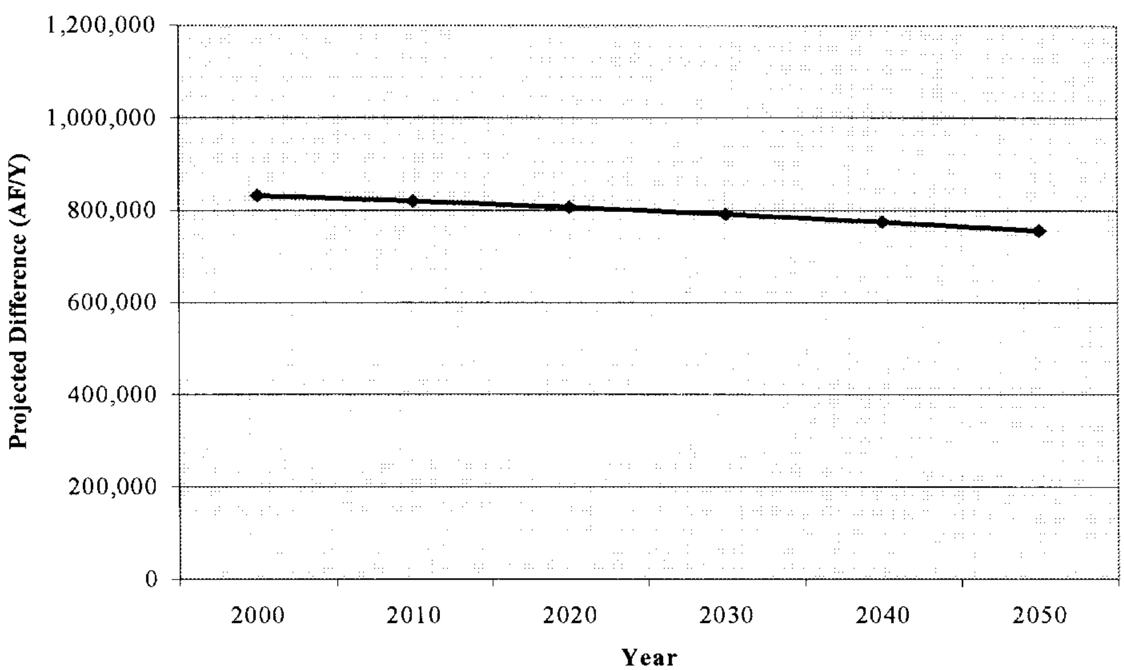


Figure 5.2: Projected Difference in Supply / TWDB Needs– Lower Basin (Does not include environmental needs)



6.0 ADDITIONAL SUPPLY FROM WATER CONSERVATION

Water conservation is a potential means of reducing the projected water demand in the Sabine Basin, which effectively reduces the projected need. The TWDB has developed different conservation scenarios in their water use projections for municipal, manufacturing, irrigation and power uses. The base projections presented in Section 2 of this report incorporate an expected level of conservation.

In this section of the report, the municipal, manufacturing and power use projections were examined to determine how much water could be saved through advanced conservation Mining, livestock, and irrigation uses were not examined to determine additional savings through conservation because they represent only a very small portion of the overall water use in the Basin.

Municipal Water Use

Municipal water use calculations incorporate population projections, weather conditions and conservation assumptions. The unique combination of these considerations result in different municipal use projections. As discussed above, the projections used for this report include the "most likely" population, below normal rainfall and expected conservation. Additional conservation savings are projected under two other demand scenarios: the advanced conservation scenario and the low demand scenario.

The advanced conservation scenario reflects the demand reductions resulting from expediting the timing of regulatory requirements and adopting more aggressive conservation programs at the local level. The low demand scenario compares projected demands for average weather conditions with no conservation to average weather conditions with advanced conservation. This evaluates the impact of conservation efforts on municipal use during normal rainfall conditions. A summary of the projected municipal water use conservation savings is presented in Table 6.1.

Table 6.1: Municipal Conservation Savings Projections

	Municipal Conservation Savings (ac-ft/yr)					
Decade	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Advanced Savings[1]	2,891	5,803	7,480	6,623	5,738	6,136
Advanced Savings[2]	7,108	15,168	21,995	24,320	26,217	27,847
Low Demand Savings	6,482	13,788	19,815	21,862	23,752	25,293

1. Savings compared to the municipal use projections used for this report (expected conservation).
2. Savings compared to municipal use projections with no conservation.

Manufacturing Water Use

Ten counties in the state account for approximately 77 percent of Texas' total manufacturing water use. Two of these counties, Harrison and Orange, are located in the Sabine Basin. In addition, the industries that demand the largest portion of industrial water in the state (chemical products, petroleum refining, and pulp and paper) are all primary industries in the Sabine Basin. Manufacturing water use in the Sabine Basin is the largest projected use type, accounting for 61 percent of the total demand in 2050.

The manufacturing water use projections used for this report assumed low oil prices with no conservation. Other scenarios developed by TWDB address industrial growth based on oil prices and conservation measures indicated by the implementation of water efficient technologies in existing and new plants.

TWDB projections assume conservation savings accrue from the implementation of water efficient practices in manufacturing processes specific to each industry. Projections assume these practices occur as a result of market forces and the availability of improved technology. Table 6.2 includes data on manufacturing demands for both the "most likely" and low oil price scenarios, with and without conservation.

Table 6.2: Manufacturing Demand and Conservation Savings

	Manufacturing Demand/ Conservation Savings (ac-ft/yr)					
Scenario	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Manufacturing Demands:						
Most likely/ No conservation	187,687	226,872	250,228	274,516	301,673	331,427
Most likely/ Conservation	182,110	212,739	225,749	237,677	261,053	286,587
Low oil price/ No conservation	190,956	235,947	265,702	299,170	337,026	383,408
Low oil price/ Conservation	185,284	221,250	239,603	258,880	291,383	331,241
Conservation Savings:						
Most likely Conservation savings	5,577	14,133	24,479	36,839	40,620	44,840
Low oil price Conservation savings	5,672	14,697	26,099	40,290	45,643	52,167

Steam Power Water Use

Power demand was projected using two different series: a High series that assumes current technology will continue unchanged, and a Low series that assumes new technology and conservation will result in net water savings. Steam electric power projections for this plan assumed the High water use scenario (with no conservation).

There are six counties in the Sabine Basin with either existing or planned power facilities: Gregg, Harrison, Hunt, Orange, Rusk and Wood. In 2050, the power demand is projected to account for 18 percent of the total water demand in the Basin. The potential exists to conserve up to 15,000 acre-feet per year by 2050 with aggressive conservation measures. Table 6.3 illustrates the projected conservation savings that could be realized if power facilities in the Basin adopt advanced technologies that Lower the gallon per kilowatt-hour water use.

Table 6.3: Conservation Savings for Steam Power Use

	Power Conservation Savings (ac-ft/yr)					
County	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Gregg	-	500	-	-	-	-
Harrison	-	-	-	5,000	5,000	5,000
Hunt	-	-	-	-	-	-
Orange	-	2,500	5,000	5,000	10,000	5,000
Rusk	-	5,000	10,000	15,000	15,000	5,000
Wood	-	2,500	2,500	2,500	(2,500)	-
TOTAL	-	**10,500**	**17,500**	**27,500**	**27,500**	**15,000**

Advanced water conservation savings contained in the TWDB water demand projections would suggest that adoption of aggressive conservation practices could significantly assist in meeting projected future water supply shortfalls. Combining projected savings for municipal, manufacturing and power categories could reduce the Basin's total projected demand in 2050 by 73,300 acre-feet per year. The combined conservation savings by decade are shown in Table 6.4.

Table 6.4: Summary of Potential Conservation Savings

	Potential Conservation Savings (ac-ft/yr)					
Water Use	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Municipal	2,891	5,803	7,480	6,623	5,738	6,136
Manufacturing	5,672	14,697	26,099	40,290	45,643	52,167
Steam Power	-	10,500	17,500	27,500	27,500	15,000
Basin Total	**8,563**	**31,000**	**51,079**	**74,413**	**78,881**	**73,303**

These projected amounts of water demand reductions, if realized, could address a significant portion of the Sabine Basin's projected needs. However, a number of factors suggest that this level of aggressive conservation will be difficult, if not impossible, to achieve. These factors include:

- For municipal use, the projected water demands already include an expected level of conservation. To achieve the additional potential savings of 6,136 acre-feet per year a total commitment to conservation by all municipal entities within the Basin would be required. The Sabine Basin has one of the lowest per capita 1990 water use rates in the state at 138 gallons per capita per day (gpc/day). With no conservation, the projected water use rate is 154 gpc/day throughout the planning period. Expected conservation assumes a reduction of nearly 20 percent in the water demand by 2050. The advanced level of conservation assumes a further reduction of approximately 6 percent in this demand. This corresponds to a very low water use rate (115 gpc/day) and may not be realistically achievable. Surveys of municipalities in the Sabine Basin suggest that public utilities are aware of the advantages of conservation, yet none have formally adopted a conservation program capable of achieving a 20 to 30 percent reduction in demands.
- A large percentage of the potential conservation savings is attributed to manufacturing use. Manufacturing conservation occurs as a result of economic forces as opposed to voluntary activity or regulatory compliance requirements. In the Sabine Basin, approximately 30 percent of the industrial demand exists in the Lower Basin which has an abundance of available water and no current market incentive to increase water conservation. In the Upper Basin, many of the large water users already employ conservation measures, and few indicate plans to implement further measures. The most common measures in place include recycling process and/or cooling water, reuse, education and maintenance of water distribution system.
- Steam power water use is similar to manufacturing use, in that conservation is often a result of market factors. With the potential deregulation of the energy industry, market forces may be in place to increase water conservation measures. However, local power producers indicate there are no plans to implement plant modifications or conversions to improve water conservation. Since there are no regulations requiring conservation in the energy industry, these savings cannot be relied on as additional supply.

The water use projections generated for this Plan account for conservation savings for municipal and irrigation use. The expected savings already incorporated in these projections (compared to no conservation) exceed 20,000 acre-feet per year. It is highly unlikely that additional conservation savings will be realized for municipal use without local commitment for aggressive conservation. There may be water conservation savings associated with manufacturing and power uses, but these savings are industry and market driven. They cannot be relied on by SRA as firm supply. In severely water supply limited locations within the Basin substantial reductions in water demands may be possible, and SRA should investigate targeting implementation of conservation measures for users in these areas. The local communities or industries can initiate aggressive conservation measures that would reduce water demands, but SRA's role in requiring such measures is limited. Therefore, for planning purposes, it is assumed that there is no additional supply from conservation measures beyond those assumed in the water demand projections.

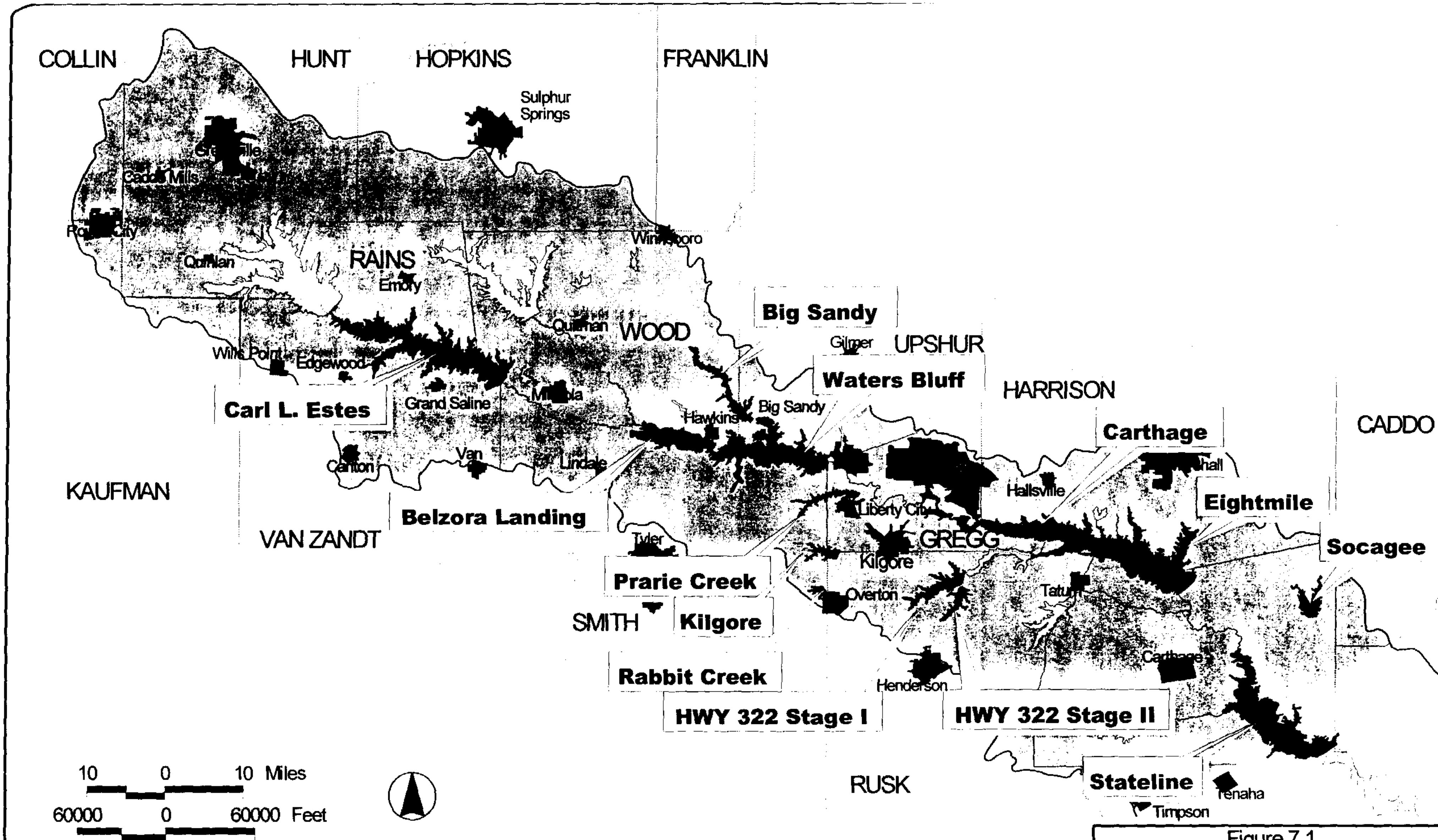
7.0 POTENTIAL SURFACE WATER PROJECTS

7.1 Previously Proposed Reservoirs

Seventeen previously proposed reservoir projects, fourteen in the Upper Sabine Basin and three in the Lower Basin, were reviewed to identify potential surface water alternatives for additional supply in the Sabine Basin. Project locations, yield, potential conflicts, environmental concerns and hindrances to development were assessed based on available data.

Seven potential reservoir projects are located on the main stem of the Sabine River (Carl L. Estes, Belzora Landing, Waters Bluff, Fredonia Lake, Carthage, Stateline and Bon Wier). The other ten reservoir sites are located on tributaries to the Sabine: Prairie Creek, Big Sandy, Kilgore, Rabbit Creek, Eightmile, Cherokee No. 2, State Highway 322, Socogee, Burkeville and Big Cow. Figures 7.1 and 7.2 show most of these potential reservoir sites. The largest reservoirs, based on projected yield, are Waters Bluff, Carthage and Bon Wier. These are all proposed main stem reservoirs that would be used as a major regional water supply. The reservoirs with the lowest yields are Rabbit Creek and Kilgore Reservoirs. These sites, if developed, would probably be considered for local supply.

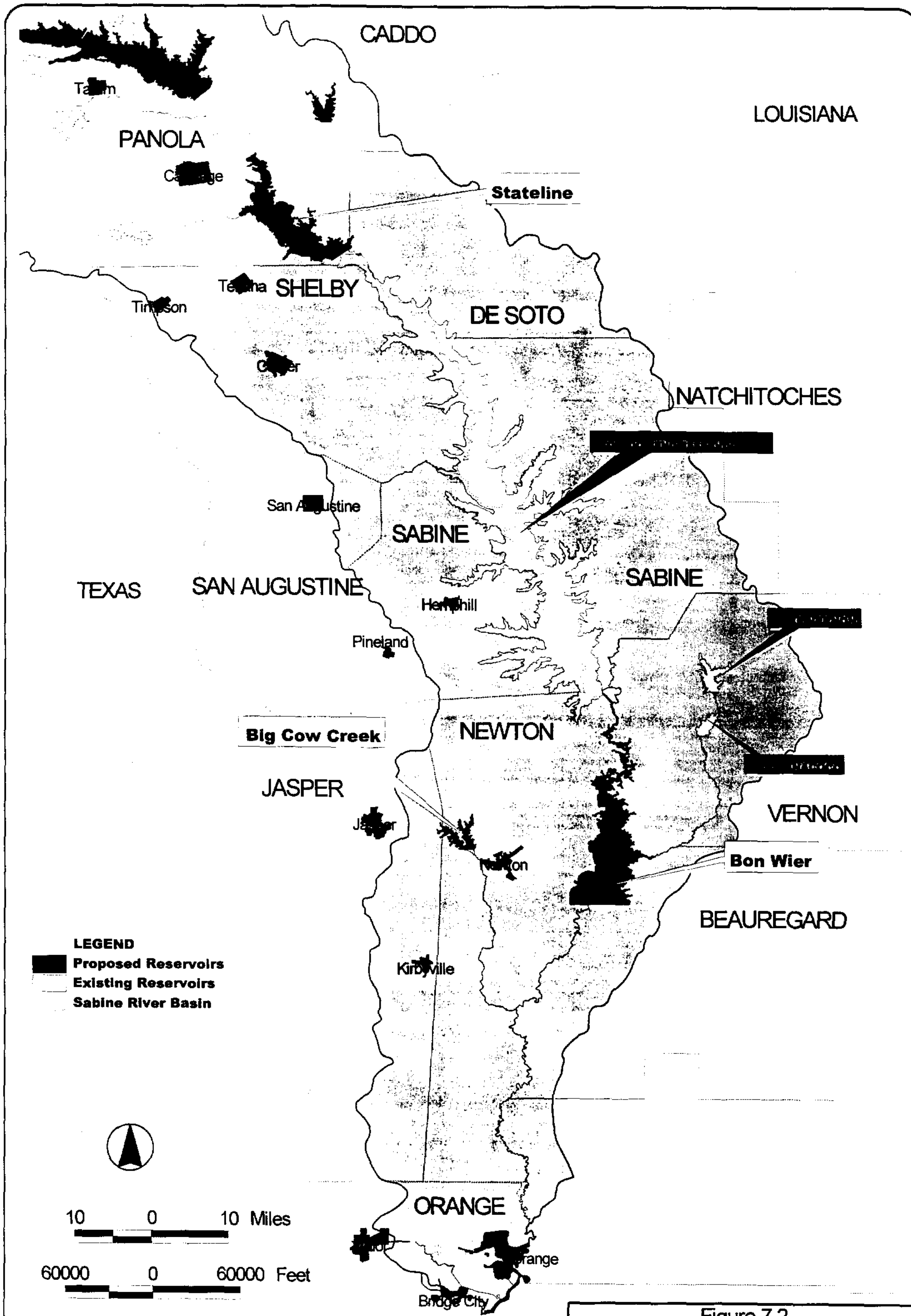
Water supply and demand analyses show there is sufficient supply to meet the projected future needs in the Sabine Basin. However, the majority of the supply is located in the Lower Basin and is not available for upstream use without a major pipeline. The total supply located in the Lower Basin is 920,000 acre-ft per year, and the projected Lower Basin demand in the year 2050 is 164,000 acre-ft per year. Proposed reservoirs located in the Lower Basin (Bon Wier, Big Cow and Burkeville) cannot be justified based on projected local water supply needs. Existing sources in the Upper Basin have a total estimated supply of approximately 768,000 acre-feet per year, with 333,000 acre-feet per year of that amount being exported to other basins. That leaves 435,000 acre-feet per year for in-basin needs. This is sufficient to meet the Upper Basin needs until about the year 2010. To provide for projected demands through 2050, it will be necessary to develop approximately 93,000 acre-feet per year of additional supply in the Upper Basin. This can be accomplished through reservoir development, importation from other basins or transfer of water from Toledo Bend Reservoir by pipeline to the areas of need. Proposed large reservoirs, such as Waters Bluff and Carthage, that provide estimated yields of 324,000 and 537,000 acre-feet per year, respectively, will be able to provide for projected needs well beyond



Source: Environmental Systems Research Institute Data and Maps, Volume 1, 1996.
Update of the Master Plan for the Sabine River
and Tributaries in Texas, 1985.

Figure 7.1
Previously Proposed
Reservoirs - Upper Basin

Comprehensive Sabine
Watershed Management Plan



Source: Environmental Systems Research Institute Data and Maps, Volume 1, 1996.
Update of the Master Plan for the Sabine River
and Tributaries in Texas, 1985.

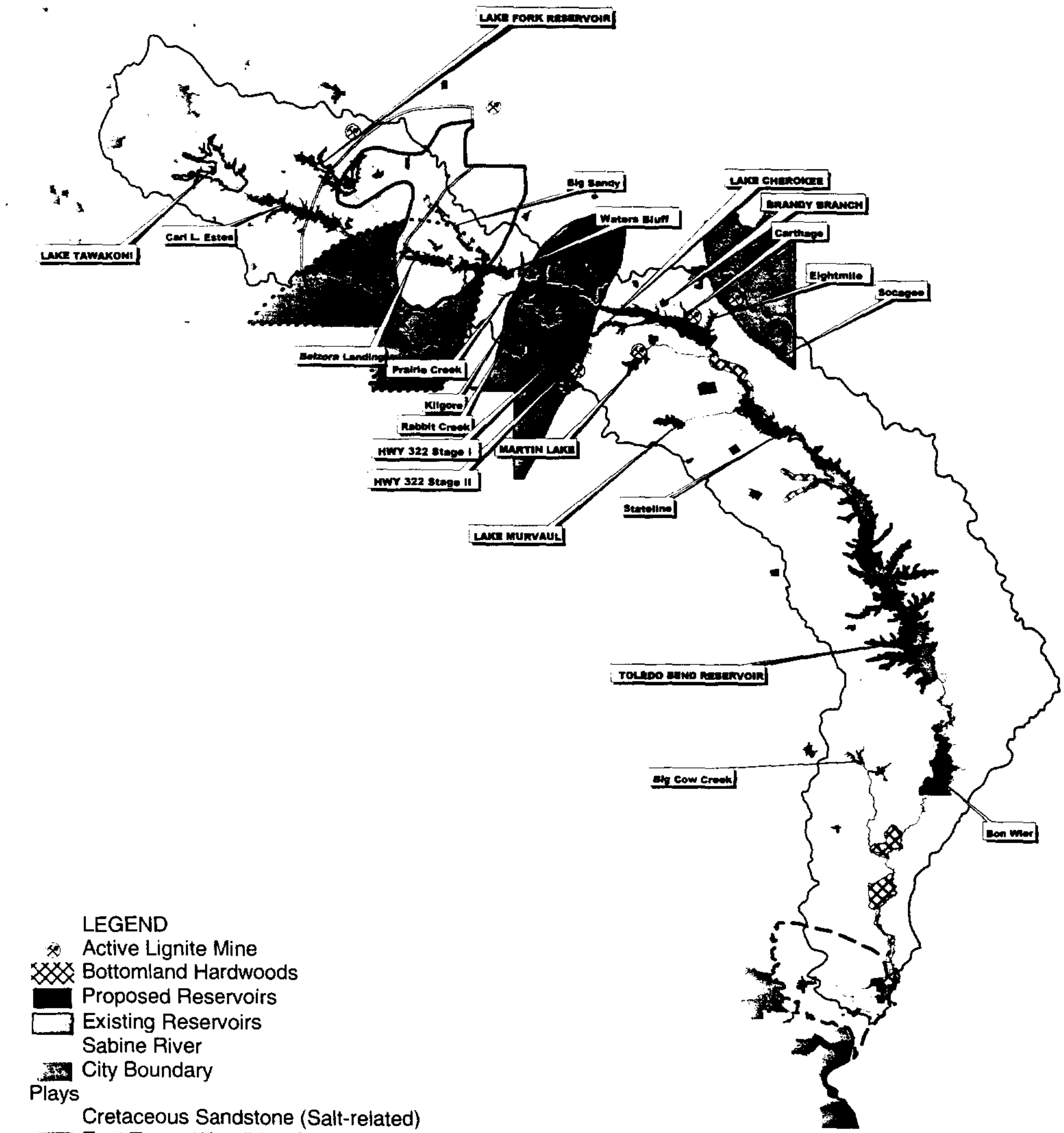
Figure 7.2
Previously Proposed
Reservoirs - Lower Basin

Comprehensive Sabine
Watershed Management Plan

2050. However, development of these large-scale projects may not be completed in time to provide for the anticipated shortfall by 2010. Smaller scale projects, such as Prairie Creek, Rabbit Creek and Big Sandy reservoirs, will provide only a portion of the estimated need in 2050. Additional water supplies need to be developed to meet the growing demands of the Upper Basin. The advantages of the smaller projects are that they could be staged to meet the demands as needed, can be completed in a shorter time frame, and can be located near local areas of need.

Preliminary findings of developmental concerns associated with each of the reservoir sites indicate that the main stem reservoir projects typically have several concerns with environmental and permitting issues. Due to the basic nature of a reservoir, some natural habitats located along the Sabine River bottoms will be lost; however, reservoir construction also has positive benefits such as fisheries and increased nesting and feeding areas for other known species in the area (e.g., the bald eagle and alligator). Preliminary screening indicates the presence of priority bottomland hardwoods in the sites for Waters Bluff, Carthage, Stateline and Bon Wier reservoirs (see Section 10.0). Lignite deposits, mineral rights and cultural resources affect three other proposed reservoirs in the Upper Basin (Carl L. Estes, Big Sandy and Highway 322). Many of the smaller reservoir projects are located outside the most environmentally sensitive areas and may have fewer hindrances to development. However, there is typically less information available on the smaller reservoirs to adequately assess the developmental concerns. A summary of known concerns is presented on Table 7.1. Several of the reservoir-siting considerations (active mines, oil and gas well fields and priority bottomland hardwoods) are illustrated on Figure 7.3. All bottom land hardwood data was taken from the 1984 U.S. Fish and Wildlife Service report, Texas Bottomland Hardwood Preservation Program. A brief description of each previously proposed reservoir project follows.

These analyses were based on the best information available at the time of this study. It is strongly recommended that new studies of flood plain vegetation and wildlife within the Sabine Basin be conducted. More current estimates of the quality, extent, and economic value of bottomland hardwood areas and threatened and endangered species would play an important role in future planning activities of SRA.



LEGEND

- Active Lignite Mine
- Bottomland Hardwoods
- Proposed Reservoirs
- Existing Reservoirs
- Sabine River
- City Boundary

Plays

- Cretaceous Sandstone (Salt-related)
- East Texas Woodbine Sandstone
- Glen Rose Carbonate (Salt-related)
- Glen Rose Carbonate (Stratigraphic)
- Piercement Salt Domes
- Woodbine Fluvial/Dletaic/Strandplain
- Sabine River Basin

25 0 25 Miles

Source: Bureau of Economic Geology
Mineral Resources of Texas, 1979, and
Mineral Resource Circular No. 76, 1985.
U.S. Fish and Wildlife Service, Texas Bottomland
Hardwood Preservation Program Category 3, 1984.

Figure 7.3
Developmental
Concerns

Comprehensive Sabine
Watershed Management Plan

Table 7.1: Previously Proposed Water Supply Reservoirs

				Development Concerns								
Reservoir	**County**	**Stream**	**Yield (ac-ft/yr)**	**B.L.H./ wetlwnds**	**T&E species**	**oil/ gas wells**	**lignite**	**cultural resources**	**permitting**	**water quality**	**other**	**Comments**
Carl L. Estes	Rains/Wood/Van Zandt	Sabine	94,000	◎		○	●	◎		◎		substantial lignite deposits
Belzora Landing	Smith/Wood	Sabine	106,400	●	○		○	◎	●		●	non-development conservation easement
Waters Bluff	Upshur/Smith/Wood	Sabine	324,000	●	○	○	○	◎	●		●	significant development and permitting issues
Big Sandy	Wood	Big Sandy	46,600	◎		◎		●		○		pre-historic/ historic sites
Prairie Creek	Gregg/Smith	Prairie Creek	19,700	◎	○	○	○				○	hardwood-pine forests
Kilgore	Rusk/Smith/Gregg	Wilds Creek	5,500	x	x	x	○	x	x	x	x	no environmental studies conducted
Rabbit Creek	Rusk/Smith	Rabbit Creek	3,500	◎	○		○					new study completed 9-24-98, yield estimated at 3,500 AF/Y
Fredonia	Gregg	Sabine	NA	◎	○	x	○	○	◎	◎	●	could flood parts of Longview, land costs are premium
Carthage	Rusk/Panola/Harrison Gregg	Sabine	537,000	●	○	◎	◎	○	◎	◎		priority 1 bottomland hardwoods (FWS study, 1984)
Eightmile	Harrison	Eightmile	42,030	x	x	x	○	x	x	◎	x	Located near Carthage, but may have fewer environmental concerns
Cherokee	Rusk/Gregg	Cherokee	57,248	x	x	x	x	x	x	x	x	no environmental studies conducted
Hwy 322 - Stage I	Rusk	Tiawichi Creek	22,000	x	x	x	●	x	x	x	x	no environmental studies conducted, lignite mining permit in proposed reservoir site
Hwy 322 - Stage II	Rusk	Mill Creek	35,000	x	x	x	●	x	x	x	x	no environmental studies conducted, lignite mining permit in proposed reservoir site
Socagee	Panola	Socagee Creek	39,131	x	x	x	◎	○	x	x	x	Lake Murvaul meets local needs
Stateline	Panola	Sabine	280,000	●	○	●		○	●	◎	●	proposed mitigation bank in site, priority 1 BLH
Bon Wier	Newton/ Beauregard/Vernon	Sabine	440,000	●	○	x		○	●	◎		located in lower basin, significant acreage of bottomland hardwoods
Burkeville	Newton	Little Cow Creek	NA	x	x	x	x	x	x	x	x	Little data, located in lower basin
Big Cow Creek	Newton	Big Cow Creek	61,700	x	x	x	x	x	x	x	x	located in lower basin, has sufficient local supply

blank	no known occurrence or no impact	B.L.H.	Bottomland hardwoods
○	potential or known occurrence, low concern	T&E	Threatened and Endangered
◎	known occurrence, moderate concern	NA	Not Available
●	known occurrence, significant concern	x	No Data

Carl L. Estes

The Carl L. Estes Reservoir, formerly known as the Mineola Reservoir, is a proposed main stem project along the Sabine River in Rains, Wood and Van Zandt counties. The dam would be located on the Sabine upstream of Highway 80. If constructed, this reservoir would provide a yield of approximately 94,000 acre-ft per year at a conservation pool elevation of 379 feet msl. The capacity would be 372,600 acre-feet, and the area would be 24,900 acres.

Developmental concerns regarding the Carl L. Estes Reservoir site include bottomland hardwoods, oil and gas rights, lignite deposits, cultural resources and the water quality of the stream segment. Bottomland hardwoods are located in the Lower third of the proposed site and are listed by the U.S. Fish and Wildlife Services (USFWS) as a Priority 2 bottomland hardwood area (USFWS, 1984). The numerous mineral rights in the area affect the acquisition of the property; but there are no known operating mines within or near the reservoir site. In 1986 there were 85 cultural resources on record (U.S. Bureau of Reclamation, 1986), and the Texas Clean Rivers Program (CRP) Water Quality data identified possible concerns for chlorides, pH and total dissolved solids (TDS).

The advantages to this reservoir are that it would be able to provide nearly all of the projected need in the Upper Basin, and it could be operated jointly with Lake Tawakoni or Lake Fork to increase the yield of the reservoir system. Carl L. Estes is located upstream of the area of need in the Upper Basin and water could be released down the Sabine to existing intake locations for distribution.

Belzora Landing

The Belzora Landing site on the Sabine River is the first stage project for the proposed larger Waters Bluff Reservoir. It is located in Smith and Wood counties, immediately upstream of FM Road 14 and about 2 miles south of Hawkins, Texas. The proposed dam at Belzora Landing is upstream of the proposed Waters Bluff dam and would form a reservoir with the same conservation level as Waters Bluff Reservoir (303 feet msl). This first phase reservoir would provide an expected yield of 106,400 acre-feet per year. The surface area would be 13,020 acres and the capacity would be 114,996 acre-feet.

Since this project was first proposed in 1985, various developments have made the initiation of this project more difficult. In 1986, a 3,802-acre non-development conservation easement (Little Sandy National Wildlife Refuge) within the project area was accepted by the USFWS. In addition, approximately 5,000 acres within and adjacent to the proposed reservoir were purchased and deeded to Texas Parks and Wildlife Department to operate as a wildlife management area. This area serves as mitigation land for the Texas Department of Transportation. As a result, construction has been deferred and development will require Congress to override the Little Sandy Refuge easement.

Other developmental concerns for the Belzora Landing site include bottomland hardwoods, cultural resources and wildlife. There is no known active mining in the area or water quality issues.

Waters Bluff Reservoir

The Waters Bluff Reservoir is a proposed main stem project on the Sabine River about 3.5 miles upstream of the Highway 271 crossing. The reservoir extends upstream into Smith, Upshur and Wood Counties, and when fully constructed would yield 324,000 acre-feet per year with a conservation pool elevation of 303 feet msl. The capacity of the entire reservoir (including the Belzora Landing portion) would be 525,163 acre-feet and the area would be 36,396 acres.

Since the initial feasibility studies, subsequent property developments have deferred construction of this reservoir in the foreseeable future (see Belzora Landing description). There are a total of four mitigation banks and one non-development conservation easement (Little Sandy National Wildlife Refuge) within the Waters Bluff boundary. Also, portions of the reservoir site lie within a USFWS-designated Priority 1 bottomland hardwood area (USFWS, 1984), and this segment of the Sabine River is highly valued for its scenic and recreational qualities. Seven prehistoric cultural sites have been identified within the project boundary. There are no known active mines in the area and no water quality issues.

Construction of Waters Bluff reservoir will require an act of Congress to override the Little Sandy easement and Congressional approval for construction of the dam since it is located on navigable interstate waters of the U.S. (Rivers and Harbors Act, 1899). The major advantage to this reservoir is the projected yield. Waters Bluff, if constructed, would provide for all the projected need in the Upper Basin through 2050 and beyond.

Big Sandy Reservoir

The Big Sandy reservoir is a proposed regional water project to supply Gregg and Harrison Counties and nearby cities in the Upper Sabine Basin. The dam site is located at stream mile 10.6 on Big Sandy Creek, north of the town of Big Sandy. The expected reservoir yield is 46,600 acre-feet per year, with a storage capacity of 67,200 acre-feet and an area of 4,405 acres at the conservation level of 340 feet msl.

The primary developmental concern with this reservoir site is the many cultural resources located within the site boundary. A cultural resource survey performed in 1985 by Prewitt and Associates identified 140 prehistoric and historic sites. The impacts to these resources can be mitigated through a comprehensive plan for cultural resources; however, there will most likely be some unavoidable losses. In addition, bottomland hardwoods have been identified in previous studies covering approximately 50 percent of the reservoir area. The CRP Water Quality data indicated a possible concern for total phosphorus in Big Sandy Creek. There are no known threatened and endangered species that would be affected by this project, and there are no active mines in the reservoir site.

The advantage to this reservoir site is its location immediately upstream of the City of Longview, which is an area of projected growth. Its firm yield will provide for approximately one half of the projected need in the Upper Basin.

Prairie Creek Reservoir

To supplement the water demands of the City of Longview and surrounding areas, a small reservoir was proposed on Prairie Creek in Gregg and Smith counties, just upstream of FM 2207. With a conservation pool elevation of 318 feet msl, the proposed Prairie Creek Reservoir would yield 19,700 acre-feet per year. The capacity would be 45,164 acre-feet and the area would be 2,280 acres. To increase the expected yield, flows from the Sabine River could be diverted to Prairie Creek Reservoir. Previous studies indicate that diversions could increase the reservoir yield to 38,400 acre-feet per year (Espey, 1985a).

There are few developmental concerns regarding this reservoir site. There are no priority-designated bottomland hardwoods, no known active mines and no identified water quality issues in the reservoir area. This is a major advantage to this reservoir site. Another advantage is the location near the areas of expected need. The Prairie Creek Reservoir, if constructed, could not meet all of the projected future demands. It could be used to supplement the water supply of the surrounding areas and/or provide terminal storage for a regional transmission pipeline.

Kilgore Reservoir

The Kilgore Reservoir is a proposed local water supply project located on the Upper Wilds Creek in Rusk, Gregg and Smith counties. It was originally proposed to supplement the City of Kilgore's water supply. The project would provide a yield of 5,500 acre-feet per year at the normal operating elevation of 398 feet msl. At that level, the area and capacity would be 817 acres and 16,270 acre-feet, respectively.

Construction of this reservoir has never been initiated, and the City of Kilgore is using diversions from the Sabine (purchased from SRA and released from Lake Fork) and ground water for its water supply. However, this project still has the potential as a local water supply source in the Kilgore area should other proposed projects not be developed. Only preliminary studies have been performed for the Kilgore Reservoir and no environmental impacts have been assessed. Based on preliminary screening data, the site is not located within a priority bottomland hardwood area; there are no known water quality issues and no active mines within the reservoir site.

Rabbit Creek Reservoir

Several reservoir projects have been proposed on Rabbit Creek for local water supply. The latest proposal for the City of Overton and surrounding communities was completed in 1998 (Burton, 1998). The proposed reservoir project is located on Rabbit Creek in Smith and Rusk counties, and would have a firm yield of 3,500 acre-feet per year. This is considerably less yield than the previous studies, which is due in part to the smaller storage capacity and conservative inflows that were assumed for the study. In the latest study, the area would be 520 acres and the capacity would be 8,000 acre-feet at a conservation level of 406 ft msl. However, this yield is considered satisfactory to meet the regional demands of the area. Environmental review of the site reports no significant concerns that would preclude development. There are also no significant cultural resources in the area, no known water quality issues, and no active mining within the reservoir area.

The advantages of this reservoir site are the few developmental concerns. However, it was rejected as a water supply alternative in the 1998 study due to costs. A large percentage of the total costs were associated with a water treatment and distribution system. Due to the relatively low yield of Rabbit Reservoir, this project could only be considered for local water supply.

Fredonia Lake

Fredonia Lake was originally proposed in 1995 by local interest as a potential reservoir site located on the Sabine River in Gregg County between the proposed Waters Bluff and Carthage reservoirs. The exact location and boundaries were not defined, and firm yield was not determined. The approximate area covered by the reservoir surface would be 9,550 acres

The developmental concerns for this site include bottomland hardwoods, water quality, aquatic life and close proximity to the City of Longview. Approximately 30 percent of the proposed site are bottomland hardwoods/wetlands; this stream segment receives discharges from several municipalities and industry and is home to several protected aquatic species. Fredonia Lake, if constructed, could potentially flood parts of the City of Longview and costs for land and conflict resolution would most likely be a premium due to the proximity to Longview and local improvements. Permitting for this reservoir will require an act of Congress since the dam is located on navigable interstate waters of the U.S. The advantage for this reservoir site is that it would have a considerable yield due to the large drainage area.

Carthage Reservoir

The Carthage Reservoir is a proposed main stem project on the Sabine River in Panola, Harrison, Rusk and Gregg counties. It is located immediately upstream of the U.S. Highway 59 crossing and downstream of the City of Longview. The yield of this reservoir, if constructed, would be approximately 537,000 acre-feet per year at a conservation pool elevation of 244 feet msl. The area and capacity would be 41,200 acres and 651,914 acre-feet, respectively.

Developmental concerns for Carthage Reservoir include bottomland hardwoods, aquatic life, lignite deposits and cultural resources. The downstream half of the site encompasses a USFWS Priority 1 bottomland hardwood area. This portion of the Sabine River is designated a significant stream segment and is home to several protected aquatic species (Bauer, 1991). Other potential conflicts with this site include oil and gas wells. Permitting for this reservoir will require an act of Congress since the dam is located on navigable interstate waters of the U.S. There is one active lignite mine, South Hallisville Mine No. 1, near the reservoir boundary.

The water quality assessment of the Sabine River (SRA, 1996a) indicates this segment of the river has possible concerns for nutrients, but the water quality is improving. The advantage of this reservoir is its large yield. The estimated yield of 537,000 acre-feet per year would provide for all projected needs well beyond the year 2050.

Eightmile Reservoir

The Eightmile Reservoir site was initially proposed in the 1955 Master Plan. It is located in the southern portion of Harrison County on Eightmile Creek about six miles upstream of the mouth and 14 miles south of Marshall. This project site abuts the proposed Carthage Reservoir on the Sabine River. The total storage associated with this reservoir is 160,000 acre-feet, and the expected yield would be 42,030 acre-feet per year.

The Eightmile site is located upstream of the identified bottomland hardwoods and there may be fewer environmental concerns than nearby Carthage Reservoir. The only water quality concern identified is potential elevated nutrient levels from municipal and industrial discharges, which can affect the taste and odor of the water.

The Eightmile site is located downstream of the identified area of need, and the estimated yield would only provide for a portion of the additional supply needed in the Upper Basin. This site, if constructed, would be used to meet local demands.

Cherokee Dam No. 2

To supplement the yield from Lake Cherokee, a second dam on Cherokee Bayou was proposed in the 1955 Master Plan. This dam would be located approximately 4.25 miles upstream of the existing Lake Cherokee dam in Rusk County. These two reservoirs would be operated as a system to provide water supply and minimize water level fluctuations in Lake Cherokee. No engineering data was developed for this proposal. In the 1962 Supplement to the Master Plan, the State Highway 322 - Stage II Reservoir was proposed in lieu of the Cherokee dam No. 2. Further discussion of this potential reservoir site is included with State Hwy 322-Stage II.

State Highway 322 Stage I

The Highway 322 Reservoir is a proposed local water supply project in Rusk County, upstream of Lake Cherokee. The project, as originally proposed, was to be developed in two stages: 1) a dam and reservoir on Tiawichi Creek (Stage I), and 2) a separate dam and reservoir on Mill Creek (Stage II). The reservoirs were to be joined by a connecting channel that would allow one spillway to serve both dams.

The proposed Stage I dam is located on Tiawichi Creek, approximately one mile upstream of its confluence with the Upper end of Lake Cherokee. The reservoir, at its normal operating elevation of 330 ft msl, would provide a net yield of 22,000 acre-feet per year. Its area and capacity would be 4,450 acres and 82,450 acre-feet, respectively. If Stage I is operated independently from Lake Cherokee, the firm yield of the reservoir would be reduced due to Lake Cherokee's superior water rights.

The primary developmental concern for the Stage I reservoir is active lignite mining. In 1995, the Oak Hill Mine expanded its current permit area to include approximately one third of the proposed Stage I reservoir area. There have been no environmental studies conducted for this site. Based on preliminary screening, the site is located outside priority bottomland hardwood areas, and there are no known water quality issues.

The advantage to this reservoir site is its location near Harrison County, which has the greatest projected need. If operated with Lake Cherokee, there is existing infrastructure for distribution of water to the City of Longview and local industry.

State Highway 322 Stage II

The State Highway 322 - Stage II reservoir is the second phase of the State Highway 322 water supply project in Rusk County. The Stage II dam would be located on Mill Creek, approximately one mile upstream of the existing Lake Cherokee. Operated at the same level as Stage I (330 feet msl), this project would provide an increased yield to the Cherokee Lake system of 13,000 acre-feet per year with added storage capacity of 112,000 acre-feet. Stage II surface area would be 2,060 acres. The State Highway 322 project (Stages I and II) and Lake Cherokee could be operated as a system to provide a total yield of 53,000 acre-feet per year and maintain the recreational and aesthetic benefits currently provided by Lake Cherokee. If State

Highway 322 project is operated independently from Lake Cherokee, the firm yield would be reduced due to Lake Cherokee's superior water rights.

The primary developmental concern for Stage II is the active lignite mining. Surface mining records indicate that the Oak Hill Mine permit encompasses much of the Stage II reservoir. Preliminary screening indicates no priority bottomland hardwoods in the reservoir area, and there are no known water quality issues. The advantages to this reservoir site is its location near the areas with projected water needs and the possibility that when mining is completed, the site will already be cleared and ready for reservoir development.

Socogee Reservoir

The Socagee Reservoir site is located in the eastern portion of Panola County on Socagee Creek, approximately six miles upstream of its mouth. The reservoir, at normal pool elevation, would have a yield of 39,131 acre-feet per year. The reservoir area would be approximately 9,100 acres and the capacity would be about 160,000 acres.

Approximately 40 percent of the site overlies existing lignite deposits. As of 1986, there was no known exploitation of the lignite deposits, and there currently are no active mines within the area. One cultural resource site is reported in the reservoir boundary. There are no known water quality issues or priority bottomland hardwoods that affect this reservoir site. Socogee Reservoir could be used to meet the local needs of Panola County; however, Lake Murvaul, which has been designated for Panola County use only, has adequate yield to meet the future needs of Panola County.

Stateline Reservoir

The Stateline Reservoir is a proposed main stem project on the Sabine River, approximately eight miles upstream of Logansport, Louisiana and about four miles upstream from the headwaters of Toledo Bend Reservoir. The project site is located in the southeastern section of Panola County and would have an estimated yield of 280,000 acre-feet per year. At the conservation level of 187 feet msl, the area and capacity would be 24,100 acres and 268,330 acre-feet, respectively.

Developmental concerns for this site include bottomland hardwoods, oil and gas wells, water quality, and permitting issues. The northern half of the site lies in a USFWS designated

Priority 1 hardwood area. The southern half is a high quality wetland area and currently being considered for a wetland mitigation bank by the SRA. The mineral rights associated with the Carthage Oilfield significantly affect land acquisition for the reservoir. The CRP Water Quality data indicated possible concerns for elevated nutrient levels, metals, low dissolved oxygen and fecal coliform. This segment of the stream is also a known habitat for several protected aquatic species. Permitting for this reservoir will require an act of Congress since the dam is located on navigable interstate waters of the U.S. (Rivers and Harbors Act, 1899). Construction of the dam and reservoir may also require consent of Louisiana for the part that will impact the state of Louisiana (Sabine River Compact). As currently proposed, the dam site is located immediately upstream of the stateline reach and there is minimal impact to Louisiana lands. However, due to the close proximity of Toledo Bend Reservoir, it is unlikely that Stateline Reservoir would be more economical than Toledo Bend in meeting the needs of the Upper Basin.

Bon Wier Reservoir

The Bon Wier dam site is located on the state line reach of the Sabine River in Newton County, Texas and Beauregard Parish, Louisiana. The reservoir will extend from about 5 miles upstream of U.S. Hwy 190 to approximately Highway 63. It was originally proposed for re-regulation of the hydropower discharges from Toledo Bend Reservoir and for the generation of hydropower. The reservoir, if constructed, would yield 440,000 acre-feet per year at a normal operating elevation of 90 feet above mean sea level. The area and capacity would be 34,540 acres and 353,960 acre-feet, respectively.

It is estimated that the Bon Wier Reservoir would affect 35,000 acres of wildlife habitat (Frye, 1990). This includes several acid bogs/baygalls, which are unique and sensitive areas of the region. Several threatened and endangered species are known to occur in this area. No cultural resource survey has been conducted, but the site is expected to impact numerous archeological and historical sites in both Texas and Louisiana. The CRP Water Quality data reported possible concerns for elevated TDS and low dissolved oxygen during the summer months. The site also requires congressional approval for construction of a dam, because it is on interstate navigable water of the U.S.

The advantages to this site is the large reservoir yield and potential for hydropower; however, it is located in the Lower Basin which has sufficient existing water supply for the planning period.

Burkeville Reservoir

The Burkeville Reservoir is located in Newton County on Little Cow Creek, approximately three miles southeast of Burkeville, Texas. The estimated storage capacity would be about 30,000 acre-feet. Project yield and area/capacity data was not determined.

The location of this site is outside priority bottomland hardwoods and known lignite deposits. There are perennial streams that would be a continual source of inflow to the reservoir. This area receives the greatest amount of rainfall in the State. However, it is located in the Lower Basin, which has sufficient supply for its projected future needs.

Big Cow Reservoir

The Big Cow Reservoir is a proposed local water supply project on Big Cow Creek in Newton County. The Big Cow Creek dam site is located about one-half mile upstream from U.S. Hwy 190, west-northwest of the Town of Newton. It is in the Lower Sabine Basin. The expected yield of the reservoir is 61,700 acre-feet per year with a storage capacity of 79,852 acre-feet and area of 4,618 acres. The conservation level would be 212 ft msl.

No environmental assessment has been conducted for this site. It appears that this site is located outside priority bottomland hardwoods and known lignite deposits. CRP Water Quality assessments reported possible concerns for fecal coliform and dissolved aluminum.

The perennial streams that feed Big Cow Creek and abundant rainfall should provide sufficient inflow for considerable yield for a reservoir of this size. Nevertheless, for this planning period (through 2050), there are no identified needs in the Lower Basin that cannot be met with existing supplies.

7.2 New Reservoirs

Potential new reservoir sites in the Upper Sabine Basin were identified from area topographic maps and reviewed for further consideration. Two sites were located on the Sabine River and five sites were identified on tributaries or off-channel streams. Several of these tributary sites were previously identified during preliminary studies for the City of Lindale. A summary of the new reservoir sites is presented in Table 7.2.

The initial screening of the potential new reservoir sites found that both main stem sites have significant development concerns. Alternative Site A, located between Carl L. Estes and Belzora Landing, was identified as an alternative site to Carl L. Estes to avoid substantial lignite deposits in the area. However, the proposed site almost entirely encompasses priority 2-designated bottomland hardwoods and extends upstream into the near-surface recoverable lignite formation. There are also several water quality concerns associated with natural deposits in the area. Due to these water quality issues, development conflicts, and the relatively shallow depth of the Upper third of the reservoir (5 to 10 ft), no further analyses were conducted for this site.

Alternative Site B is located between the proposed Waters Bluff and Carthage reservoirs, and downstream of the Little Sandy National Wildlife Refuge non-development conservation easement. To limit impacts to this property, a conservation pool elevation of 280 feet msl was assumed. This resulted in an average reservoir depth of 8.4 feet and would still slightly impact the Little Sandy property. In addition, this reservoir, if constructed, would flood hundreds of active and inactive oil well sites located in the East Texas Oilfield, an existing sewage disposal facility, salt water disposal well, and possibly flood part of the Gladewater Municipal Airport. The estimated yield of Site B Reservoir is 175,000 acre-feet per year, but due to the shallow depth and other conflicts this site does not appear more feasible than the previously proposed reservoir sites in the area.

Five tributary reservoir projects were reviewed as potential local water supplies. Several of these sites (North Prairie Creek, Mill Creek and Hatley Creek) have relatively small drainage areas that do not support reservoir development. The two largest reservoir sites, Duck Creek and Saline Creek, have estimated yields of approximately 13,000 acre-feet per year each, and could be considered for scalping to enhance yield. There are few developmental concerns identified for these tributary reservoirs and they should be considered for potential local water supply in the Lindale area.

Table 7.2: Newly Proposed Water Supply Reservoirs

Reservoir	County	Stream	Yield* (ac-ft/yr)	Development Concerns: B.L.H.	wetlands	T&E species	lignite	cultural resources	permitting	water quality	other	Comments
Sabine Site A	Van Zandt, Wood, Rains	Sabine	NA	●	●	○	⭘	⭘	○	●		Priority 2 bottomland hardwoods; WQ concerns for chlorides,
Sabine Site B	Gregg, Smith, Upshur	Sabine	175,000	●	●	○		○	●	○	●	Would flood oil wells and several mitigation banks.
North Prairie Creek	Smith	North Prairie Creek	3,100	x	x	x	x	x	x	x		Small drainage area.
Duck Creek	Smith	Duck Creek	13,250	x	x	x	x	x	x	x		Could be local water supply reservoir
Mill Creek	Smith	Mill Creek	NA	x	x	x	x	x	x	x		Small drainage area.
Saline Creek	Smith	Saline Creek	13,400	x	x	x	x	x	x	x		Could be local water supply reservoir
Hatley Creek	Harrison	Hatley Creek	NA	x	x	x	x	x	x	x	●	Small drainage area. Affects I-20.

* Yield was determined from operation studies with no downstream releases.
Reservoir yield was reduced 15 to 20% when TNRCC recommended downstream releases were made.

blank	no known occurrence or no impact	B.L.H.	Bottomland hardwoods
○	potential or known occurrence, low concern	T&E	Threatened and Endangered
⭘	known occurrence, moderate concern	NA	Not Available
●	known occurrence, significant concern	x	No Data

7.3 Pipeline from Toledo Bend Reservoir to the Upper Basin

One potential water supply project for the Sabine River Basin is the transfer of water from the Lower Basin to the Upper Basin. Water transfers can be made directly to the demand center (e.g., water treatment plant) or to a reservoir system. Pumping to a reservoir system would allow storage of water for use during high demand periods and could increase the available yield of the receiving reservoir system. Direct pumping is less flexible.

Since such a transfer would be an effective means of maximizing water resources in the Basin, two transmission pipeline routes from Toledo Bend Reservoir to the Upper Basin were reviewed. As shown on Figure 7.4, both routes are similar, with one terminating at the proposed State Highway 322 Reservoir, and the other route continuing to the proposed Prairie Creek Reservoir. Three different flow rates were considered for transmission intended to supply 50,000, 75,000 and 100,000 acre-feet per year. Pipelines for each flow rate and route were sized based on economic conceptual design. The pump station at Toledo Bend Reservoir was located approximately 25 miles downstream of the reservoir headwaters to ensure available water during dry seasons. A minimum of one additional pump station along the route was assumed. A summary of the transmission pipeline analyses is presented on Table 7.3.

The Toledo Bend pipeline option has become particularly attractive in recent months. Tenaska, a power generating company, is building a power generating facility in Rusk County and has contracted to purchase Toledo Bend water from SRA for their facility. Tenaska is now building a water supply pipeline from Toledo Bend to about half way to Prairie Creek Reservoir. In their contract with Tenaska, SRA has stipulated that they be able to share the right-of-way for the pipeline. This represents a substantial cost savings to SRA in purchasing easements. It would decrease the cost of this option even below the amount presented in this report.

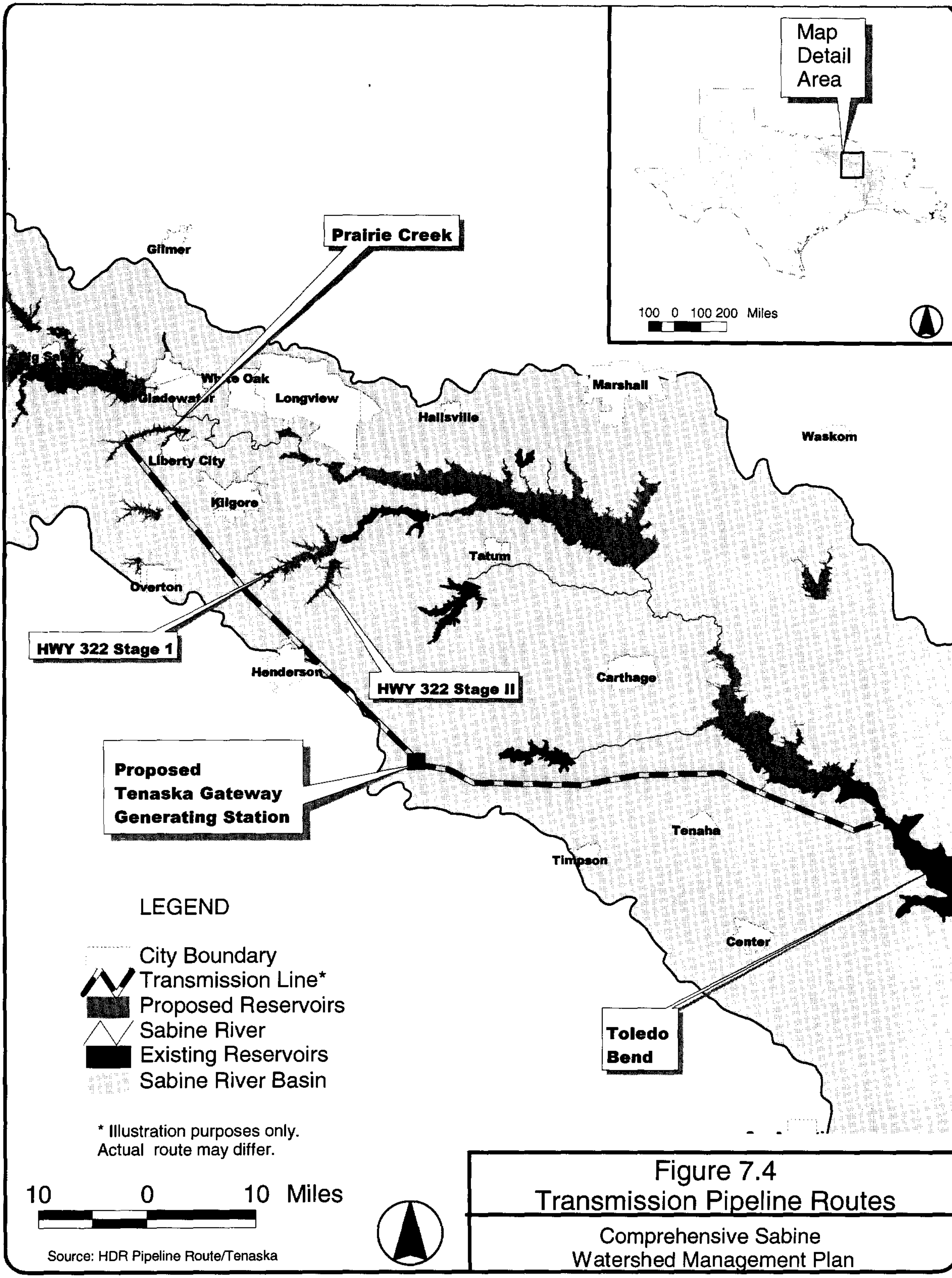


Figure 7.4
Transmission Pipeline Routes

Comprehensive Sabine
Watershed Management Plan

Table 7.3: Transmission Pipeline Analyses

Terminus	Length (miles)	Supply (ac-ft/yr)	Pipe Diameter (inches)	Peak Flow Velocity (f/s)	Combined Yield[1] (ac-ft/yr)
Prairie Creek	87	50,000	60	3.71	67,890
		75,000	66	4.57	90,468
		100,000	90	3.30	115,000
Hwy 322 Stage I&II	65	50,000	60	3.71	88,300
		75,000	78	3.27	110,600
		100,000	90	3.30	131,900
Hwy 322 Stage II only	65	50,000	60	3.71	70,300
		75,000	78	3.27	94,800
		100,000	90	3.30	119,100

1. Combined yield was determined from operation studies for reservoir and transmission flow rate.

7.4 Diversions from the Sabine River

Diversions from the Sabine River to off-channel reservoirs would increase the firm yield of the reservoirs. In the 1985 analysis of the Prairie Creek reservoir, such diversions were projected to increase the estimated yield by 18,700 acre-feet per year, nearly doubling the yield. Since scalping operations are most easily implemented near the main stem of the Sabine River, tributary reservoirs located near the Sabine are the most likely candidates for scalping.

Diversions from the Sabine River were evaluated for three proposed off-channel reservoirs: Big Sandy, Prairie Creek and State Highway 322 (Stage I). Operation studies were conducted for these reservoirs with varying diversions. The Lyons method, which is TNRCC's preferred method, was used to determine when there was sufficient flow for diversions (Lyons, 1979). This method recommends minimum streamflows of 40 percent of the monthly median flows for October through February and 60 percent of the monthly median flows for March through September. The recommended diversion for each reservoir site was based on economic considerations (i.e., lowest annual cost per acre-feet per year). The results of the operation studies with the recommended diversions are summarized on Table 7.4.

Table 7.4: Diversion Operations for Proposed Reservoirs

Reservoir	Big Sandy	Prairie Creek	Hwy 322 (Stage I)
Average diverted (ac-ft/yr)	11,943	13,024	18,438
Maximum diverted (ac-ft/yr)	30,163	34,239	65,489
Pipe diameter (inches)	60	66	78
Flow rate (cfs)	137	137	137
Average pumping time (%)	12%	13%	19%
Combined yield (ac-ft/yr)	61,373	29,685	43,762

7.5 Importation

Importation of water from outside the Basin is a water supply option presently used in the Sabine Basin, and could be expanded if proposed reservoirs in adjacent Basins are constructed. The City of Longview is currently building a pipeline to Lake O' the Pines for water supply. The cities of Gladewater and Marshall are also considering importing water from Cypress Basin. Review of the adjudication rights authorized for Lake O' the Pines indicates that under critical drought conditions, the total amount of available uncommitted water is approximately 46,500 acre-feet per year. This is relatively a small amount of reserves and the local water districts would most likely be reluctant to commit this supply to an out of basin transfer. On a smaller scale, Gilmer Lake may be a viable source for future importation for areas located near Gladewater.

7.6 Opinion of Estimated Costs

Based on the preliminary screening of the previously proposed reservoirs and discussions with SRA staff, six Upper Basin reservoirs were retained for further review and cost comparisons: Carl L. Estes, Big Sandy, Waters Bluff, Prairie Creek, State Highway 322 and Carthage. Each of these sites is located in the area of identified need and provides sufficient yield to be considered for regional supply. None of the new reservoir sites identified warranted further review as a regional water supply source. The two largest new tributary reservoirs, Duck Creek and Saline Creek, could be developed for local supply and should be further reviewed by local authorities.

For each of the reservoir sites, a cost estimate was prepared based on the previously proposed engineering designs. Conflicts associated with each site were identified; mitigation costs were assumed equal to the land acquisition costs; and permitting costs were assigned a percentage of the land acquisition and construction costs based on identified conflicts and permit issues. Cost estimates were also developed for the two transmission pipeline routes from Toledo Bend Reservoir to the Upper Basin and the different alternatives for diversions from the Sabine River. A summary of the estimated capital and annual costs for each project is presented on Table 7.5. Details of the cost estimates for each alternative and a description of the costs are included in Appendix F.

These estimated costs were used as a tool to assess the relative economic feasibility of the surface water projects. Actual costs for mitigation and permitting may vary considerably from the assumptions. Accurate mitigation costs require detailed environmental evaluations and coordination with the appropriate government agencies. Costs associated with the transmission systems from the surface water projects to areas of need were not evaluated. Depending on the location of the water supply project, these costs may significantly impact the final delivery cost of the water. Also, no dollar values were assigned to recreational benefits, hydropower, or exportation of surplus water supplies.

In light of these considerations, the different surface water projects provide raw water at an estimated cost of \$0.21 to \$0.92 per 1,000 gallons. Based on the total annual yield, the two largest reservoirs, Waters Bluff and Carthage, provide water at the lowest costs per 1,000 gallons. However, the yields of these reservoirs are significantly greater than the identified Upper Basin need of 93,000 acre-feet per year. If the costs were adjusted for the amount of water needed (shown on Figure 7.5), the estimated cost per 1000 gallons in 2050 would increase to \$1.20. This indicates that the development of these large projects would require an out-of-Basin partner to use a substantial portion of the supply. Without such a partner, the most economical reservoir (without diversions) for projected needs is Big Sandy with a cost of \$0.41 per 1,000 gallons.

The most economical source of additional raw water is diversions from the Sabine. These diversions increase reservoir yield at a relatively low cost. Based on the diversion operation assumptions, the reservoirs located further downstream (e.g., Hwy 322) can divert a larger quantity of water than those located upstream (Big Sandy). The unit costs for reservoirs

Table 7.5: Estimated Costs for Proposed Reservoir Projects

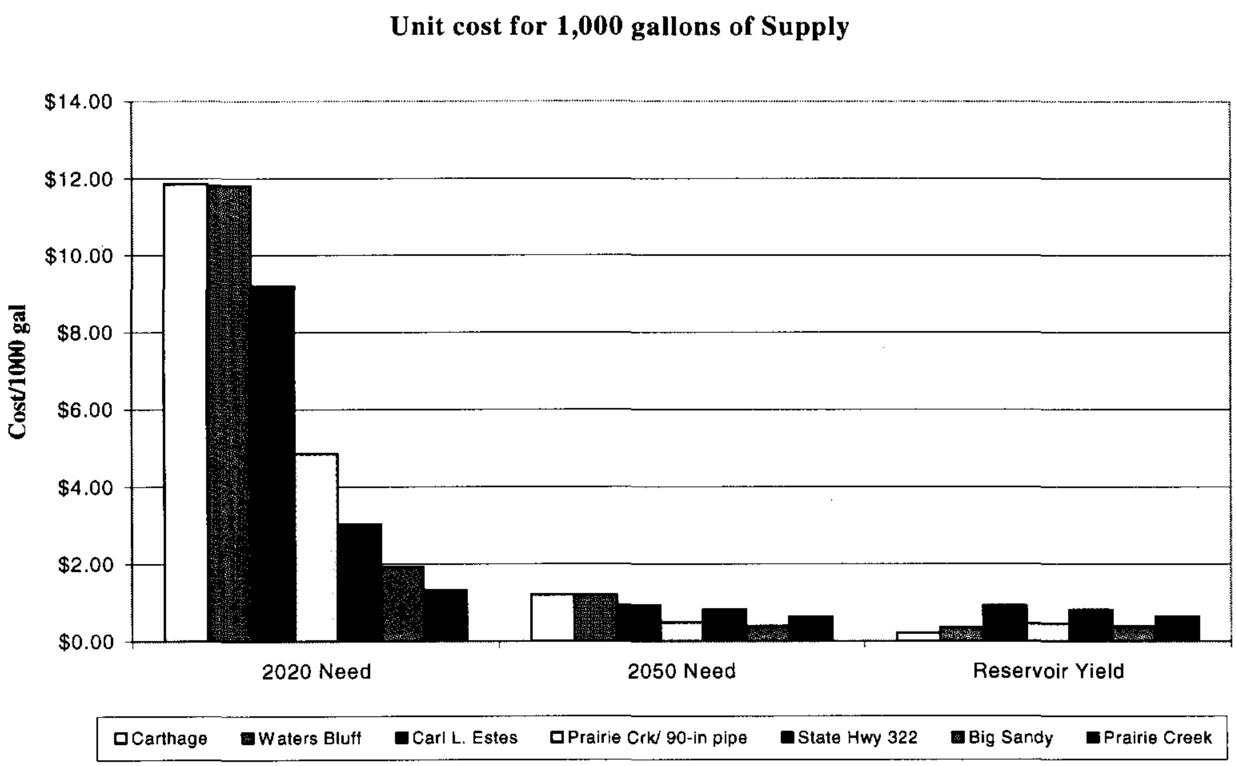
		CAPITAL COSTS				
Reservoir	**Yield (ac-ft/yr)**	**Total**	**Annualized**	**O&M**	**Total Annual**	**Cost/1000 gal**
Carl L. Estes	94,000	$373,815,200	$27,157,267	$1,098,447	$28,255,714	$0.92
Big Sandy	46,600	$82,817,644	$6,016,612	$141,458	$6,158,070	$0.41
Waters Bluff	324,000	$489,531,800	$35,563,952	$719,746	$36,283,698	$0.34
Prairie Creek	19,700	$55,696,190	$4,046,268	$181,844	$4,228,112	$0.66
State Hwy 322 (Stages I & II)	35,000	$127,469,820	$9,260,544	$438,442	$9,698,986	$0.85
Carthage	537,000	$495,837,500	$36,022,055	$423,092	$36,445,147	$0.21
Big Sandy w/ diversion	61,373	$87,559,324	$6,361,090	$396,902	$6,757,991	$0.34
Prairie Creek w/diversion	29,685	$60,247,790	$4,376,936	$414,745	$4,791,681	$0.50
Hwy 322 (I) w/ diversion[1]	43,762	$74,111,710	$5,384,135	$849,094	$6,233,229	$0.44
87-Mi pipeline (Prairie Crk)						
60-in pipe	50,000	$86,738,608	$6,301,465	$3,976,447	$10,277,913	$0.63
66-in pipe	75,000	$107,719,373	$7,825,695	$6,469,223	$14,294,918	$0.58
90-in pipe	100,000	$118,856,553	$8,634,799	$6,316,323	$14,951,122	$0.46
65-Mi pipeline (Hwy 322)						
60-in pipe	50,000	$66,180,398	$4,807,934	$3,585,644	$8,393,578	$0.52
78-in pipe	75,000	$101,579,764	$7,379,659	$4,625,192	$12,004,852	$0.49
90-in pipe	100,000	$116,007,816	$8,427,842	$4,606,472	$13,034,314	$0.40
Reservoir & pipeline from Toledo Bend						
Prairie Crk & 60-in pipe	67,890	$142,434,798	$10,347,733	$4,158,291	$14,506,024	$0.66
Prairie Crk & 66-in pipe	90,468	$163,415,563	$11,871,963	$6,651,067	$18,523,030	$0.63
Prairie Crk & 90-in pipe	115,000	$174,552,743	$12,681,067	$6,498,167	$19,179,234	$0.51
Hwy 322 & 60-in pipe	88,300	$193,650,218	$14,068,478	$4,024,086	$18,092,563	$0.63
Hwy 322 & 78-in pipe	110,600	$229,049,584	$16,640,203	$5,063,634	$21,703,837	$0.60
Hwy 322 & 90-in pipe	131,900	$243,477,636	$17,688,385	$5,044,914	$22,733,299	$0.53
Hwy 322 (II) & 60-in pipe[1]	70,300	$129,915,308	$9,438,206	$3,804,865	$13,243,070	$0.58
Hwy 322 (II) & 78-in pipe[1]	94,800	$165,314,674	$12,009,931	$4,844,413	$16,854,344	$0.55
Hwy 322 (II) & 90-in pipe[1]	119,100	$179,742,726	$13,058,113	$4,825,693	$17,883,807	$0.46

1. Yield was determined from operation studies with only one stage of the reservoir completed. Capital costs for one stage were estimated at 50 percent of both Stage I & II.

with diversions range from $0.34 to $0.50 per 1,000 gallons of water, which are typically lower than the other alternatives. However, these diversions individually do not produce enough water to meet the identified need.

The costs for the transmission pipeline alternatives from Toledo Bend Reservoir were evaluated for two different terminal points and three different flow rates (supplying 50,000, 75,000 and 100,000 acre-feet per year). The estimated transmission costs for the Toledo Bend water alone range from $0.40 to $0.63 per 1000 gallons. The costs associated with the transmission line and a new terminal storage reservoir range from $0.46 to $0.66, an increase of 3 to 15 percent. The costs for additional water supply via a transmission line with terminal storage at an existing reservoir, such as Lake Cherokee, would be similar.

Figure 7.5 Cost Comparison for Projected Need



7.7 Recommendations

To meet the future water supply needs in the Sabine Basin, it is recommended that SRA develop potential surface water projects in stages over the planning period. This approach provides the supply as needed, and allows flexibility for adjustments if projected needs change. Large-scale projects, such as Carl Estes, Waters Bluff, and Carthage, will provide for all the future need, but will require large initial capital costs and may not be completed in time to provide for the anticipated shortfall in 2010. Since these capital costs may not be recovered if the water need does not increase, the cost per 1,000 gallons of needed supply for the large reservoirs would be much higher than the costs associated with some of the smaller reservoirs. Also, the developmental issues associated with Waters Bluff and Carthage reservoirs pose significant obstacles to land acquisition and permitting. Construction of Waters Bluff Reservoir will require an Act of Congress to override the Little Sandy National Wildlife Refuge non-development conservation easement; Carthage Reservoir affects a significant area of priority-designated bottomland hardwoods and is located downstream of the areas with future needs. The development of either of these two reservoirs is potentially feasible only if there is an out-of-Basin customer that is willing to support initial capital costs in return for surplus supply.

The most economical reservoir development alternatives appear to be Big Sandy (with or without diversions), Prairie Creek with diversions, and State Highway 322 (Stage I) with diversions. Each of these sites is located in or near areas identified with future needs. The primary developmental concerns with Big Sandy are the numerous cultural resource sites and bottomland hardwoods. Prairie Creek is located in an area with fewer environmental concerns and is centrally placed in the Upper Basin. The firm yield of Prairie Creek is the lowest of the three tributary reservoirs. Diversions from the Sabine make this reservoir a viable water supply alternative. State Highway 322 is located further downstream and shares the same watershed with Lake Cherokee. This reservoir site is currently being mined for lignite and may not be available for reservoir development prior to the anticipated shortfall in 2010. The advantage to this site is it offers terminal storage for potentially large diversions from the Sabine, resulting in an increase in yield of approximately 25,000 acre-feet per year.

The transmission pipelines from Toledo Bend to the Upper Basin also offer alternatives to provide water supply in a staged program. When considering capital costs only, the most economical means of transporting water would be to deliver directly to a water treatment facility. Construction of a reservoir and a transmission pipeline will slightly increase the unit cost of providing raw water. However, terminal storage provides the most flexibility in operating the pipeline system by lowering peak pumping rates, and would Lower the yearly operating costs of the pipeline. A proposed reservoir such as Prairie Creek or Highway 322 could be used as terminal storage for the pipeline. Some of the advantages to a transmission pipeline are that it can provide water to points along the route; the line can be routed to avoid conflicts; and it can be staged to meet future demands as needed. A transmission pipeline from Toledo Bend Reservoir should be seriously considered as part of the future water supply for the Upper Basin.

8.0 POTENTIAL GROUND WATER RESOURCES

8.1 Development of New Ground Water Supplies

Some quantities of ground water can still be developed within the Sabine Basin. However, due to the limitations in aquifer transmissivities and deteriorating water quality with aquifer depth, large volumes of water typically cannot be obtained from a localized area. The groundwater availability reported for each aquifer and county was determined for the entire aquifer area within the county. The amount of water that can be obtained from a well field is limited to the well field's area of influence, which is commonly only a portion of the available ground water within the county. In light of these considerations, it is not reasonable to expect to fully develop all ground water resources within the Basin to meet large demand centers. However, new ground water developments are viable resources for small local supplies.

The Carrizo-Wilcox aquifer is the most important ground water resource in the Sabine Basin and has the greatest potential for future development. Based on a TWDB evaluation, an additional amount of ground water could be obtained from the aquifer with proper development. However, in some areas of the Basin ground water recharged to the Carrizo-Wilcox moves into the adjacent Neches River Basin. Also, the variability of the transmissivity in portions of the Carrizo-Wilcox can limit movement of recharge through the aquifer. This effectively reduces the potential to develop this aquifer as a regional water supply source.

A large amount of good quality water from the Gulf Coast aquifer is available in Jasper, Newton, and Orange counties. Most wells in the Gulf Coast aquifer system produce from the shallowest aquifer available that contains the amount of water necessary to meet intended needs. Additional ground water from lower aquifers is often also available. For example, the Jasper is largely underdeveloped because it lies beneath the Evangeline and Chicot aquifers, both of which are heavily used in the region. Most wells producing from the Jasper are located in the outcrop area or close to it and there are very few downdip wells. Although a large amount of ground water can be developed from the Gulf Coast aquifer, it is not likely to be developed because the Gulf Coast region already has adequate water supply.

The Nacatoch is only valuable as a local ground water resource, but is available as a backup source for temporary use by the City of Commerce. Water-quality deterioration limits its use in the downdip direction.

The utilization of the Queen City aquifer is fairly small since the amount of water potentially recoverable from this aquifer is limited. Most of the water recharged to the aquifer is later discharged as spring flow, before it can be captured by wells. Where the Queen City is overlain by the Sparta, wells can be drilled and completed in both aquifers to increase productivity. For some areas it is particularly important that wells within the Queen City be adequately spaced due to limitations of aquifer transmissivity. Wells spaced too closely and over pumping will result in water level decline and possible water quality deterioration.

The Sparta aquifer is similar to the Queen City in that its outcrop area and saturated thickness are limited, and much of the water that enters the aquifer as recharge is quickly discharged as spring flow. The aquifer will likely continue to be used primarily for light demands. However, if properly constructed and spaced, wells can yield as much as 300 to 500 gallons per minute (gpm). Additionally, production can be increased considerably by drilling and completing wells in both the Sparta and Queen City aquifers.

The Yegua aquifer is limited to Sabine County and therefore represents only a small percent of ground water availability in the Sabine Basin. Although the aquifer is limited in extent, the formation does attain sufficient thickness to potentially allow for moderately high yields in downdip locations.

8.1.1 Ground Water Availability

Section 4.2 of this report details the methodology by which ground water availability was determined. Tables 4.4 and 4.5 show that availability. To determine how much of the available ground water is likely to be developed, future shortages and their location need to be identified. Based on the comparison of current supply to year 2050 demand, four counties in the Sabine Basin showed a shortage. All of these counties are in the Upper Basin. The potential ground water availability and supply shortage amounts for those counties is listed in Table 8.1

Table 8.1: Potential New Ground Water Supply
(all values are in acre-feet per year)

County	Aquifer	Year 2000 Projected Pumpage	Annual Availability	Potential New Ground Water Supply	Projected 2050 Shortage
Harrison	Carrizo-Wilcox	2,606	4,958	2,352	83,959
	Queen City	0	2,756	2,756	
Hopkins	Carrizo-Wilcox	557	2,066	1,509	2,098
	Nacatoch	319	29	-290	
Rusk	Carrizo-Wilcox	3,256	4,130	874	10,323
	Queen City	137	2,756	2,619	
Wood	Carrizo-Wilcox	3,950	7,437	3,487	9,359
	Queen City	2,601	10,920	8,319	

When looking at the projected need in Harrison County, almost all of the future shortage is due to increased manufacturing use. As explained above, aquifer development will need to take place by smaller users on a very localized level. Large demands in one area (like manufacturing) cannot expect to develop all of the county's potential future ground water supply. For these reasons, manufacturing users will probably not use groundwater. Therefore, it is likely that only very little of the potential future groundwater supply in Harrison County will be developed.

In Hopkins County, it is conceivable that the additional 1,200 acre-feet per year (1,509 minus 290) could be developed on local levels because most of the growth in the county is in municipal use (small towns) and livestock use.

In Rusk County, over the 50-year planning period, there is an increase of only 700 acre-feet per year for municipal use, which would generally be in smaller towns. The remainder of the increase in need (16,700 acre-feet per year) is for steam electric use. Steam electric power plants generally do not use groundwater for their operations. They almost always have on-site surface reservoirs. Therefore, it is likely that only about 700 acre-feet of groundwater can expect to be developed.

In Wood County, total water use is expected to increase by 21,000 acre-feet per year from 1990 to 2050. Almost 13,000 acre-feet per year of this demand is in the mining use category. As with manufacturing use in Harrison County, these mining operations would have large localized demands, which cannot be supported by local well fields. Reported water level declines in the Carrizo-Wilcox and lower transmissivities in the Queen City Aquifer indicate large-scale ground water development in this county is unlikely. In addition, through the meetings with water providers some ground water quality problems were identified in Wood County. Bright Star-Salem Water Supply Corporation, who has wells in Wood and Rains Counties, has requested to buy surface water from SRA due to the deteriorating quality of their ground water. Given the reasons above, only a small portion of the 11,700 acre-feet per year of potential supply is likely to be developed.

Summary

With proper well location and construction, and conservative pumping rates, the aquifers located in the Sabine Basin can continue to be a water source for the region. As noted in Section 4, historical water-level declines are mostly the result of overpumpage from individual wells or well fields and generally have not resulted in regional declines. Water quality problems do exist in portions of the Basin's aquifers, but these problems can sometimes be remedied or avoided by proper well placement and construction. When local entities are considering development of ground water resources, in-depth studies should be performed. At that time down-hole surveys could be conducted to identify potential water quality problem zones. Once identified these zones can be avoided for future wells by proper location of screened intervals when setting the well casing.

Proper development of an aquifer may also significantly increase the amount of recharge to the aquifer by increasing the hydraulic gradient downdip of the outcrop areas and reducing the amount of recharge that is locally rejected. However, this additional recharge cannot be counted on nor can it be estimated.

Good quality water should be obtainable from many sections of the Carrizo-Wilcox aquifer in the study area. Whether these supplies will be developed depends heavily on the location, amount, and concentration of the future demands. Evaluation of water quality in different zones should be performed to identify potential bad quality zones. To limit significant declines in water levels, the location of well fields, spacing of production wells, and the pumping rates must also be considered. Further studies are necessary to fully evaluate the potential of the Carrizo-Wilcox aquifer in the Sabine Basin area, and to determine the best way to properly develop this water resource.

8.1.2 Costs

The costs associated with developing future ground water supplies can vary significantly based on several factors. These costs can generally be grouped into two categories: 1) costs associated with a feasibility analysis, and 2) costs associated with installation of the well or wells and the infrastructure necessary to get the water to the end user. The cost of a feasibility study is only a small component of the cost of developing a well or well field. The majority of the costs are in the drilling and installation of the well(s) and the installation of a distribution and treatment system. Desired yields of less than 200 gpm can generally be achieved with wells completed at moderately shallow depths for relatively low costs. Significantly higher costs are required for high production wells (greater than 1,000 gpm). In addition, wells of this size require greater saturated thickness and are limited to the Carrizo-Wilcox aquifer in the Sabine Basin. While high capacity wells are relatively expensive to construct as compared to small capacity wells, the overall cost is often less expensive than a new surface water alternative.

8.2 Aquifer Storage and Recovery

Artificial recharge is a method of augmenting the natural recharge that occurs to an aquifer system. The injection of water into an aquifer as an artificial recharge technique has been practiced in the United States for several decades. Aquifer Storage and Recovery (ASR) is a term that has been developed to describe recharge of an aquifer and the subsequent recovery of the water for a beneficial use. ASR is a method to inject treated surface water into the aquifer during periods of low water demand, which normally occurs during the winter months. The water would subsequently be available for withdrawal using existing or new wells during months of high water demand. If feasible, ASR could relieve peak demands on the water treatment system and delay the need for the construction of additional surface water treatment facilities.

For this study, the geology of the Basin was examined to identify geologic formations that would be conducive to the ASR process. The formations must be capable of storing volumes of water without transferring them to other areas in the aquifer. A number of counties in the Upper Basin fit this first criteria. The next criteria for selection was selecting entities that already had both existing surface water and ground water facilities. Cities that utilize ground water and surface water within Rains, Smith, Van Zandt, and Wood counties were considered as potential candidates for artificial recharge. Discussions with the staff of the Sabine River Authority also provided information on cities that may be interested in artificial recharge as a water supply option. Kilgore in Smith County, Emory in Rains County, Canton and Grand Saline in Van Zandt County and Quitman in Wood County were considered as candidates. The City of Kilgore was considered a viable option for further study because of its well field in the Carrizo-Wilcox aquifer, the water-level decline(about 70 to 100 feet since 1952) that has occurred in the well field due to past pumping, and the availability of treated surface water from the City's system. The City of Canton in Van Zandt County also was considered a viable candidate because of the combined surface water and ground water supply and the increase in water demand that is occurring in the City due to growth and the commercial and reselling market served by the City's water supply system. Representatives of Canton and Kilgore also expressed an interest in the feasibility of artificial recharge to help provide additional water supply.

Quitman in Wood County has an adequate surface water supply and does not have the projected increase in demand as other cities. Grand Saline was not selected because treated surface water to the City would have to be provided via pipeline from another city in the area. Emory in Rains County is a town with 963 people and does not represent a large enough potential project to warrant further consideration.

The cities of Kilgore and Canton were selected also because they would represent a study of artificial recharge for a larger city of about 11,000 and the study of artificial recharge of a smaller city with a population of about 3,000. The aquifer conditions for the Kilgore well field in Smith County and for the water wells utilized by Canton indicate that it should be possible to store the water in the aquifer and have it retained there for utilization by the cities. There is very limited pumpage in proximity to Canton and the City of Kilgore well field.

Water usage by the City of Kilgore was 2,950 and 3,095 acre-feet per year (af/y) in 1996 and 1997, respectively. The municipal water demand for Kilgore is projected to be 2,794 af/y, 2,854 af/y, and 2,940 af/y by 2010, 2020, and 2030, respectively. In addition, Kilgore supplies approximately 700 af/y to wholesale municipal and industrial customers. Data for the City of Canton show that water usage was about 649 acre-feet in 1996 compared to 484 acre-feet in 1986. Municipal water demand is projected to be 681 af/y, 679 af/y, and 658 af/y by 2010, 2020, and 2030, respectively. In addition, Canton supplies approximately 100 af/y to wholesale municipal customers.

8.2.1 Kilgore Site

The City of Kilgore's well field is located about 9 to 11 miles southwest of the City. Currently, there are nine producing wells screened in the Carizzo-Wilcox formation that provide part of the City's water supply (see Table 8.2 at the end of this section). The remaining portion of the City's supply is provided by treated surface water from the City's water treatment plant. The ground water wells have a combined pumping rate capacity of 3,100 gallons per minute (gpm) or about 4.4 million gallons per day (MGD). Average daily well pumpage in 1997 was about 1.67 MGD. Total water use by the City for 1997 averaged 2.75 MGD, with peak month usage averaging 3.66 MGD.

The existing surface water treatment plant has a capacity of about 3.5 MGD, and the City is considering increasing the capacity to about 7 MGD in the future to meet needs during heavy demand periods. To delay the need to increase surface supply and treatment, an artificial recharge project can augment the ground water supply during the high demand summer months. In concept, an ASR project would route excess treated water in the winter (when total demand is less than the capacity of the water treatment plant) to the well field for injection via the production wells for storage. This water would raise the water levels in the wells and would then be used to help supply peak demands in the summertime. It would also reduce the demand on the treatment plant during the summer months. The water also might be used by other water supply entities located in proximity to the City's well field if the City wanted to sell water to them. When the City expands its surface water treatment plant capacity to 7 MGD, there should be additional water that could be routed to the well field for artificial recharge and short-term or long-term storage.

The City of Kilgore well field is located in an area with limited pumpage and a Lowered aquifer piezometric head (about 95 feet of decline), both of which contribute to a favorable storage area for injected water. Another advantage of the well field as an artificial recharge site is that the Carrizo Sand permeability is relatively high which helps increase the likelihood of wells accepting water during injection operations and not plugging. It is estimated that about 1 MGD could be available for injection based on data provided by the City of Kilgore Water Department.

Using available well capacity data, injection at two wells would be sufficient for this rate of recharge. Initial reviews indicate that Wells 1,3,7 and 9 may be the best candidate wells for artificial recharge.

City of Kilgore - Aquifer Parameters

Values of transmissivity, permeability and storage coefficient of the aquifer at the City of Kilgore well field have been calculated based on available data. Production Wells No. 1 through No. 9 in the well field screen sands in the Carrizo Sand or in the Carrizo Sand and underlying Wilcox aquifer and at the time of the tests, the aquifers were under artesian conditions. Pumping tests in the well field provide a coefficient of transmissivity that ranges from about 19,000 to 38,000 gallons per day per foot (gpd/ft) with the range in transmissivity values caused by the differences in thickness and permeability of sands screened by the wells. In general, the permeability of sands in the Carrizo Sand is higher than the permeability of the sands in the Wilcox aquifer. The test results show this to be the case and the data indicate an average value of permeability of about 152 gallons per day per square foot (gpd/ft^2) for the sands. Interference drawdown tests indicate an average coefficient of storage of about 0.0002 which is in line with the coefficient of storage values for unconsolidated sand aquifers under artesian conditions.

The specific capacities of the City of Kilgore Wells Nos. 1 through 9 range from 6.4 to 37.4 gallons per minute per foot of drawdown (gpm/ft) and average 19.9 gpm/ft. The specific capacities indicate that the sands screened have good permeability and could be less susceptible to clogging during injection than wells with lower specific capacities.

City of Kilgore - Two-Dimensional Modeling of Recharge Effects

An aquifer model code was used to estimate the amount of water-level rise that would occur in the recharge wells as a result of artificial recharge. The results are based on 347 gpm (0.5 mgd) being injected through two wells for a period of five months followed by a non-injection period of one day. The two wells selected for the example are Wells 1 and 3 located about 1,700 feet apart in the well field. The aquifer was assumed to have a transmissivity of 18,000 gpd/ft and a storage coefficient of 0.0002. These values are in line with those obtained from pumping tests in the well field with the value of transmissivity being on the conservative side. Based on these assumptions, it was estimated that the water-level rise in the two wells would range from 20 to 30 feet at the end of five months of injection followed by one day of non-injection. During the injection period, the water-level rise in the wells could be in the range of 50 to 100 feet. With the static water level of the wells in the range of 250 to 320 feet, the well water levels during injection periods should remain 150 to 200 feet below land surface.

8.2.2 Canton Site

The City of Canton began drilling water wells as early as 1957. Currently, there is one producing well screened in the Wilcox formation (Well No. 4) that provides about 0.25 MGD (see Table 8.2). This water is used to supplement treated surface water for the City's water supply. In 1997, the total City water usage averaged 0.77 MGD, with a peak month usage of 1.15 MGD. The City's water treatment plant has a capacity of 2 MGD, which is adequate for existing demands. The City is considering expanding the treatment plant to meet demands that occur on the weekends and First Monday Trade Days, which attract a large number of people to Canton and creates very high peak demands. A proposed ASR project may delay this need for plant expansion and maximize the use of its surface water supply.

Similar to the ASR project proposed for Kilgore, excess treated water would be routed to the existing well field during low demand months and injected for storage to be used during high demand periods. The water could be injected directly through Well No. 4 or a new well. Currently, water from Well No. 4 is obtained from the Wilcox aquifer at a depth of approximately 250 to 500 feet. The static water level is about 150 feet below ground surface, representing about 50 feet of decline. Based on an average permeability of 5.2 feet per day, it is estimated that the treated water could be injected at a rate of 100 to 140 gpm. This would cause the water level to rise during injections periods, but should be at least 40 feet below land surface. To ensure controlled water level rise, a high level cut-off switch could be installed in the well casing.

There is adequate treated surface water available for injection based on data from the City of Canton Water Department. Pilot testing should occur to assess the injection rate for the well and the overall feasibility of ASR. Periodic maintenance will probably be required due to plugging of the formation sands by the injection water. If water is injected at a rate of 120 gpm for 150 days (five months), this equates to approximately 80 acre-feet of water stored. If injection through one well is proven successful, then possibly an additional injection well would increase the amount of water available for peaking purposes.

City of Canton- Aquifer Parameters

Limited data are available on the transmissivity, permeability, and storage coefficient values for the Wilcox aquifer in the vicinity of Canton. Pumping tests have been performed on a number of wells in Rains and Van Zandt that screen the Wilcox aquifer with results provided in Texas Water Development Board Report 169 "Ground-Water Resources of Rains and Van Zandt Counties, Texas". The report gives values of permeability that range from 13.4 to 89.7 gpd/ft^2 and average 38.9 gpd/ft^2. Using an estimated value of permeability of 38.9 gpd/ft^2 and a screened interval for City of Canton Well No. 4 of 107 feet, results in an estimated value of transmissivity of 4,062 gpd/ft. The one-half hour specific capacity of Well No. 4 was measured at 3.3 gpm/ft in 1987. The value of specific capacity is consistent with the estimated transmissivity for the aquifers screened by the well. It is estimated that the coefficient of storage for the sands screened by City of Canton Well No. 4 is in the range of 0.00025 to 0.0004. A pumping test has not been performed on the well with an accompanying observation well to obtain an coefficient of storage based on empirical data. A coefficient of storage of 0.00038 was calculated from an interference drawdown test of wells for the town of Grand Saline which is located about 11 miles from Canton and has wells that screen sands of the Wilcox aquifer.

City of Canton - Two-Dimensional Modeling forWell No. 4

An aquifer model code was used to estimate the amount of water-level rise that could occur in Well No. 4 as the result of artificial recharge. The results are based on 120 gpm being injected through the well for a period of five months followed by a non-injection period of one day. The aquifer is assumed to have a transmissivity of 4,000 gpd/ft and a storage coefficient of 0.00025. These values are estimated are based on pumping test data from wells in Rains and van Zandt counties and on the estimate of transmissivity for Well No. 4. Based on theses assumptions, it is estimated that the water-level rise would range from 15 to 20 feet during five months of injection followed by one day with no injection. During the injection period, the water-level rise in the well could range from about 70 to 110 feet and with a static water level in the well of about 150 feet the wells water level during injection could remain 40 to 80 feet below land surface.

8.2.3 Preliminary Cost Estimates for ASR

Preliminary Cost Estimate for the City of Kilgore

Further studies and pilot testing of ASR are the next steps in assessing the feasibility of a recharge project. The chemical compatibility of the aquifer water and of the treated surface water should be studied and geochemical models used to help determine if chemical plugging of the well and aquifer may occur as the result of artificial recharge. The estimated cost is about $4,000 to $5,000 for collecting samples from the well and surface water supply, performing chemical analyses, and geochemical modeling. Pilot testing should be performed using probably Well No. 3 (34-48-202) to evaluate the aquifer response and well response to the injection of water.

At the ground storage facilities located in Kilgore, it is estimated that a small 500 gpm pump station would be required to pump surface water to the well field ground storage tank. It is estimated that the pump and motor, electrical equipment and piping modifications required at the ground storage tank in Kilgore could cost in the range of $40,000 to $50,000.

Piping and valving modifications and possibly a booster pump and motor and electrical controls would be required at the ground storage tank in the well field to route water back to Well No. 3. Minor piping modifications should be required at Well No. 3, along with installation of a filter or strainer, to route water down the well using the existing discharge piping and pump column assembly. It is estimated that the piping modifications, pump and motor and electrical costs in the well field could be about $40,000.

With the water delivery modifications completed at the ground storage facilities in Kilgore and in the well field and with the piping modifications performed at probably Well No. 3, pilot testing in the well field could begin. Pilot testing would help assess the rate at which the well will accept water and the response of the aquifer to the injection. The pilot testing would include injecting water and subsequently pumping it from the well and possibly repeating the sequence a number of times. It is estimated that the cost of pilot testing could be in the range of about $15,000. If the results of the pilot testing are satisfactory, Well No. 3 could be permanently equipped for ASR and additional booster pump and piping modifications could be completed to help automate the injection of water. Other wells in the well field also could be pilot tested as candidates for ASR. Considering all the above items, the total capital and pilot testing costs for ASR in Kilgore would range form $99,000 to $110,000.

Operating and maintenance costs are estimated as follows:

1. Electric power cost to pump water from Kilgore to well field for 175 feet of lift (500 gpm flow rate).	6.6¢ per 1,000 gallons
2. Labor cost at 4 hours per day at $20 per hour for 720,000 gallons of injection per day.	11.1¢ per 1,000 gallons
3. Treated surface water cost estimate from City of Kilgore	$1.32 per 1,000 gallons
4. Electric power cost for 375 feet of lift to pump water from well.	14.2¢ per 1,000 gallons
5. Well Maintenance/Cleaning ($15,000/two years with 5 months of injection per year at 500 gpm or 0.72 mgd.	6.6¢ per 1,000 gallons
Total O&M Cost	$1.71 per 1,000 gallons

If successful results are obtained during pilot testing and the artificial recharge system is enlarged to inject more than 500 gpm, then the booster pump facilities in Kilgore and at the well field would be expanded along with piping and monitoring modifications at additional wells. To increase the size of the system to handle about 1,050 gpm, it is estimated that it could cost an additional $150,000 to $200,000. The expenditure would be about evenly divided between facilities at the ground storage tanks in Kilgore and facilities modifications and additions in the well field. Utilization of an artificial recharge program would delay the construction of the next surface water treatment module of 3.5 million gallons per day. The estimated cost of that additional capacity is about $2.8 to $3.5 million.

The preliminary cost estimates are for a conceptual design of an ASR project. Pilot testing is required to help assess if ASR is a feasible water supply option. An economic comparison between a conceptual ASR project and other water supply options that may be considered by Kilgore is beyond the present scope of the study.

Preliminary Cost Estimate for the City of Canton

Further studies and pilot testing of ASR are needed to help assess the feasibility of a recharge project. The chemical compatibility of the treated surface water and the aquifer water should be studied and geochemical models used to help determine if chemical plugging of the well and aquifer may occur as the result of artificial recharge. It is estimated that it could cost about $4,000 to $5,000 for collecting samples from the well and surface water supply, performing chemical analyses, and for geochemical modeling. Pilot testing should be performed using Well No. 4 (37-26-407) to evaluate the aquifer response and well response to the injection of water.

Piping and pump modifications will be required at Well No. 4 to facilitate the injection of surface water. The well pump should be removed and small diameter injection tubes, probably no greater than 2 inches in diameter would be installed to extend below the static water level. The injection tubes would be connected to the well discharge piping and valves and a filter or strainer installed so that water could be routed from the distribution system to the injection tubes. Pump foundation and discharge head modifications may be required to perform the piping modifications. Safety equipment such as a high water-level cut off switch may be required to help insure that the water level does not rise too high in the well. It is estimated that the pump removal and reinstallation, injection tube installation, piping modifications, strainer, and electrical modification at Well No. 4 could cost about $30,000.

Following completion of the geochemical studies and the equipping and modifications at Well No. 4, pilot testing could begin. Pilot testing would help evaluate the rate at which the well will accept water and the response of the aquifer to the injection. Several cycles of injecting water and subsequently pumping it from the well could be required during the pilot testing phase. It is estimated that the cost of the pilot testing could range from about $10,000 to $15,000. If the pilot testing provides satisfactory results, Well No. 4 could be equipped on a permanent basis for ASR. Considering all the above items, the total capital and pilot testing costs for ASR in Kilgore would range form $44,000 to $55,000.

Operating and maintenance costs are estimated as follows:

1. Electric power cost for 270 feet of lift to pump water from well.	10.2¢ per 1,000 gallons
2. Labor cost at 2 hours per day at $20 per hour for 144,000 gallons of injection per day.	27.7¢ per 1,000 gallons
3. Treated surface water.	$1.30 per 1,000 gallons
4. Well Maintenance/Cleaning ($10,000/two years with 5 months of injection per year at 100 gpm or 0.144 mgd.	22.6¢ per 1,000 gallons
Total O&M Cost	$1.91 per 1,000 gallons

The study of the feasibility of artificial recharge would include, as mentioned previously, performing pilot studies, followed by artificial recharge using Well No. 4. Assuming artificial recharge using Well No. 4 is successful, the City could consider drilling additional wells at locations compatible with its distribution system to inject water into the Wilcox aquifer.

Utilization of artificial recharge to provide water to meet peak demands should help delay the expansion of the existing surface water treatment plant that is rated to provide 2 million gallons per day. Expansion of the plant, which could occur within the next 5 years, would be to a capacity of 4 million gallons per day. The estimated cost for expansion is about $1.6 to $2.0 million.

The preliminary cost estimates are for a conceptual design of an ASR project. Pilot testing, as stated previously, is required to evaluate the feasibility of the ASR option. An economic comparison between a conceptual ASR project and other water supply options that may be considered by Canton is beyond the present scope of the study.

Table 8.2: Water Supply Well Data for the Cities of Canton and Kilgore

State Well Number	City Well Number	Date Completed	Drilling Firm	Aquifer (1)	Well Elev. (feet) (2)	Depth of Well (feet)	Screened Interval (feet)	Well Diameters (inches)	Specific Capacity (gpm/ft)	Pumping Rate (gpm)	Static Water Level (feet) (3)	Date	Use of Water (4)
City of Canton													
34-26-401	Well No. 2	1964		Wc	500	505	300-505	--	--	--	90	1964	P(U)
34-26-404	Well No. 3	1969		Wc	480	461	--	--	--	--	97	7/25/1969	P(U)
34-26-407	Well No. 4	1971		Wc	505	521	259-496	10, 7	--	--	149	6/25/1984	P
City of Kilgore													
34-48-202	Well No. 3	1952	Texas Water Wells	Cz/Wc	510	534	313-524	20, 12	11.0	508	180	8/27/1952	P
34-48-203	Well No. 1	1952	Texas Water Wells	Cz/Wc	540	760	350-750	14, 12	26.0	1,120	230	5/12/1952	P
34-48-204	Well No. 4-R	1978	Layne-Texas Co.	Cz/Wc	530	748	353-724	20, 14			226.7	10/1/1952	P
34-48-303	Well No. 7	1963	Texas Water Wells	Cz/Wc	470	646	290-638	20, 12	25.4	942	200	5/20/1963	P
34-48-304	Well No. 9	1967	Katy Drilling, Inc.	Cz/Wc	527	698	330-688	20, 12	33.3	1,200	273	3/7/67	P
34-48-501	Well No. 2	1952	Texas Water Wells	Cz/Wc	563	508	374-499	20, 12	7.4	408	240	7/17/1952	P
34-48-502	Well No. 5	1957	Montgomery Drilling	Cz/Wc	560	476	340-470	24, 12	10.7	556	258	2/8/1957	P
34-48-503	Well No. 6	1957	Texas Water Wells	Cz/Wc	548	470	340-460	16, 8	7.1	307	244	9/11/1957	P
34-48-604	Well No. 8	1965	Katy Drilling Inc.	Cz/Wc	530	569	226-575	20, 12		784		7/8/1965	P

EXPLANATION:

(1) Aquifer:
Cz = Carrizo aquifer
Wc = Wilcox aquifer

(2) Approximate well elevations from U.S. Geological Survey (USGS) and/or Texas Water Development Board (TWDB) data and/or maps. USGS and/or TWDB reported well elevations are not the same for some wells.

(3) Static water level depths shown are reported depths to water below the measuring point datums for the wells, which are generally about 2 to 3 feet above the land surface elevation. USGS, TWDB and other reported water-level data may not be the same as shown if the water-level datums are different

(4) Use of Water: P = Public water supply
(U) = Unused

9.0 WATER AND WASTEWATER TREATMENT NEEDS

9.1 Water and Wastewater Treatment Survey

A survey of water and wastewater providers, local and regional governments, and industrial water users was conducted to define various issues pertinent to the provision of water in the basin. Each group received a survey designed to assess their specific conditions and needs. The surveys investigated the amount and source of current water supply, projected needs and the sources proposed to meet future needs. Information was also gathered on treatment facilities, planned expansions of service areas, water supply facilities or treatment plants, and conservation and drought management planning in the basin.

Approximately half of the surveys were completed and returned. The information obtained from these surveys was compiled and verified through meetings with the major water suppliers and wastewater providers (those that have an average flow of more than 5 million gallons per day). A list of these entities is presented in the Table 9.1.

Table 9.1: Major Water Suppliers and Wastewater Providers

Cities	Water Supply Corporations	Industries
Bridge City Carthage Center Gladewater Greenville Kilgore Longview Marshall Orange White Oak	Cash WSC Combined Consumer WSC MacBee WSC	Bayer Corp Chevron DuPont East Texas Saltwater Disposal Inland Paperboard & Packaging, Inc. Texas Eastman Texas Utilities (Martin Lake)

Based on the surveys and meeting with large suppliers, it was found that:

- There are no large increases to needs expected in the short-term.
- While some water providers and industrial users have water conservation plans, few of these plans specify conservation goals or mechanisms to quantify conservation savings. Even fewer providers and users have drought contingency plans.

- There appears to be sufficient water and wastewater treatment capacity for the next 10 to 20 years among the large suppliers.
- The surveys and interviews indicate a need to improve the knowledge and understanding of local suppliers on specific issues. Most of the larger entities know about the upcoming Safe Drinking Water Act regulations and Clean Water Act regulations and are adjusting or modifying their treatment systems to comply with them. Most of the smaller entities also know about the regulations but either: 1) do not know how to address them, or 2) know what needs to be done but do not have the money to modify their treatment facilities.
- Most of the larger entities do not have existing problems with treatment, whereas many smaller entities do have existing problems with their treatment facilities.
- Only one major wastewater provider, Chevron, is currently investigating reuse potential of their effluent.

A summary of the data compiled from the surveys and information meetings is presented on Tables 9.2 and 9.3 at the end of this section.

9.2 Septic Systems

Much of the basin's population is rural and is on septic systems. From the current water quality monitoring data, it appears that fecal coliform contamination due to septic systems is a problem within the basin. This should continually be monitored as part of the basin's source water protection program. TNRCC is currently performing studies that will result in better methods of detecting contamination from septic systems. In addition, there is new technology that can be used to pinpoint the contamination. It is an instrument that uses fluorescent lighting to detect household detergents leached out of a septic system. This can be very effective in identifying septic system problem areas.

9.3 Recommendations

The results of the water and wastewater survey identified several areas that could be improved, particularly with regard to expanding local technical expertise on water supply, treatment, and quality issues. The following recommendations focus on expanding local entity understanding and awareness of regulatory matters that impact water supply, quality or management in the Sabine Basin.

1. SRA, through its public involvement program, should develop a technical assistance program and educational and informational activities for specific use groups on relevant issues, as follows:
   - Maintain a database of contact names and addresses for all small water supply entities in the basin to be used to contact these suppliers with information on new EPA and TNRCC regulations.
   - Provide recommendations on treatment options to help small water supply entities comply with regulations.
   - Host and/or facilitate any available TWDB and TNRCC seminars or workshops regarding water or wastewater treatment. Hold these seminars at the SRA local offices in both the Upper and Lower basin and encourage local water and wastewater providers to attend.
   - Facilitate the TNRCC plant optimization program within the basin. This plant optimization program allows plant operators to visit other plants and learn new processes and also gives entities the opportunity to have outside operators come into their own plant to help optimize the treatment processes within the plant.
   - Train entities within the Sabine Basin that collect water quality data in approved data collection and analysis methods so that this information can be used in the Clean Rivers Program and SRA's Information System database. Currently much of the data cannot be integrated into the Clean Rivers Program or into the Information System database because the data is not obtained using standard, EPA-approved data analysis methods.
   - Host and/or facilitate TWDB drought management and contingency planning seminars to assist all of the water suppliers in the region with their plans.

2. If necessary, hire local consultants on an as-needed basis to help with a technical assistance program for local water and wastewater providers.
3. Study further the opportunity of implementing regional water and wastewater treatment facilities, particularly in the Lower basin where there was significant interest expressed in regional wastewater treatment by those entities in the meetings.
4. Incorporate any new TNRCC monitoring methodologies into SRA's water quality monitoring plan.
5. Use GIS and other analysis methods to continue monitoring for water quality problems that may be related to wastewater treatment effluent and septic systems. If necessary, utilize new technology to identify point source septic system contamination.

Table 9.2: Water Supply Information for Large Water Suppliers/Users in the Sabine Basin

Entity	Source	Amount of Source (MGD)	1996 Avg Day Use (MGD)	1996 Peak Day Use (MGD)	Plant Capacity (MGD)	2000 Avg Day Use from entity* (MGD)	2020 Avg Day Use from entity* (MGD)	2000 Avg Day Use from TWDB** (MGD)	2050 Avg Day Use from TWDB** (MGD)	Future Source
Bridge City	Ground water	2.38	0.77	1.156	NA			0.73	0.87	Additional wells
Carthage	Lake Murvaul & Ground water	12.0 & 1.1	2.50 (including wholesale customers & in city industry)	4.0	5.2	4.0	6.1	1.45	1.24	Lake Murvaul
Center	Lake Center & Lake Pinkston	1.3 & 3.4	2.8	3.7	4.6	2.3	3.76	0.84	0.97	None needed
Gladewater	Lake Gladewater	1.5	1.06 in city, 0.15 to wholesale customers	2.2	2.5			1.07	1.29	Currently applying to TNRCC for additional 1.5 mgd from L. Gladewater. Also considering new lake at Gilmer, Texas.
Greenville	City Lakes & Lake Tawakoni	3.7 & 19.0	4.46	7.52	13.0	5.17		5.26	5.07	No additional supply needed. City may return some of its Lake Tawakoni supply to SRA
Kilgore	Lake Fork & Ground water	3.5 w/ 2.5 option, 5	2.3 in city, 0.2 to wholesale customers	6.0	3.5			2.44	2.85	None needed
Longview	L. Cherokee, Lake Fork, Sabine River, Big Sandy Cr.	14.3 17.9 12.4 4.8 =49.4	18.67 in city, 2.44 to wholesale customers	31.0	42.0	19.8	23.8	14.16	17.11	Agreement to purchase 17.9 mgd from Lake O' the Pines with option for more. Developing system to deliver 30 mgd from that source.

* Estimated use from the entities includes manufacturing use and wholesale customers.
** Estimated use from the TWDB does not includes manufacturing use and wholesale customers.

Table 9.2 (continued) : Water Supply Information for Large Water Suppliers/Users in the Sabine Basin

Entity	Source	Amount of Source (MGD)	1996 Avg Day Use (MGD)	1996 Peak Day Use (MGD)	Plant Capacity (MGD)	2000 Avg Day Use from entity* (MGD)	2020 Avg Day Use from entity* (MGD)	2000 Avg Day Use from TWDB** (MGD)	2050 Avg Day Use from TWDB** (MGD)	Future Source
Marshall	Big Cypress Bayou	14.3	4.58	9.02	14.0	5.0	6.5	3.48	3.13	Currently looking at rights in Caddo Lake. Lake O' the Pines is also an option.
Orange	Ground water	4.25	3.36	3.7	NA	3.5	4.2	3.96	4.85	Plan to add 1.4 mgd of ground water within next 10 years.
White Oak	Big Sandy Creek (purchased from Longview)	3.0	0.869	1.907	2.0	.747	1.123	0.74	0.90	None needed
Cash WSC	Lake Tawakoni, Lake Fork, Lake Lavon	1.5 1.68 1.18 =4.36	1.2	2.187	2.7	1.59	5.46			Have requested 1.0 mgd from Lake Fork if it becomes available.
Combined Consumer WSC	Lake Tawakoni, Lake Fork	1.5 0.5	0.7	0.8	2.0	1.0	2.6			Lake Tawakoni, if available.
MacBee WSC	Lake Fork (actual use is from Tawakoni) & Ground water	0.5 with 1.5 option 0.9	0.511	1.026	2.0	.7	1.6			No plans for future sources.
Bayer Corp	SRA Canal, Ground water	1.0 1.0	2.0 1.0	4.3	4.0	4.5	4.5			2.9 mgd additional from SRA Canal division for plant expansion.
Chevron	SRA Canal, Ground water	2.0	5.75 diversion, 2.6 consumptive 0.15 gr. Water use	NA	6.0	3.0 consumptive use	3.0 consumptive use			.

* Estimated use from the entities includes manufacturing use and wholesale customers.
** Estimated use from the TWDB does not includes manufacturing use and wholesale customers.

Table 9.2 (continued) : Water Supply Information for Large Water Suppliers/Users in the Sabine Basin

Entity	Source	Amount of Source (MGD)	1996 Avg Day Use (MGD)	1996 Peak Day Use (MGD)	Plant Capacity (MGD)	2000 Avg Day Use from entity* (MGD)	2020 Avg Day Use from entity* (MGD)	2000 Avg Day Use from TWDB** (MGD)	2050 Avg Day Use from TWDB** (MGD)	Future Source
DuPont	SRA Canal, Ground water, Adams Bayou	22.0 0.1 Brackish Only	1.1 consumptive use	1.6	3.0	1.1	1.1			Possibly increase their use by 20% within 5 years and another 20% within 10 years. Will get this from SRA Canal.
Inland Paperboard & Packaging	SRA Canal, Ground water	20.0 1.6	15.3	16.2	16.0	16.0	16.0			None needed
Texas Eastman	Sabine River, Lake Fork, L. Cherokee, Longview, On-site reservoirs	20.0 3.12 4.9 0.70	18.8 total diversion, 15.1 consumptive use		NA	20.3	29.3			Additional on-site reservoirs being developed now. Other supplies not needed for next 25 years.
Texas Utilities	Martin Lake, Lake Fork (from SRA), Lake Fork (from Dallas), Ground water	22.3 10.7 15.2 0.16	19.3		0.9	19.3	19.3			None needed.

* Estimated use from the entities includes manufacturing use and wholesale customers.
** Estimated use from the TWDB does not includes manufacturing use and wholesale customers.

Table 9.3: Wastewater Information for Large Wastewater Providers in the Sabine Basin

Entity	1996 Avg Day Flow (MGD)	1996 Peak Wet Weather Flow (MGD)	Plant Capacity (MGD)	2000 Avg Day Flow (MGD)	2020 Avg Day Flow (MGD)	Expansion Plans	Reuse Potential
Bridge City	0.9	4.0	1.6	0.9	1.3	None	
Carthage	2.6	9.0	3.6			None	
Center	0.6	1.55	1.75	0.8	0.9	None	
Gladewater	0.655	1.398	1.4	0.8	1.2	None	
Greenville	2.9	7.0	4.23	3.1	3.8	Will enlarge plant in 3-5 years	
Kilgore	2.0	4.9	3.0			Add 3.0 mgd in year 2001.	
Longview	10.37	18.9	16.5	17.0	24.0	21 mgd in 1998-99.	
Marshall	3.6	4.7	5.9	3.7	4.0	8.0 mgd in 1998.	
Orange	3.5	9.5	7.0	4.0	6.0	None	
White Oak	0.55	1.6	1.0	0.8	1.4	Plant can be uprated to 1.2 mgd without modification. If 4th clarifier is added, it can be uprated to 1.4 mgd.	
Bayer Corp	2.5	11.83	20	2.5	2.5	None	
Chevron	2.29	7.75	3.6	2.5	2.5	None	In year 2001, they are looking at potential reuse project where they will reuse 90% of outfall
DuPont	7.0	15.0	12.0	10.0	10.0	None	

Table 9.3 (continued): Wastewater Information for Large Wastewater Providers in the Sabine Basin

Entity	1996 Avg Day Flow (MGD)	1996 Peak Wet Weather Flow (MGD)	Plant Capacity (MGD)	2000 Avg Day Flow (MGD)	2020 Avg Day Flow (MGD)	Expansion Plans	Reuse Potential
Inland Paperboard	18.8	24.3	20.0	20.0	20.0	None	
Texas Eastman	4.0	4.0					
Texas Utilities	0.01	0.02	0.4	0.01	0.01	None	

Note: No WSCs are involved in wastewater treatment.

10.0 WATER QUALITY AND ENVIRONMENTAL ISSUES

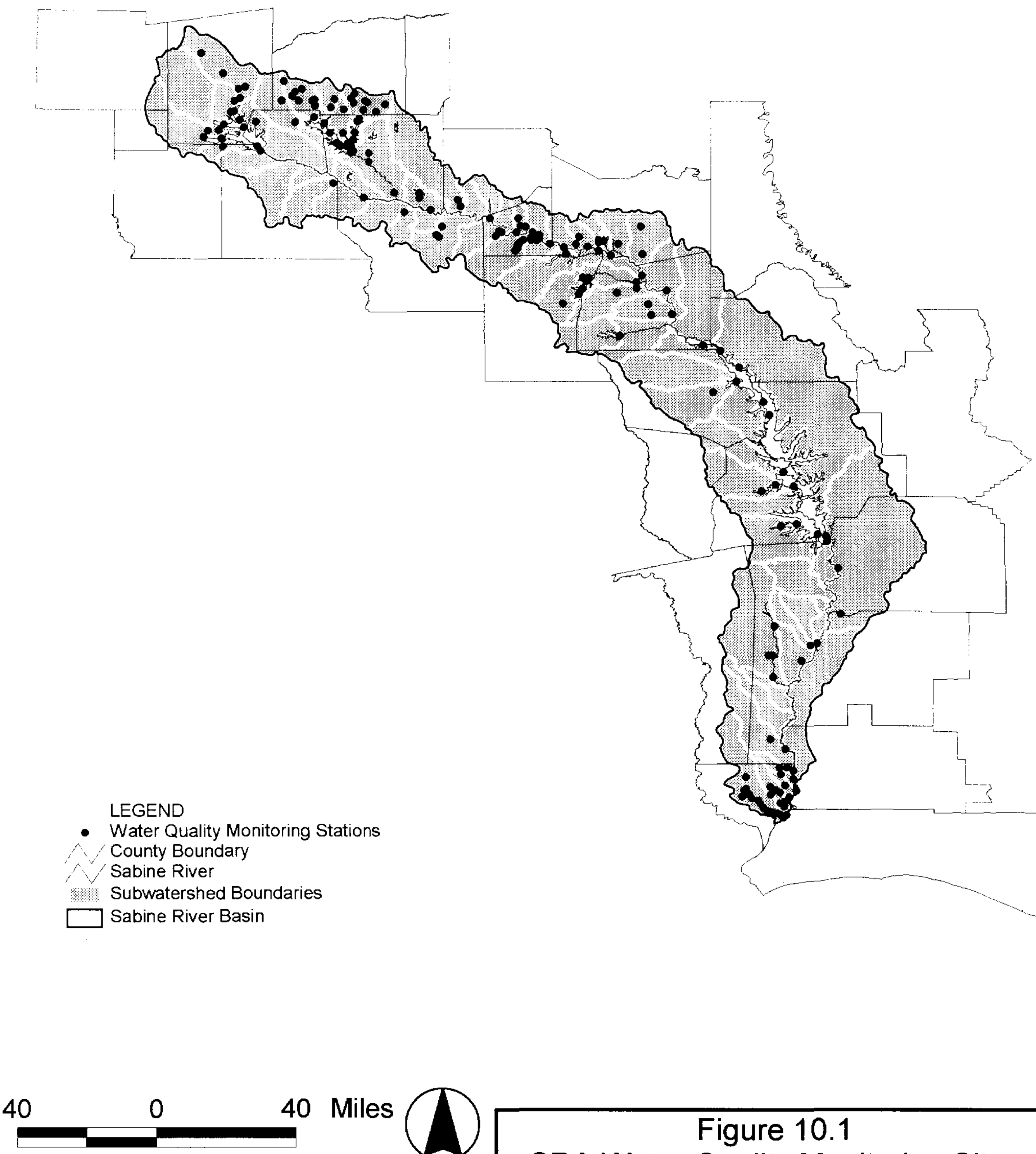
10.1 SRA Water Quality Monitoring Program

SRA has been involved with water quality issues since 1954, when operational activities were initiated. During the 1960's SRA compiled all available water quality data for the Basin to aid the Texas Water Quality Board, the predecessor to the Texas Natural Resource Conservation Commission (TNRCC), in the establishment of the first water quality standards criteria in Texas. In 1972 the program was expanded to include Basin-wide ambient monitoring. Building on years of experience and detailed knowledge of the watershed, the SRA has successfully integrated its mission and existing watershed monitoring program with the watershed management process put forth by the Texas Clean Rivers Program (CRP). SRA utilized the CRP to enhance its existing program and developed the subwatershed approach to water quality monitoring in the Basin, which has received statewide recognition. In September of 1998, the SRA received an exemplary rating by the TNRCC for its performance under the CRP. This section summarizes the SRA basin–wide monitoring plan with respect to its effectiveness in 1) addressing state and federal mandates and 2) identifying and addressing local water quality issues.

10.1.1 SRA Monitoring Program

In order to meet the CRP requirements for water quality assessments within the Sabine River Basin, SRA has developed a comprehensive Basin-wide monitoring plan consisting of three major components: Water Quality Monitoring Program (WQMP), Subwatershed Monitoring Program, and Special Studies. Technical decisions and activities associated with water quality monitoring are carried out within the framework provided by the SRA Basin-wide monitoring plan. SRA managers using input from the SRA steering committee and CRP guidance documents make decisions regarding technical issues such as site selection and sampling regime. Figure 10.1 illustrates water quality monitoring sites located in the Sabine River watershed.

The TNRCC's surface water classifications, designated uses, and identification of threatened and impaired water bodies were used to evaluate the SRA monitoring plan and its effectiveness in addressing water resource management issues. The TNRCC divides streams,



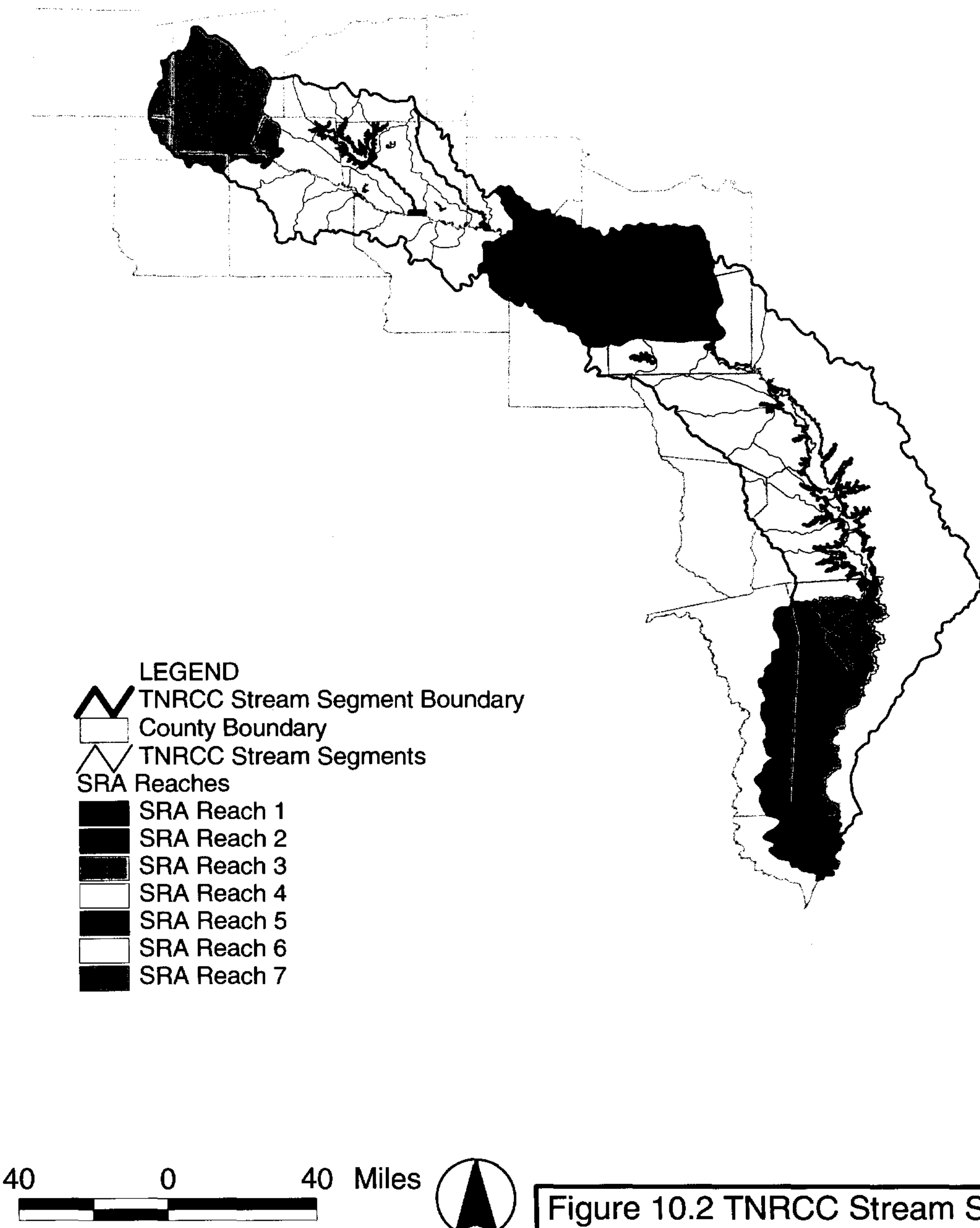
Source: Sabine River Authority
www.sra.dst.tx.us/pub/sra/srwmp/swi/gis/waterquality/

Figure 10.1
SRA Water Quality Monitoring Sites

Comprehensive Sabine
Watershed Management Plan

reservoirs, and lakes into geographic units called segments that are classified by the agency according to their quality, functions, and uses. The classifications assigned to each segment afford various levels of protection for water bodies through regulatory requirements and specific numeric water quality criteria. Figure 10.2 shows the relationships between the TNRCC's classified segments and the SRA's reaches and subwatersheds.

Based on regional assessments of each water body the TNRCC compiles a List of Impaired and Threatened Water Bodies in the state, also known as the State of Texas Clean Water Act (CWA) Section 303(d) List. Water bodies placed on the 303(d) list are subject to the development of a Total Maximum Daily Load (TMDL) under the CWA, as well as an evaluation of the appropriateness of existing segment criteria. In the Sabine Basin there are six water body segments identified on the 1998 303(d) list. According to the 1996 State of Texas Water Quality Inventory, one of these segments, Lake Tawakoni, continues to support all designated uses. Lake Tawakoni was placed on the 1998 303(d) list for atrazine in finished drinking water. The remaining segments on the 303(d) list do not support all designated uses, and include the Sabine River above Toledo Bend Reservoir, Toledo Bend Reservoir, Sabine River below Toledo Bend Reservoir, Adams Bayou (tidal) and Big Cow Creek. To address these water quality issues, SRA has focused a significant portion of their monitoring program on the identified segments. A total of 61 percent of the 102 water quality monitoring sites, and 50 percent of the 704 sampling events contained in the 1998-99 SRA Basin–wide monitoring plan are dedicated to collecting data from these five water bodies. Table 10.1 contains a summary of sampling activities associated with the SRA monitoring plan, the occurrence of water bodies on the 1998 303(d) list, and the support of designated uses for classified segments.



Source: Texas Natural Resource Conservation Commission
www.tnrcc.state.us/gis/base.html
Sabine River Authority
www.sra.dst.tx.us/pub/sra/srwmp/swi/gis/basemap/

Figure 10.2 TNRCC Stream Segments and SRA Reaches and Subwatersheds

Comprehensive Sabine Watershed Management Plan

Table 10.1 Water Quality Monitoring Regime for 1998-99

Water Body			WQMP		SMP/Special Studies*		Water Quality Management Issues	
SRA Reach	Segments and (Tributaries)	Description	Sites	Samples	Sites	Samples	On 1998 303(d) list	Supporting All Designated Uses
1	501	Sabine River Tidal	3	36			no	yes
1	(501)	Tributaries to 501	2	24			n/a	n/a
2	503A	Sabine R. Below Toledo Bend Res. (Lower half)	1	12			yes	no
2	(503A)	Tributaries to 503A			1	4	n/a	n/a
3	503B	Sabine R. Below Toledo Bend Res. (Upper half)	2	24			yes	no
3	(503B)	Tributaries to 503B	1	12			n/a	n/a
4	504	Toledo Bend Reservoir	6	72			no	yes
4	(504)	Tributaries to 504	5	60			n/a	n/a
5	505	Sabine R. Above Toledo Bend Reservoir	6	72			yes	yes
6	506	Sabine R. Below Lake Tawakoni	2	24			no	yes
6	(506)	Tributaries to 506			6	24	n/a	n/a
7	507	Lake Tawakoni	3	36			yes	yes
7	(507)	Tributaries to 507			9	36	n/a	n/a
1	508	Adams Bayou Tidal			20	80	yes	no
1	511	Cow Bayou Tidal			29	116	no	no
6	512	Lake Fork Reservoir	3	36			no	yes
2	513	Big Cow Creek	1	12			yes	no
6	514	Big Sandy Creek	1	12			no	yes
6	515	Lake Fork Creek	1	12			no	yes
Total			37	444	65	260		

n/a= Not Applicable
**SMP= Subwatershed Monitoring Program*

10.1.2 Watershed Influences on Water Quality

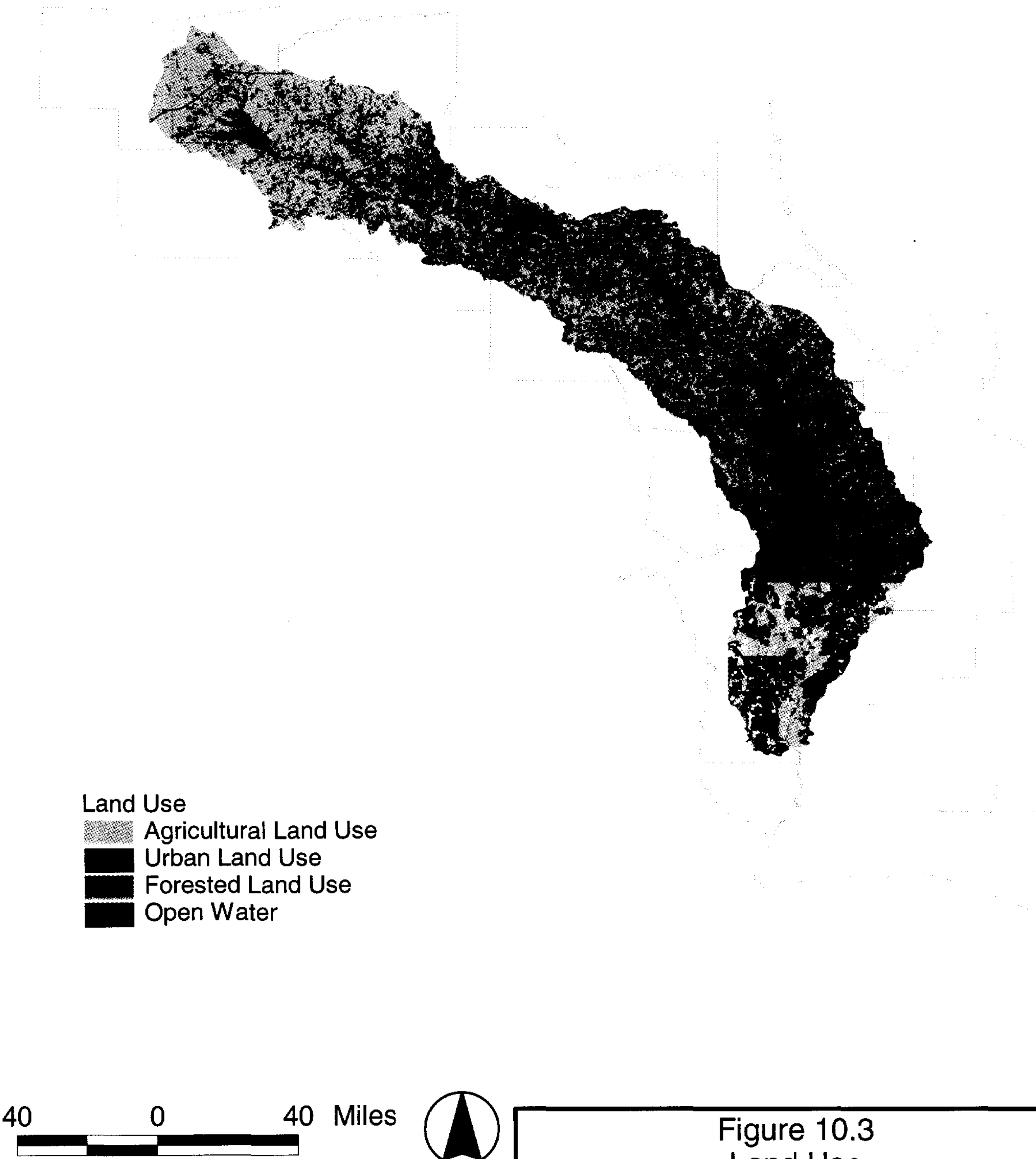
The monitoring program used in the subwatershed approach designed by SRA, characterizes water quality at the smallest practical drainage areas within the Basin. Water quality data at this level are compared to land use and other watershed information to determine potential sources of contamination to water bodies.

SRA's subwatershed approach takes into consideration the factors that place certain segments at risk for water quality concerns. These risk factors are determined from inventories of watershed activities and used to determine the overall risk of water quality impairment for each subwatershed. This information is then used in the decision making process for the allocation of future monitoring resources. The risk factors considered in the development of the subwatershed approach are: water quality, ambient toxicity, biological condition, superfund sites, permitted dischargers, cities with populations greater than 5,000, and landfills.

Effects of Land Use

To assess the effects of land use on water quality, a simple geographic information system (GIS) analysis was performed. Quantitative determinations of the percent cover by major land use categories (agricultural, forest, urban, water, and other) shown on Figure 10.3 were performed for each subwatershed. The land use data shown on Figure 10.3 was obtained from the Sabine River Authority's current GIS database. SRA originally obtained the data from the Environmental Protection Agency (EPA). Note that the sudden discontinuities of land use south of Toledo Bend appear to represent problems with the data rather than actual changes in land use. Using SRA's 1996 Regional Water Quality Assessment, the subwatersheds were grouped according to the type of water quality issue, either biological or physiochemical (Figure 10.4). The results of these analyses were then compared to determine potential relationships between land use coverage and water quality.

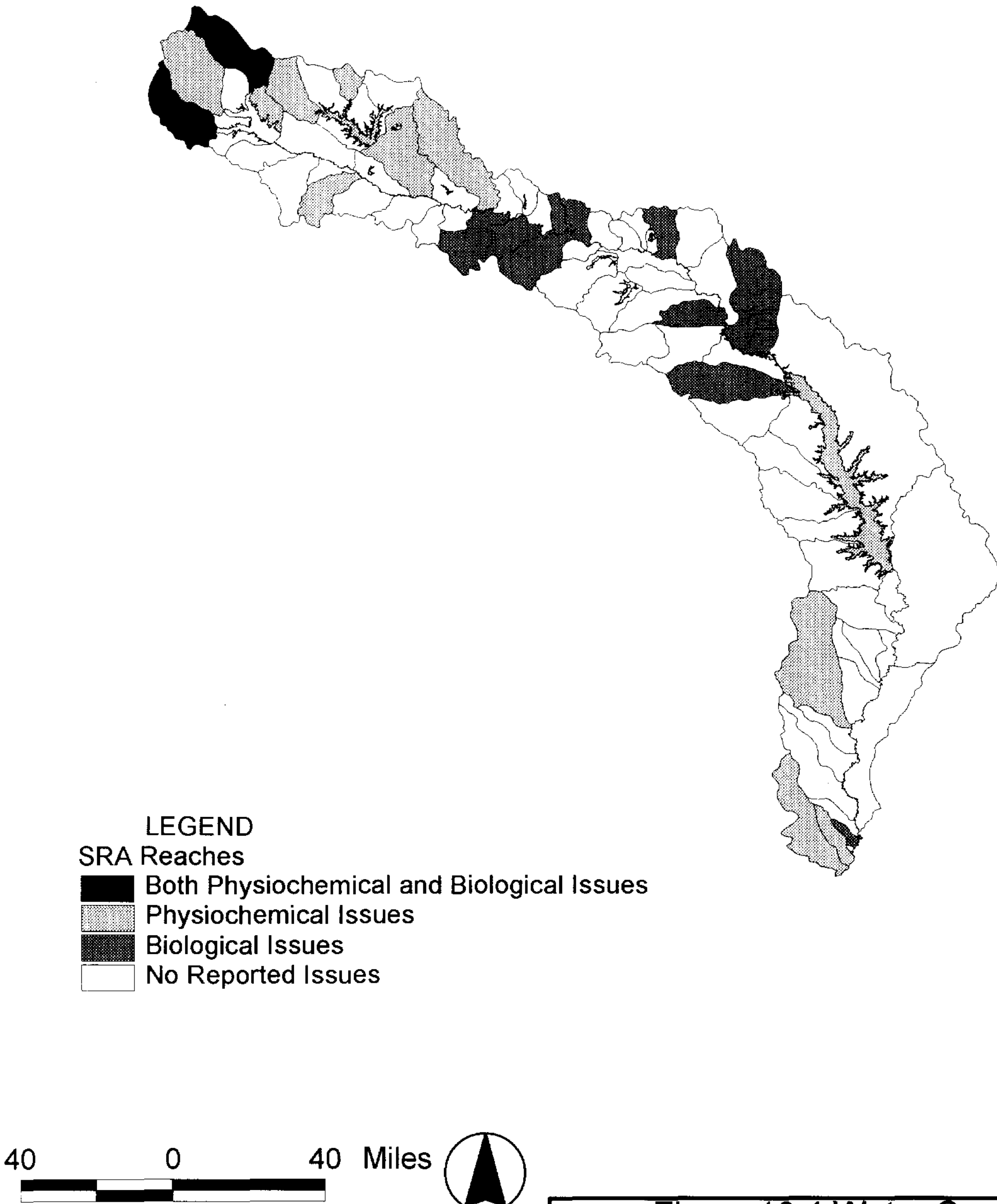
The percent coverage by major land uses for subwatersheds identified with physiochemical water quality issues is illustrated on Figure 10.5. GIS analyses indicate that the major land use occurring in these subwatersheds is agriculture and that the degree of water quality concern appears to be directly related to the percent of agricultural use. Two of these subwatersheds, Caney/Timber Creeks and South Fork Sabine River, also have biological impairment concerns, but due to their physiochemical concerns and predominant agricultural



Source: Enviromental Protection Agency
Sabine River Authority
www.sra.dst.tx.us/pub/sra/srwmp/swi/gis/landuse/

Figure 10.3
Land Use

Comprehensive Sabine
Watershed Management Plan



Source: Sabine River Authority's Water Quality Data

Figure 10.4 Water Quality Issues Associated with Subwatersheds

Comprehensive Sabine
Watershed Management Plan

land use they are discussed here. Nine of the 14 subwatersheds are located in areas either recently monitored or scheduled to be monitored by SRA under the Subwatershed Monitoring Program. As part of this program, water bodies are subject to a more intensive monitoring regime than the Basin-wide monitoring program (WQMP), including frequent water quality sampling, bioassessment, and ambient toxicity testing.

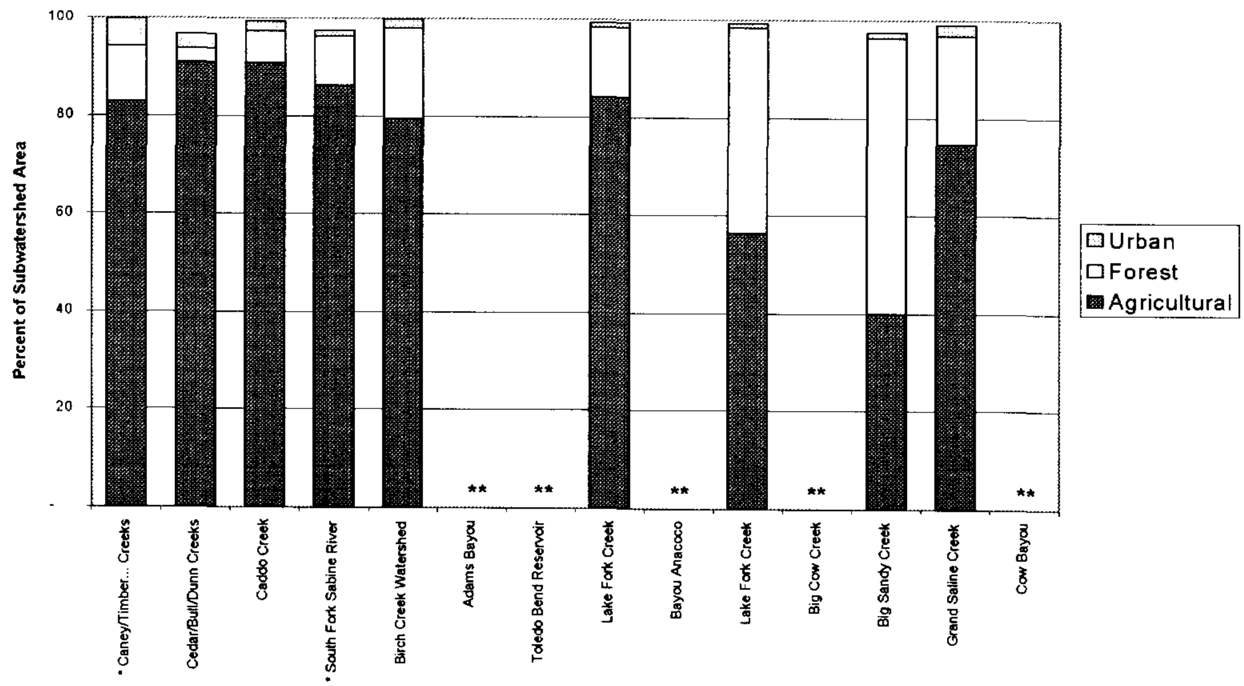
Figure 10.6 illustrates the percent coverage by major land uses in subwatersheds identified as having biological impairment. The major land use category dominating the subwatersheds with biological impairment is forest. Urban land use is less than 10 percent in all but two subwatersheds, the Iron Bridge/Grace Creeks and Hawkins Creek subwatersheds, which receive drainage from the cities of Longview and White Oak. Although most of these subwatersheds are dominated by forested areas, the degree or occurrence of biological impairment does not appear to be related to any major land use category. Because of the lack of other water quality issues in these subwatersheds, it is possible that biological impairment is not being caused by any of the major contaminants analyzed under the SRA chemical monitoring program. This could indicate that one or more contaminants are present which have an ecological effect but may not be detectable under the current monitoring program design.

Effects of Landfills and Dischargers

A similar GIS subwatershed analysis was performed for landfills and TNRCC permitted dischargers. Figures 10.7 and 10.8 illustrate the locations of landfills and permitted dischargers in the Sabine River watershed. Geographically, the locations of landfills are fairly evenly distributed among all subwatersheds, with no apparent relationship between water quality issues and the number, type, or location of landfills.

It should be noted that the dairy discharge information contained in the TNRCC database reflects only information provided for permitted dairies and does not include dairies that are below the minimum size to require a discharge permit. The eight dairy discharge permits that are located in the Sabine River Basin are located in or near the Lake Fork watershed. Although few subwatersheds in this area are reported to have water quality concerns or potential concerns, the Lake Fork Reservoir watershed has been the focus of an ongoing effort by TNRCC and other agencies to control nonpoint source pollution from agricultural activities.

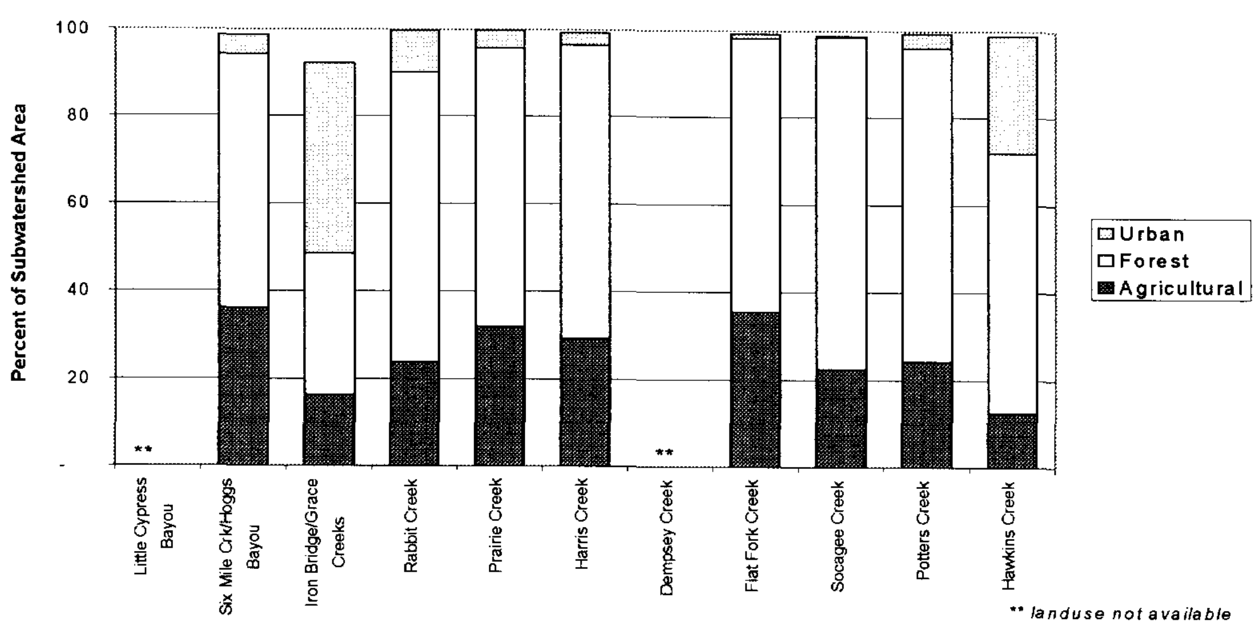
Figure 10.5 Land Use of Subwatersheds with Physiochemical Water Quality Issues



*site also has biological impairment ** landuse not available

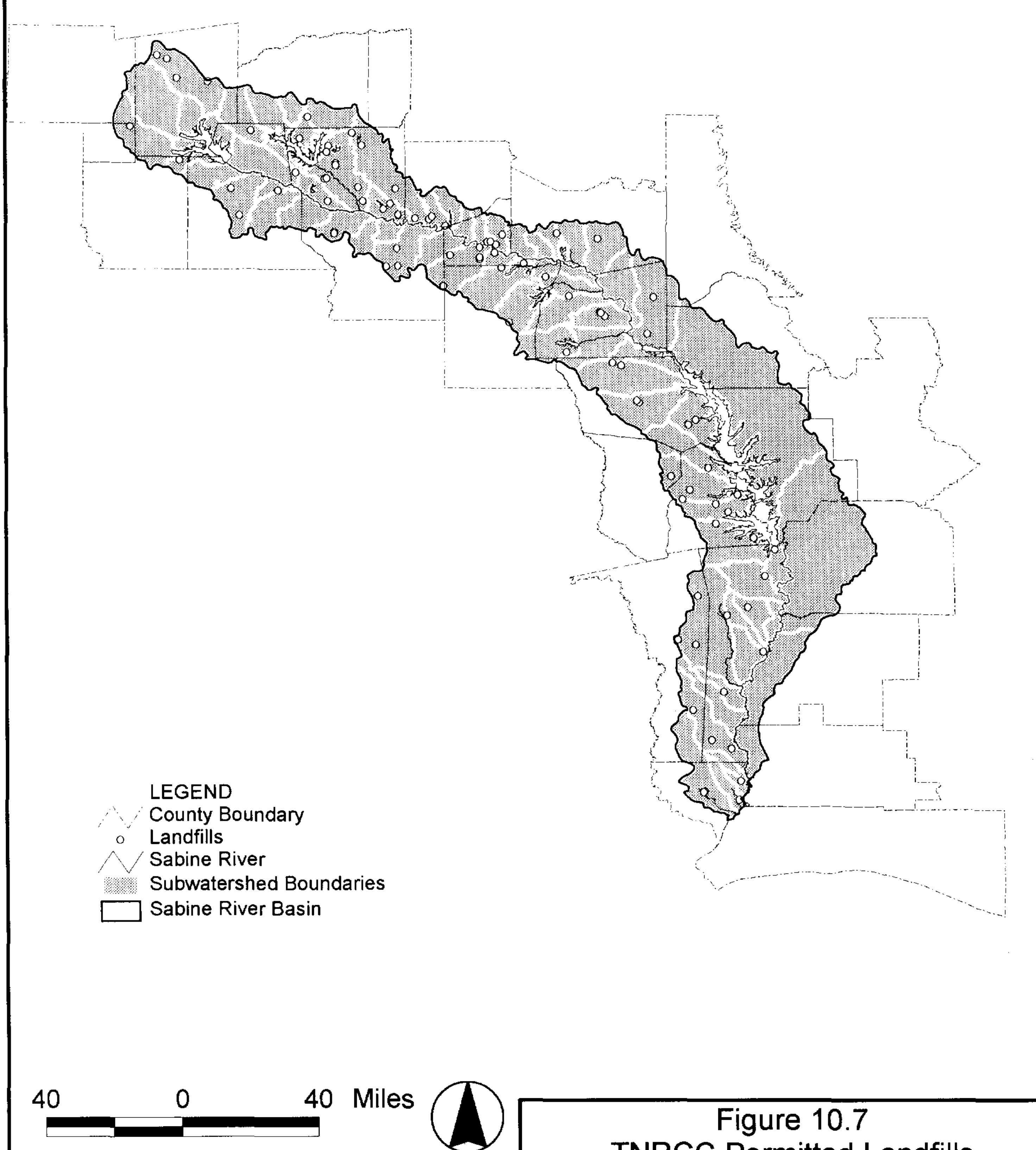
Subwatersheds are presented in order of decreasing water quality concerns.

Figure 10.6 Land Use of Subwatersheds with Biological Water Quality Issues



** landuse not available

Subwatersheds are presented in order of decreasing biological impairment concern.



Source: Texas Natural Resource Conservation Commission
Sabine River Authority
www.sra.dst.tx.us/pub/sra/srwmp/swi/gis/landfills/

Figure 10.7
TNRCC Permitted Landfills

Comprehensive Sabine
Watershed Management Plan

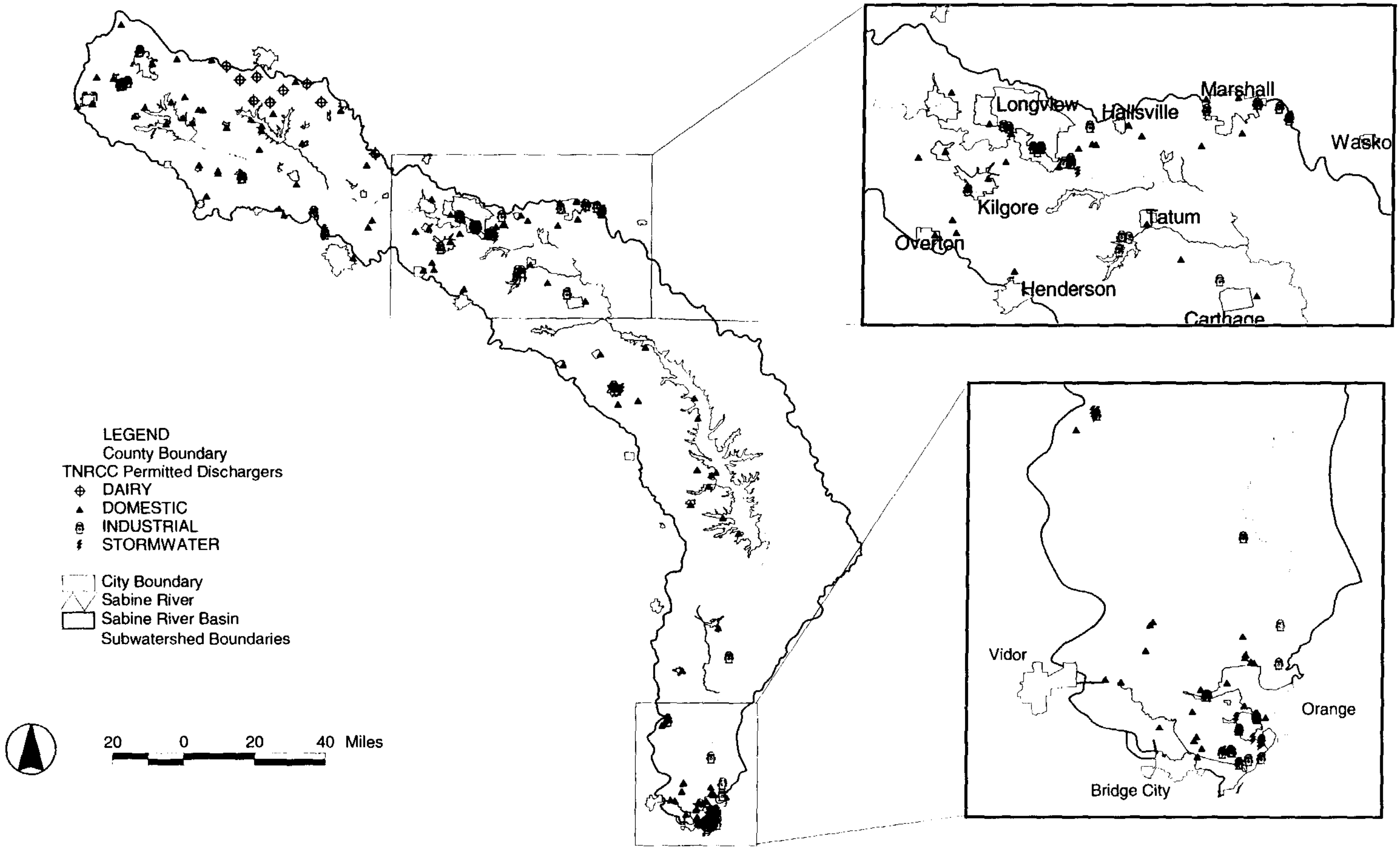


Figure 10.8
TNRCC Permitted Dischargers

Comprehensive Sabine
Watershed Management Plan

Source: Texas Natural Resource Conservation Comission
Sabine River Authority
www.sra.dst.tx.us/pub/sra/srwmp/swi/gis/outfalls/

10.1.3 Recommendations for the SRA Water Quality Monitoring Program

The priorities associated with the SRA Water Quality Monitoring Program (WQMP) appear to be compatible with the priorities and assessment requirements of regional water planning districts, such as those formed by Senate Bill 1, and Clean Water Act mandates such as the TMDL program. Integration of these programs at the local level will provide the most efficient use of SRA resources for water quality protection.

Continued development of the SRA's subwatershed approach, including the integration of water quality data with land use and point source information, will continue to provide the tools to make informed decisions about the quality of Sabine River watershed water resources. The local and regional processes that are in place should continue to actively support the Clean Rivers Program.

Watershed influences on water quality should continue to be a high priority in monitoring program design decisions. SRA should continue to use GIS technology to identify high priority areas as well as potential sources of water quality contamination. Existing Basin–wide land use databases are adequate for gross analyses but are inadequate at the subwatershed level. An effort to compile databases from all available sources that contain subwatershed-level information pertinent to the Sabine Basin would be a useful tool in the program design for future monitoring.

The current SRA monitoring program adequately characterizes baseline water quality conditions in the watershed, particularly in those areas included in the Subwatershed Monitoring Program. This approach identifies major contaminants and probable contaminant sources at the subwatershed level. Special Studies, the third major component of the program, are a useful addition to the monitoring program and can be used to incorporate high flow or storm sampling studies into the subwatershed studies where contaminants have been characterized and potential sources have been identified using the Subwatershed Monitoring Program. As an example, in rural areas sampling of storm runoff could be used to identify loadings from various parcels of land. This type of data could also be used by other agencies such as the Natural Resource Conservation Service in local non-point source demonstration projects within high priority watersheds. In urban areas, stormwater runoff data could be used by municipalities and industries to identify management practices or previously unknown problem areas that, if corrected, could improve the quality of the Sabine River. SRA could coordinate voluntary source identification surveys to better characterize unidentified water quality contaminants.

Characterization of stormwater quality and watershed runoff is an essential part of the TMDL concept. Any special studies that may be developed to address local contaminant issues should be designed if appropriate to be of use in modeling efforts associated with future studies such as TMDLs or Source Water Protection Programs.

As evidenced by the analyses presented in this report, the use of bioassessments in the SRA monitoring program complements the routine chemical monitoring procedures. It is possible, however, that existing bioassessment data from the Sabine River watershed may provide more useful information at the subwatershed level if a more regional approach was used. For example, the existing biological data may provide more distinction between levels of water quality impacts if regional tolerance values or analytical methods developed for local eco-regions were employed. The use of bioassessment data in regional assessments will become more crucial as the TNRCC develops biocriteria and implements them in the water quality standards.

Another ecological concern related to water quality in the Sabine River watershed is the increase in aquatic vegetation in reservoirs and the introduction of exotic aquatic vegetation. Three species, water hyacinth, hydrilla and salvinia, are aggressive invaders which have also caused water use problems in other parts of the state and country. The TPWD is currently revising its Aquatic Vegetation Management Plan for Texas based on input from aquatic vegetation scientists and other experts from around the state, including SRA staff members. The plan will include recommendations to control excessive increases of exotic and endemic aquatic vegetation. SRA is addressing the problem by continuing to identify and reduce sources of contaminant loading to the Sabine Basin that affect natural balances. By reducing the disturbance of natural aquatic communities, the likelihood of excessive aquatic plant growth of any kind is reduced. SRA should continue to implement appropriate control measures for streams and reservoirs in accordance with the TPWD Aquatic Vegetation Management Plan.

10.2 Environmental Considerations and New Reservoir Development

Environmental considerations that have the potential to alter planned reservoir development in the Sabine Basin include issues relating to:

- state and federally protected plant and animal species;
- bottomland hardwood forests;
- "waters of the United States", including wetlands and other special aquatic sites;

- cultural resources; and
- other protected areas. Protected areas include wildlife refuges, wetland mitigation banks, and conservation easements.

Complying with pertinent regulations requires extensive consultations and negotiations with state and federal regulatory agencies before a reservoir project would be approved. As part of the permitting process, issues such as threatened and endangered species, habitat protection, wetlands, and cultural resources would have to be addressed. An acceptable mitigation plan would have to be developed to compensate for unavoidable impacts. Major environmental issues that may affect proposed reservoirs in the Sabine Basin are discussed in the following sections.

10.2.1 Environmental Regulations

Due to the potential impacts of reservoir construction on the environment, water resource projects are regulated by a multitude of environmental laws. This section lists environmental rules that may apply to potential water resource projects in the Sabine Basin, including dams, reservoirs, canals, pump stations, aqueducts, wastewater re-use and aquifer recharge.

U.S. Army Corps of Engineers (COE)

Clean Water Act of 1972, Section 404 Permit The Clean Water Act applies to any action that adds dredge or fill material to Waters of the United States, including wetlands and non-navigable waters. New reservoirs in the Sabine Basin will require a 404 permit since they place a dam in waters of the United States. Canals, aqueducts or pipelines and levees may require 404 permits if they cross jurisdictional waters or wetlands.

Rivers and Harbors Act of 1899, Section 10 Permit Sections 9 and 10 of the Rivers and Harbors Act of 1899 affects all actions that may affect navigation in navigable waters of the United States, including dams, bridges, bulkheads, piers and docks. New reservoirs on major rivers in the Sabine Basin will require a Section 10 permit. This is usually applied for at the same time as the Section 404 permit. Navigable waters are subject to the Rivers and Harbors Act of 1899, which does not allow the construction of an obstruction within the waterway without Congressional approval. The main stem of the Sabine River below the confluence of Big Sandy Creek is considered navigable waters of the U.S.

U.S. Department of the Interior, Fish & Wildlife Service (USFWS)

Fish and Wildlife Coordination Act of 1966 The USFWS has the duty of reviewing and commenting on any action by another federal agency that affects natural resources such as fisheries, wildlife, and special habitats like wetlands. This is in addition to their specific regulatory requirements for endangered species, discussed below. Water resource projects in the Sabine Basin that affect wildlife habitats such as wetlands, bottomland hardwoods, free-flowing streams and mature forests would be subject to this Act.

Endangered Species Act of 1973, Section 7 Consultation and Section 10 Permit During coordination with the Fish & Wildlife Service, the agency may require a biological assessment under the Section 7 provisions of the Endangered Species Act. This report assesses the potential effects of a project on endangered or threatened species. If a project will affect, but not jeopardize, the existence of an endangered or threatened species, the project's sponsor is required to obtain a Section 10 permit for incidental taking of endangered or threatened species before construction. Mitigation for the remaining population and habitat is often required as a condition of this permit. Coordination with the Fish and Wildlife Service for major water projects in the Sabine Basin would generally include a Section 7 biological assessment of endangered species and possibly mitigation.

U.S. Department of the Interior, Bureau of Reclamation

The U.S. Bureau of Reclamation is not a permitting agency but a sponsor of water resource projects, especially in the western states, that benefit agriculture and industry. Bureau of Reclamation-sponsored projects must comply with all federal, state and local permit requirements. They are generally authorized by specific appropriation from the U.S. Congress.

Federal Energy Regulatory Commission, Federal Power Act, License for Electric Generating Stations

The Federal Energy Regulatory Commission issues licenses to entities wishing to build power generating facilities that benefit the public. These projects often require an environmental impact statement and other approvals. Water resources projects in the Sabine Basin that include hydropower generation will require a license from the Federal Energy Regulatory Commission.

All Agencies, National Environmental Policy Act of 1969, Environmental Impact Assessment

Each federal agency has its own rules for implementing the National Environmental Policy Act, which requires major federal actions that significantly affect the environment to prepare an environmental impact statement describing the action and alternative actions, detailing the environmental impacts, and proposing mitigation measures to reduce or eliminate impacts. Federal actions may include direct construction, funding and approval of permits. Water resource projects in the Sabine Basin will involve federal actions such as permitting and may involve federal funding.

Texas Natural Resource Conservation Commission (TNRCC)

Water Rights Permit Chapter 11 of the Texas Water Code and Section 30 of the Texas Administrative Code require anyone wishing to divert, use, or store surface water, or to transfer surface water between Basins, to obtain a permit from the TNRCC. The permit application includes environmental, hydrologic and conservation assessments. Water resource projects in the Sabine Basin may involve modification of existing permits or creation of new permits which are subject to TNRCC's assessment. The agency requires water conservation and drought contingency planning with all permit actions and may impose conditions for instream flow and water conservation. All applications for water rights that lie within 200 river miles of the coast must include an assessment of the right's affect on bays and estuaries.

Clean Water Act of 1972, Section 401 Certification The Texas Natural Resource Conservation Commission must certify that each project that obtains a Section 404 permit by the Corps of Engineers will not degrade water quality below state standards. The agency has recently issued draft guidance for implementing Section 401 certification. The guidance requires demonstrations from the applicant that the project has no practical alternative that would not affect the waters, and that losses of wetlands and waters have been avoided, minimized and mitigated in that order.

Clean Water Act of 1972, TPDES Discharge Permit The Texas Natural Resource Conservation Commission has recently been delegated authority to permit wastewater discharges under Section 402 of the Clean Water Act of 1972 from the United States Environmental

Protection Agency. Anyone who discharges wastewater into the Sabine Basin requires a Texas Pollutant Discharge Elimination System permit from the TNRCC.

Texas Water Development Board (TWDB), Texas Water Plan Consistency

The TWDB provides funding assistance to water resource projects that are part of the Texas Water Plan, developed under Senate Bill 1, and are consistent with the plan's goals. Water resources projects in the Sabine River Basin that are not in the plan or are inconsistent with the State Water Plan are unlikely to receive state funding.

Texas Parks & Wildlife Department (TPWD), Sand, Gravel and Marl Extraction Permit

All projects that involve excavation or removal of sand, gravel, or marl from state owned streambeds must have a permit from the Texas Parks & Wildlife Department. Water resources projects in the Sabine Basin will require a permit from the Texas Parks and Wildlife Department prior to start of construction once the Texas General Land Office (GLO) has determined that the impacted water course is state owned.

Texas General Land Office

Coastal Management Plan Consistency Determination All projects involving state and local permits or funding in the coastal counties of Texas must also be consistent with the Texas Coastal Management Plan. Water resources projects in Orange County in the Sabine Basin should also be reviewed for consistency with the Texas Coastal Management Plan as part of obtaining other permits to ensure that this process will go smoothly.

Grant of Easement All projects that cross or otherwise impact state owned waterways must obtain a Grant of Easement from the Texas General Land Office prior to start of construction.

Aquifer Recharge Rules Permitting authority for aquifer recharge resides with TNRCC. A Class V injection well permit would be required. If surface water is the source, a new or amended water right permit may also be required.

Municipal Zoning and Land Use Codes

Many cities in Texas have zoning and land use regulations that require project approval or permitting. Some water resources projects may not be initially consistent with local regulations and may require local approval of variances to local zoning or land use plans.

10.2.2 Existing Conditions

Threatened and Endangered Species

Federal and state lists of endangered and threatened species that are likely to occur in the counties where reservoir development is proposed are presented in this section. The locations of the six reservoirs analyzed in detail in Section 7 include portions of Rusk County (State Highway 322), Panola County (Carthage), Smith County (Waters Bluff and Prairie Creek), Upshur County (Big Sandy and Waters Bluff), Wood County (Big Sandy, Carl L. Estes, and Waters Bluff), Van Zandt County (Carl L. Estes), Rains County (Carl L. Estes), Gregg County (Prairie Creek and Carthage), and Harrison County (Carthage). Table 10.2 contains the names, protection status, and preferred habitats for each species according to the county lists published by the USFWS (USFWS, 1998) and the TPWD (TPWD, 1999). The county lists are not specific to individual reservoir sites, and a field survey to determine the presence or absence of species or habitats would be necessary if any of the recommended sites are selected for reservoir development.

Direct impacts of reservoir development on endangered and threatened species include flooding and removal of vegetation, and the potential for habitat fragmentation or isolation. Inundation of existing floodplains and the creation of open water habitat would decrease the habitat available for mammals, terrestrial snakes, and stream fishes, but would increase or enhance the habitat and forage area for other species such as birds, reptiles, and lake species of fish.

Table 10.2 Endangered and Threatened Species Potentially Occurring in the Counties of Proposed Reservoir Development

Category	Common Name	USFWS Status *	TPWD Status *	Preferred Habitat	Upshur	Wood	Smith	Van Zandt	Rains	Rusk	Panola	Gregg	Harrison
Birds	American Peregrine Falcon		T	High cliffs, near water	X	X	X	X	X	X	X	X	X
	Arctic Peregrine Falcon		T	Nests in Arctic, winters along coasts and in meadows	X	X	X	X	X	X	X	X	X
	Bald Eagle	T		Along rivers, near large water bodies with large trees	X	X	X	X	X	X	X	X	X
	Interior Least Tern	E	E	Along sand and gravel bars within braided streams and rivers								X	
	Wood Stork		T	Prairie ponds and flooded areas, nests in tall snags									X
Fishes	Blackside Darter		T	Clear gravelly streams, pools and riffles					X		X		X
	Bluehead Shiner		T	Swamps and backwater areas									X
	Creek Chubsucker		T	Headwater streams, seldom in impoundments	X					X			X
Mammals	Black Bear	T	T	Bottomland hardwood forests			X				X		X
	Louisiana Black Bear	T	T	Bottomland hardwood forests	X		X			X	X	X	X
	Rafinesque's Big-Eared Bat	T	T	Hollow trees of forested regions									X
Reptiles	Alligator Snapping Turtle		T	Deep and shallow water with mud bottom and vegetation		X	X		X	X	X		X
	American Alligator	T (SA)		Broad river valleys, marshes, estuaries, and sluggish creeks		X							
	Louisiana Pine Snake		T	Mixed deciduous-longleaf pine woodlands		X							
	Scarlet Snake		T	Pine, hardwood and mixed forests		X	X						X
	Texas Horned Lizard		T	Open, arid and semi-arid regions			X	X		X	X		
	Timber/Canebrake Rattlesnake		T	Swamps, floodplains, woodlands, riparian zones		X	X						
Total Species		6	15		5	8	9	4	5	7	8	5	12

From: USFWS web site http://ifw2es.fws.gov/endspcs/spp_lists/txttexas.exe (12/17/98), and TPWD Annotated County Lists of Rare Species (2/12/99)
* T = Threatened; E = Endangered; C = Candidate; SA = Similarity of Appearance
X = Species is listed as potentially occurring in the county

10.2.3 Priority and Protected Areas

Wetland Mitigation Banks and Conservation Easements

Mitigation banks and conservation easements are two tools used to protect and preserve wetland and other natural resources. These areas are considered protected properties and are used in the screening of proposed reservoir sites in this report.

Wetland mitigation banking involves the creation, restoration, or increased protection of a functioning wetland to offset anticipated wetland impacts of the same habitat type, and was developed to expedite the regulatory approval process for mitigating wetland impacts. Mitigation banks were originally developed for entities, e.g. departments of transportation, repeatedly involved in projects resulting in wetland impacts. The mitigated impacts are generally for projects within the same watershed as the mitigation bank for cases where on-site or off-site in-kind compensation cannot be achieved or would not be as environmentally beneficial. Mitigation banks may be owned by either an agency or an individual and may be operated either for profit or as a not for profit endeavor.

Conservation easements are similar to mitigation banks in that they may be used as a conservation or preservation tool to preserve, protect, or enhance wetland and other natural resource areas. Conservation easements differ from mitigation banks in that the property owner legally (and voluntarily) restricts the type and amount of activity that may take place on their property. These easements may be managed by private land trusts, state entities such as the TPWD, or federal entities such as the USFWS or U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS). The restrictions of each easement are unique to the property and to the interests of the land owner, and are limiting to the degree that is necessary to protect the significant values of the property. The entity holding the easement is responsible for enforcing the easement restrictions.

Five wetland mitigation banks were identified in the Sabine Basin, encompassing a total of 10,189 acres of bottomland hardwood habitat. Two banks, the Anderson Tract Mitigation Bank and the Blue Elbow Swamp Mitigation Project, were established to compensate for future impacts to wetlands by Texas Department of Transportation construction activities. Others in the Sabine Basin include the Byrd Tract Mitigation Bank established by Enron Oil and Gas Company, the Klamm Mitigation Bank, and the Hawkins Mitigation Bank. One conservation easement was identified in the Sabine Basin and is owned by the Little Sandy Hunting and Fishing Club.

The Sabine Basin contains 12,675 acres protected by conservation easements. These easements are held by two conservation organizations - the Archeological Conservancy and the Texas Nature Conservancy (TNC), and two government agencies - the USFWS and NRCS.

Evaluation of Three Potential Mitigation Banking Sites

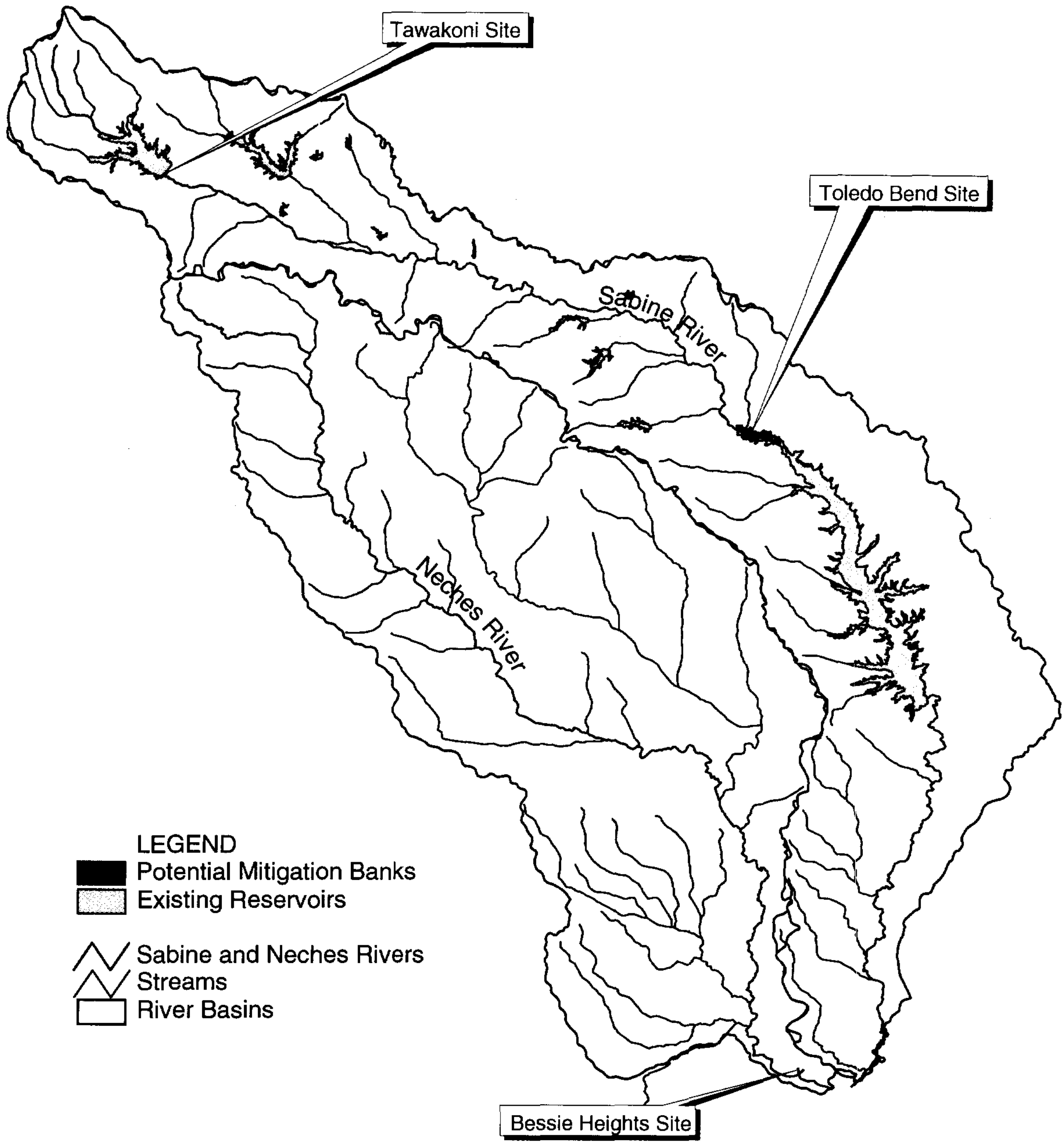
The five wetland mitigation banks located in the Sabine River watershed cover 10,189 acres of bottomland hardwood habitat and comprise 54 percent of the statewide acreage of mitigation banks. These banks have shown, with varying degrees of success, that mitigation banks can be a useful tool for individuals, private industry, and agencies in the mitigation of impacts due to different types of development.

A screening study was performed to evaluate two areas in the Sabine Basin and one area in the Neches Basin regarding the suitability for development as wetland mitigation banks. Data were used to determine potential environmental and physical constraints to development of the three sites as wetland mitigation banks. Site locations are shown on Figure 10.9. These banks could be used by SRA to mitigate impacts of its actions to wetlands in the Sabine Basin.

The Toledo Bend Site is located upstream (north) of the northern reaches of Toledo Bend Reservoir in Panola County and contains approximately 8,063 acres. The Tawakoni Site is located downstream (south) of the Lake Tawakoni Dam in Rains and Van Zandt Counties and contains approximately 1,140 acres. The Bessie Heights Site is located on the northeast side of the Neches River in Orange County and contains approximately 400 acres. The SRA owns all three sites.

Factors used in the screening of these sites included the quality and quantity of existing wetlands, soil surveys and hydric soils list, degree of prior disturbance, frequency and duration of flooding, vegetation cover type, size of the area, proximity to other wetlands or water bodies.

The Toledo Bend and Tawakoni sites are located primarily in the floodplain and bottomlands of the Sabine River and are occupied by jurisdictional wetlands. Existing wetlands at these sites are high quality wetlands that could not be improved easily and would not generate substantial amounts of wetland credits above what they currently provide. For this reason, the



30 0 30 Miles

Figure 10.9 Potential SRA Wetland Mitigation Banking Sites

Comprehensive Sabine Watershed Management Plan

Source: Sabine River Authority

Sabine River Authority would not receive many wetland credits while incurring substantial costs to develop most of these areas.

The Bessie Heights Site includes upland areas (and associated freshwater wetlands) that developed when dredge spoil from the Neches River was deposited in diked disposal areas, brackish wetlands along the estuary, and open water. The open water area is now part of the estuary to the east of the site and is associated with the Bessie Heights Oil and Gas Field. Construction of a mitigation bank on the spoil disposal areas of the Bessie Heights Site is feasible only on the areas that are close to the elevation of the surrounding water. This may not be desirable due to the difficulty of acquiring and permitting new spoil disposal areas. A mitigation bank at the Bessie Heights Site would be suitable for mitigating impacts to brackish marshes in the area, but not for mitigating impacts to bottomland hardwood forests elsewhere in the Sabine River Basin. Mitigation bank credits must generally be used for similar habitats in the same river Basin. Therefore, a wetland mitigation bank at Bessie Heights may not be very useful to SRA.

Bottomland Hardwood Habitat (Floodplain)

Bottomland hardwood areas identified in the USFWS Bottomland Hardwood Preservation Program (USFWS, 1984) were used as a screening tool for potential environmental concerns at each proposed reservoir site. Other types of wildlife habitat may exist in the vicinity of the proposed reservoirs, but these were not specifically addressed. Figure 10.10 illustrates the proximity of the proposed reservoir sites to the USFWS-designated Priority 1 and Priority 2 bottomland hardwood areas.

Estimates of mitigation acreage and ratios for wildlife habitat losses were taken from intensive studies of the Waters Bluff site (TPWD, 1998) and the Big Sandy and Carl L. Estes sites (Frye & Curtis, 1990). Assessments of land cover and vegetation at these sites were performed using remotely sensed data (thematic mapping imagery and aerial photography) followed by agency field surveys. The quality of wildlife habitat at the Waters Bluff and the Carl L. Estes sites was evaluated using the Wildlife Habitat Appraisal Procedure (WHAP) (Frye, 1986), while the Big Sandy site was evaluated using the Habitat Evaluation Procedure (HEP) (USFWS, 1980). Habitat data for the remaining three reservoir sites (Carthage, Prairie Creek, and State Highway 322) were not available at the time of this report. More detailed analyses

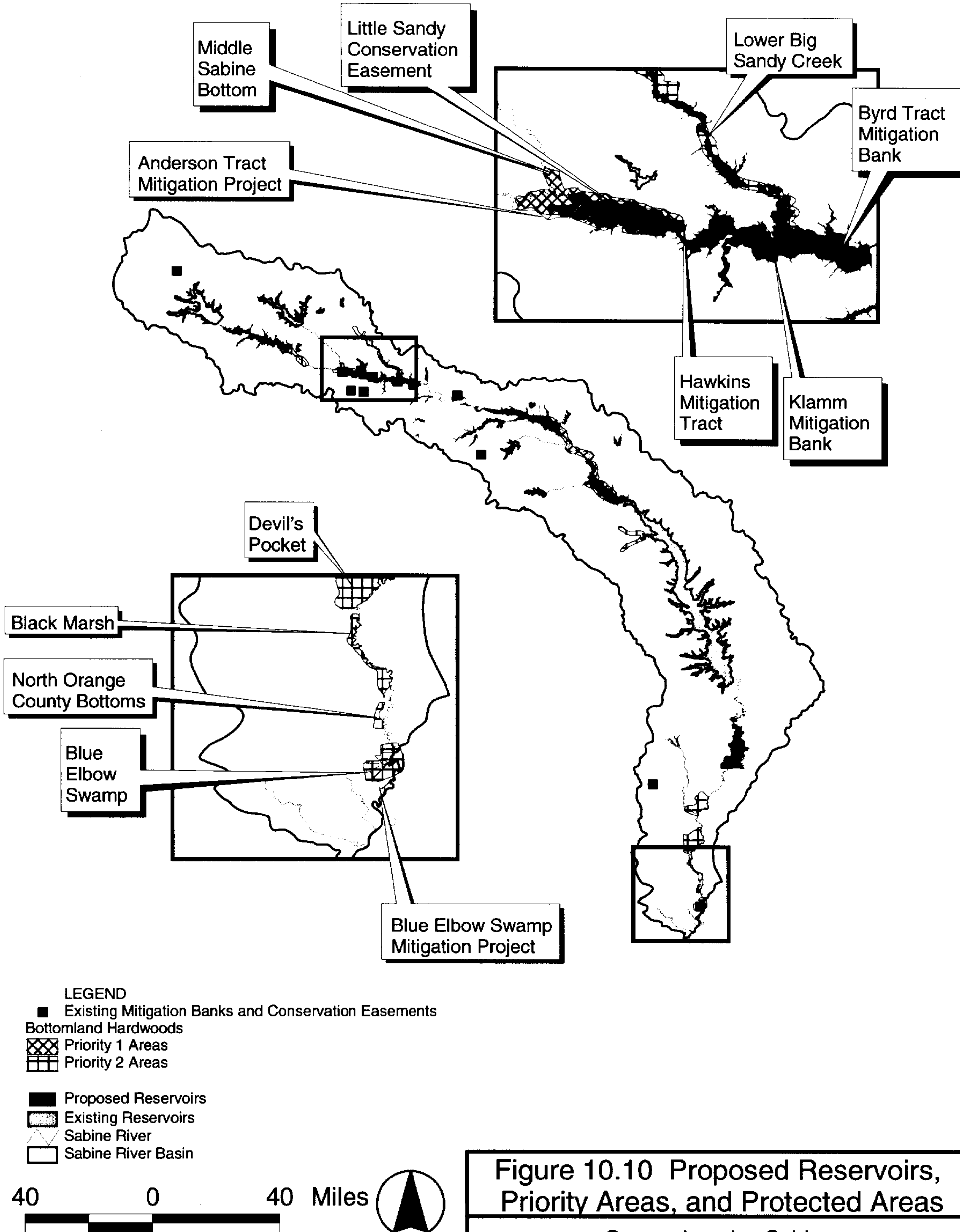


Figure 10.10 Proposed Reservoirs, Priority Areas, and Protected Areas

Comprehensive Sabine Watershed Management Plan

would be necessary to quantify available habitat and determine the extent of mitigation required for site development.

Table 10.3 includes a summary of each of the recommended reservoir sites with respect to the location of bottomland hardwood areas, wetland mitigation banks, known conservation easements, and estimated acreage of similar habitat that may be required for mitigation of impacts due to site development.

As evidenced by available information, four of the six proposed reservoir sites intersect with at least one USFWS priority bottomland hardwood area. Detailed habitat assessments of three of these sites (Waters Bluff, Big Sandy, and Carl L. Estes) have provided estimates of mitigation requirements under different management regimes. Mitigation requirements for the Carthage site were not available at the time of this report. Data identifying habitat at the Big Sandy and Carl L. Estes sites were collected in 1980 and may not reflect current conditions. Development of the Prairie Creek and State Highway 322 sites would not intersect any areas identified in the USFWS program, but could potentially impact other important areas of wildlife habitat. For specific sites targeted for development, updated habitat assessments should be performed to determine mitigation requirements for current habitat conditions.

Based on USFWS priority areas, current mitigation banks, and known conservation easements, development of the Waters Bluff site would impact the largest area and the greatest number of sites. Thirty nine percent of the proposed site (20,350 acres) would impact seven separate areas of concern, including two USFWS priority areas, four wetland mitigation banks, and one USFWS National Wildlife Refuge protected through a conservation easement. The extent of the proposed reservoir site and the high habitat quality assessed in 1997 (TPWD, 1998), combine to influence the mitigation requirements. The TPWD determined that between 141,575 and 566,039 acres of similar habitat would be required to mitigate the entire reservoir, depending on the intensity of the habitat management employed at the mitigation site. This acreage corresponds to mitigation ratios of between 4.5:1 and 18:1. According to the TPWD report, it is uncertain whether one or even several tracts could be found that could satisfactorily meet the mitigation requirements set forth for development of the Waters Bluff site. The significant mitigation requirement and a relatively great number of protected and priority areas would provide significant obstacles to development of the Waters Bluff site.

Table 10.3 Priority and Protected Areas Located at Proposed Reservoir Sites and Estimated Mitigation

Proposed Reservoirs		USFWS Priority Areas, Mitigation Banks, and Protected Areas Located in the Proposed Reservoir Site			Estimated Acreage Required for Mitigation of Site Development		
Name of Reservoir	Total Area (acres)	Name of Priority/Protected Areas	Acres Impacted	Percent of Proposed Reservoir Site	Minimum Management	Moderate Management	Maximum Management
Big Sandy	5,460	Upper Big Sandy Creek & Glade (P2) Lower Big Sandy Creek (P2)	640 2,168	52	21,344 (M1)	10,716 (M1)	5,359 (M1)
Waters Bluff	29,598	Lower Big Sandy Creek (P2) Middle Sabine Bottom (P1) Little Sandy National Wildlife Refuge Anderson Tract Mitigation Project Hawkins Mitigation Bank Klamm Mitigation Bank Byrd Tract Mitigation Bank	817 8,885 3,802 4,937 175 1,251 483	39	566,039 (M2)	283,150 (M2)	141,575 (M2)
Carthage	37,781	Lower Sabine Bottom (P1)	10,371	27	undetermined	undetermined	undetermined
Carl L. Estes	29,824	Upper Sabine Bottom (P2)	4,659	16	146,705 (M1)	73,363 (M1)	36,681 (M1)
Prairie Creek	2,280	none	n/a	n/a	undetermined	undetermined	undetermined
State Highway 322	6,510	none	n/a	n/a	undetermined	undetermined	undetermined

P1 = USFWS Priority 1 Bottomland Hardwood Area *M1 = Mitigation requirements from Frye & Curtis, 1990*

P2 = USFWS Priority 2 Bottomland Hardwood Area *M2 = Mitigation requirements from TPWD, 1998*

n/a = not applicable

Approximately 16 percent of the Carl L. Estes site is located on 4,659 acres of the Upper Sabine Bottom. A 1986 assessment of the Carl L. Estes site (TPWD, 1990) indicates that between 36,681 acres and 146,705 acres of similar habitat would be required to mitigate for the entire reservoir, depending on the level of management employed at the mitigation site. This corresponds to mitigation ratios ranging from 1.7:1 to 6.9:1. The same report used a 1980 assessment of the Big Sandy site to determine that between 5,359 and 21,344 acres would be required for mitigation of the entire reservoir (corresponding to a mitigation ratio range of 1.2:1 to 4.8:1). Approximately 52 percent of the Big Sandy site is located on 2,808 acres of the Upper Big Sandy Creek & Glade and the Lower Big Sandy Creek, USFWS priority bottomland hardwood areas.

The Carthage site is also located in an area identified in the USFWS program, with approximately 27 percent of the site located in the Lower Sabine Bottom. No previous assessments of the extent or quality of wildlife habitat have been performed for this site, therefore no estimates of mitigation requirements have been established.

Available data indicate that the Prairie Creek and State Highway 322 sites would not impact any USFWS priority areas, wetland mitigation banks, or known conservation easements. In the absence of habitat assessment data, it is not possible to estimate potential mitigation requirements for development of either of these sites.

Floodplain Hydrology

Reservoir construction results in the replacement of terrestrial and stream habitat with deep water habitat. Shallow water habitat area is increased along the perimeter of the reservoir and by the backwater effects along rivers and other tributaries. As an example, Toledo Bend Reservoir created approximately 1,200 miles of shoreline habitat. The effects of reservoirs on downstream floodplain hydrology and habitat are not as easily stated. Changes in the frequency and duration of downstream flood events may be expected after reservoir development. The degree of impact to floodplain hydrology and corresponding changes in vegetation, including bottomland hardwood forests, are determined by the magnitude and timing of releases from upstream reservoirs and the contribution of uncontrolled runoff from portions of the watershed below the reservoir.

10.2.4 Recommendations for New Reservoir Development

Development of a new reservoir takes considerable time and effort to avoid, minimize, and/or mitigate adverse environmental impacts so that the required permits and regulatory approvals are obtained. Therefore, a reservoir site with as few environmental concerns as practical should be selected.

Important environmental issues identified for the proposed reservoir sites include the following:

- actual or potential presence of threatened or endangered species, and
- presence of high value or protected lands such as wetlands, riparian bottomland hardwood forests, conservation easements, and mitigation banks.

These factors were used to rank the six proposed reservoir sites on a relative scale to provide an indication of environmental acceptability. Table 10.4 shows the relative level of environmental concern and the issues behind these concerns. Development of the Prairie Creek or State Highway 322 sites would provide the least impact to threatened and endangered species, existing mitigation banks and conservation easements, and identified bottomland hardwood forests. Although mitigation requirements have not been established for these sites, they would potentially incur less mitigation costs because of their relatively small acreage and fewer environmental concerns.

In addition to considerations for construction and permitting issues, plans for development of new reservoirs should include a strategy for reducing impacts to downstream hydrology and floodplain vegetation due to reservoir operations. To determine these potential impacts, data about the quality and quantity of existing communities and corresponding hydrologic requirements would need to be collected.

It is strongly recommended that new studies of floodplain vegetation and wildlife within the Sabine Basin be conducted. More current estimates of the quality, extent, and economic value of bottomland hardwood areas and threatened and endangered species, would play an important role in future planning activities of SRA.

Table 10.4 Relative Level of Environmental Concern Related to Proposed Reservoir Sites

Level of Concern	Reservoir	Issues
Highest	Waters Bluff	greatest number of potential threatened and endangered species, conservation easements and mitigation banks, priority bottomland hardwood forests, and highest mitigation costs of any of the proposed reservoirs
|	Carl L. Estes	potential threatened and endangered species, priority bottomland hardwood forests, high cost of mitigation
|	Big Sandy	potential threatened and endangered species, priority bottomland hardwood forests, and high cost of mitigation
|	Carthage	potential threatened and endangered species, priority bottomland hardwood forests, and unknown cost of mitigation
|	State Highway 322	least number of potential threatened and endangered species and unknown cost of mitigation
Lowest	Prairie Creek	potential threatened and endangered species, least acreage of any of the proposed sites, and unknown cost of mitigation

11.0 OTHER WATER-RELATED ISSUES

11.1 Recreation, Tourism and Economic Development

Water related development is important for the future growth of the Sabine Basin economies. Water is needed to support municipal growth, provide power, and promote industrial development. In addition, water projects themselves can generate growth. These projects provide recreational opportunities that generate tourism and support industries. Eco-tourism, tourism associated with nature activities, is a potential means for economic growth in the region.

In the Sabine Basin, existing reservoirs support significant numbers of recreational activities and facilities. Numerous public and private recreational facilities have been developed on the banks of these reservoirs including boat ramps and docks, camping and picnic sites, and commercial support services. Several lakes have been constructed in the Basin primarily to provide recreational opportunities. They include Lake Cherokee, Lake Gladewater and the Wood County lakes. These lakes are operated to preserve water front use for surrounding property owners and visitors. Generally, most other reservoirs are operated to meet the primary function of each reservoir (water supply, power supply, flood control), but consideration is also given to maximizing recreational opportunities in the watershed.

Visitors spending time at recreational facilities in the Sabine Basin add revenue to the local economy in many ways. In 1997 leisure travel in the Sabine Basin generated approximately $450 million. Much of this is attributed to eco-tourism. Currently, the centerpiece of the Basin's water recreation is sport fishing. The numerous reservoirs, tributaries and streams offer many opportunities for anglers. Lake Fork Reservoir is perhaps the most famous for the Florida largemouth bass that have been stocked there since 1978. Lake Tawakoni has traditionally been known as one of the top Texas reservoirs for catfish, and Toledo Bend offers numerous species, including crappie, catfish and bass. Economically, the total direct expenditures made by Lake Fork anglers in 1995 were more than $27 million. Another popular recreation activity in the Sabine River Basin is hunting. There are also several state and local parks, hiking trails, and campgrounds throughout in the Basin. The Sabine National Forest in Southeast Texas contains more than 150,000 acres around the Toledo Bend Reservoir.

The Sabine Basin already attracts thousands of visitors a year, but with additional facilities the tourism industry could grow significantly. This is possible through a coordinated approach to a recreation-based economic development program. It will require local area leaders, along with SRA support, to identify potential growth areas and constraints, develop local and Basin-wide attraction and service goals, and develop an advertising program to promote the diverse activities within the Basin.

However, this program must be coupled with education and information on the natural cycles of reservoir management. SRA's primary responsibility is to provide water to the Basin's citizens. Operation of water supply reservoirs will include fluctuations of water levels. During drought conditions lake elevations may drop to levels that do not support recreational facilities. This must not be over-looked when pursuing water resource based economic development activities. In addition, local communities must be aware that there are economic and social costs inherent in any type of new development. Increased usage of existing facilities means additional competition for facilities, higher density usage and perhaps increased costs to local users. Keeping these issues in mind, there are opportunities to increase the economic benefits from development of the Basin's natural resources. The SRA can encourage this type of development in several ways.

- Provide leadership and technical assistance for regional efforts to develop recreation, or eco-tourism programs in the Basin. The SRA can assemble regional interests and encourage the development of a regional recreation plan and regional and national advertisement of available amenities and events.
- Encourage local involvement with Texas Parks and Wildlife Department and USDA Forest Service on programs expanding eco-tourism in Texas such as the Texas Coastal Bird Trail, the Scenic Rivers program, Wildlife Management Areas and several fishing programs.
- Improve public access to selected reservoirs and recreation sites. Roadway improvements and waterside parks, picnic grounds and fishing piers, as noted in a regional recreation plan, could be developed in conjunction with other public and private entities.
- Improve boat access at selected reservoirs. The Authority can supplement existing boat ramps in conjunction with recreation planning.
- Provide financial assistance for improvements to amenities in the Basin.

11.2 Flood Control

With the increasing urbanization of the Sabine Basin, future needs for flood control impoundment may become necessary. Currently, SRA does not own or operate any projects specifically constructed for flood control. Two proposed reservoirs, Big Sandy and Carl Estes, were authorized for flood control and water conservation under the Flood Control Act of 1970. However, neither of these reservoirs has been constructed. The existing flood control projects within the Basin are the four Wood County lakes: Lakes Quitman, Winnsboro, Hawkins and Holbrook.

SRA supports local flood control management through research and reservoir operations. A study of recent flood events in Newton and Orange counties was completed in 1992, and an evaluation of the Toledo Bend spillway gate operations to control flooding in the Lower Basin was completed in 1994. These studies provide information necessary to administer floodplain management to reduce the impact of flooding on local communities. SRA also provides flood plain management through monitoring weather, river and lake conditions, assessing potential flood events and notifying Basin residents. The Alert System, which was installed in 1993, provides real-time information to SRA staff for downstream flood management.

11.3 Environmental Flows

The State of Texas is actively pursuing development of methods to define necessary streamflow and estuary inflow to protect the environmental conditions of its river and lakes system. To date, no site-specific stream flow assessments have been conducted in the Sabine Basin. However, pending the final recommendations for environmental flows, the TNRCC has established default values for instream flows that would apply to the Sabine River. As currently defined, the default environmental criteria do not apply to existing reservoirs. Therefore, existing supply yields within Lake Fork, Lake Tawakoni, Toledo Bend Reservoir, and other water supply reservoirs will not be affected by these criteria. Future river diversions will however be affected by these criteria. Also, any future reservoir project and most future proposed tributary diversions will be subject to maintaining some minimum quantity of flow defined as needed for maintaining environmental habitats.

11.4 Navigation

Navigable waters are those waters subject to tidal influences and/or are presently used, have been used in the past, or may be used in the future for interstate or foreign commerce. The U.S. Army Corps of Engineers (COE) considers the Sabine River a navigable waterway from Sabine Lake to the confluence with Big Sandy Creek. Currently commercial navigation in the Sabine Basin is limited to the Lower Sabine River from Sabine Lake to the Port of Orange. The COE, who is responsible for maintaining federally designated commercial waterways, operates river and harbor dredging projects in this portion of the Basin to ensure required operating depths. Navigational charts for the Gulf Coast, Sabine Lake and Lower Sabine River are available through NOAA.

Current navigation in the Basin should not be impacted by proposed water supply projects. However, consideration of "navigable waters" is needed during the planning process. Interstate navigable waters are subject to the Rivers and Harbors Act of 1899, which does not allow the construction of an obstruction within the waterway without Congressional approval. Also, construction within any waters of the United States will require a 404 permit. These permitting issues are further discussed in Section 10.

12.0 INFORMATION MANAGEMENT AND PUBLIC PARTICIPATION

12.1 Information Resource Issues

SRA handles large volumes of data for a variety of purposes. Many of this data are technical and are used for operation and management of its water supply system. SRA collects water quality data from its own sampling stations in the watershed, monitors water volumes in its canal system and tracks reservoir discharges and hydroelectric power generation. SRA also maintains an ALERT system to record rainfall and reservoir storage levels and to predict potential flood situations. Other data that SRA maintains are used to inform the staff and public of its activities and issues pertinent to the management of the water resources in the Basin.

To better utilize SRA's current information system and provide for future needs in information management, an Information Management Plan was prepared and submitted to SRA as a separate document. This plan was developed in context of SRA's goals to improve its responsiveness and management of its increasingly large information resources. The plan provides a framework for SRA's developing system to organize data and data flow throughout the system, and to expand SRA's role as an information resource for water issues in the Sabine Basin. A summary of the Information Management Plan and its development is presented in the following sections.

12.1.1 Goals

SRA is committed in developing an effective and efficient information system. To accomplish this, SRA management and staff identified the following information management goals:

1. Provide information to SRA personnel for planning, operations, regulatory reporting and compliance, administration and financial analysis.
2. Provide information for public education on water quality, water resource planning, water conservation, economic development and recreation.
3. Position SRA as regional information clearinghouse for planning and environmental data for Northeast and Southeast Texas within the Sabine River Basin.

12.1.2 Current Information System

SRA's current information management system is comprised of manual and automatic measurement, data transcription from one medium to another, data transmission, storage, and retrieval. There are five semi-independent data systems that are used to handle data maintained by SRA. These are:

- Environmental Services Division/Development Branch wide-area network;
- Arc/INFO Geographic Information System (GIS);
- Internet Web server;
- ALERT system; and
- Operations data in hard copy and on the Internet web server.

These systems contain data in different formats and have limited interaction. The Environmental Services Division network is used to manage water quality data generated from SRA's field offices and laboratory. These data are currently entered into two different data management systems, depending on the sample location. Date are combined by hand into a single database to generate reports and provide information for the SRA web site.

The GIS includes a mapping program and a database that are linked to each other and can be used to store, display and analyze geographic information. The system is currently used to store planning data such as land use, hydrologic and physical features of the watershed, and watershed segment, reach and sub-watershed boundaries. The GIS is also used to index and store raster images (digital ortho-photographs) of the watershed.

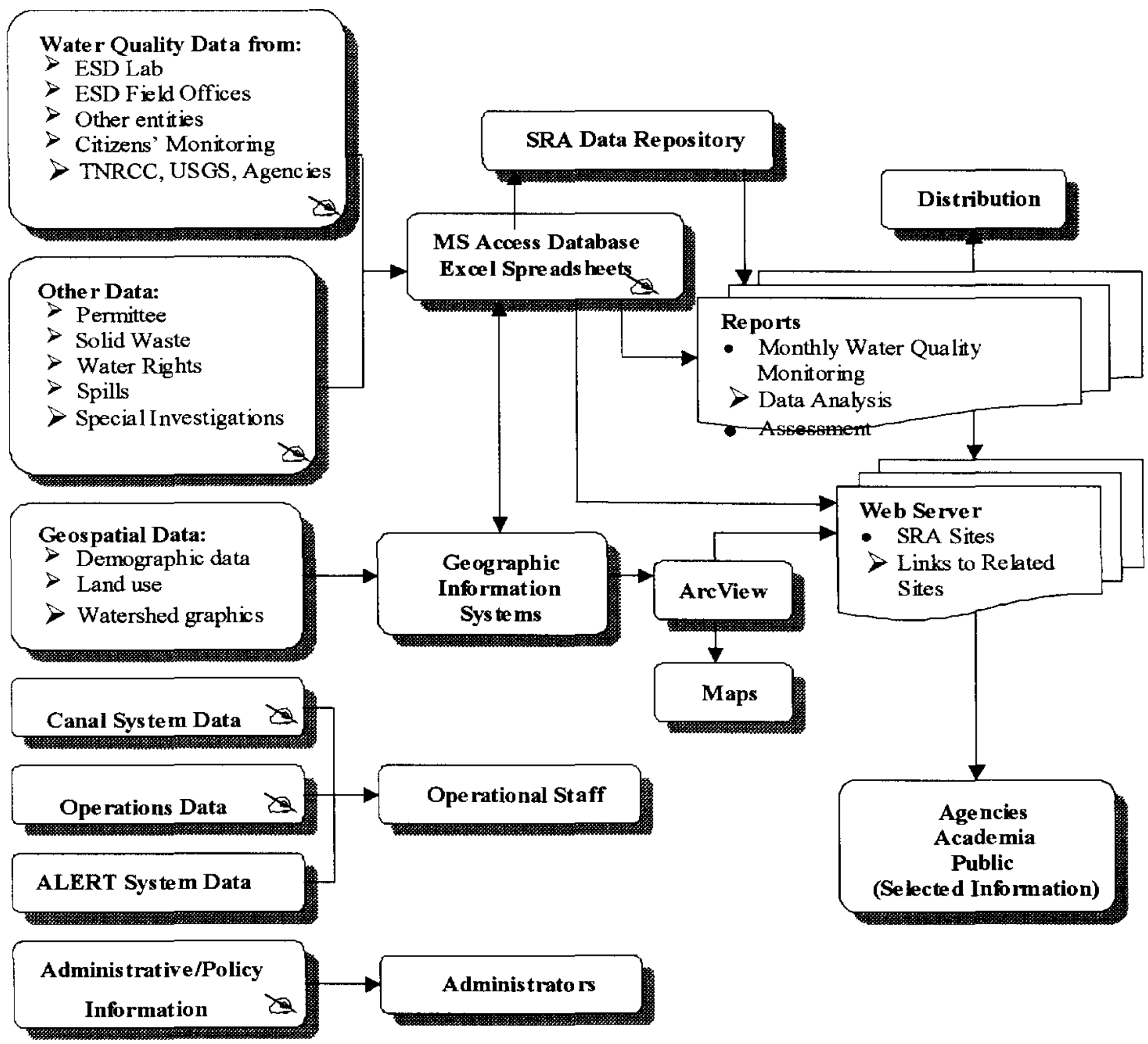
The SRA's World Wide Web server allows Internet users to access data regarding the watershed. The Web site contains agency information, community socioeconomic profiles, water resources statistics for the watershed, and other information about the Sabine River Basin.

The ALERT system is a proprietary information management system for flood alert. It monitors lake levels and sends an alert to the SRA headquarters if the level rises to preset trigger levels. The monitoring data in this system are stored and are available to

SRA if converted to a standard format. Currently these data are not used for other purposes.

Operations data for reservoir and canal system management are generated by hand and maintained in hard copy format. These data and the Alert data can not be readily integrated into databases through electronic means. Some of the operations data are converted by hand and placed on the web site. A diagram of SRA's current information system is illustrated on Figure 12.1.

Figure 12.1: Current Information System Configuration



The elements of the system (boxes) are data sets, and the arrows that connect them are data flow operations. A writing hand (✍) indicates that the operation is done manually. All other operations are electronic transfers.

Data Processing and Maintenance

Currently, data from different sources are entered, transcribed, processed and retrieved in different manners, using processes developed by the individuals using the data. While these processes are functional they are presently not easily used by others in the organization and may be difficult to integrate with the GIS or other new systems.

Data are maintained as numerous computer files on the network server, the Web server and on each user's computer hard drives and floppy disks. Data are stored in different file formats; some are also stored as handwritten forms or as hard copy paper printouts in files. Data quality control is performed at different levels for different data. Water quality data are checked using documented QA/QC procedures, while other data are checked by the user.

12.1.3 Conclusions and Recommendations

The current SRA Information Management framework meets basic agency needs, but restructuring offers the opportunity to operate with greater effectiveness and efficiency. SRA is beginning to collect more data than it can comfortably handle under the current data management systems. As data volume increases, the need to automate data collection and transcription and to process and analyze data for end users will become more pressing. This may be SRA's major challenge for its information system over the next five years

SRA is successfully implementing a World Wide Web site on the Internet that provides easy access to data, often in innovative forms such as mapping applications, but this can not adequately serve as SRA's data management system. The Internet is basically a communications system, not a database system. Recent acquisitions of hardware will allow expansion of SRA's ability to provide large amounts of data to users. However, without a master database, data from different sources do not have relationships that can be used to deduce trends. Modern database programs allow users to filter data sets to get just what they need, summarize the data or analyze it for trends and patterns

Based on these conclusions, it is recommended that SRA:

- Continue to evaluate more efficient means of handling data. This should incorporate software that permits data filtering and analysis.
- Improve the information system for collection, storage, retrieval and analysis of watershed planning and environmental data for SRA use, compliance with regulations and dissemination to the interested public;
- Develop a standardized and accessible record control system for SRA documents; expediting document location, preventing storage of multiple document versions, and facilitating migration to an electronic document management system.
- Improve the communications process between SRA divisions, and tie these locations into the SRA data system;
- Create automated tools to analyze Sabine River watershed data for watershed operations and planning; and
- Maintain its Internet World Wide Web site to communicate with federal, state, and local agencies, institutions, and SRA field offices and to inform and educate the public.

The objective of these recommendations is to improve efficiency through better access to information and analytical tools. In so doing, SRA will increase the value of its information management system to the organization and to the public it serves. A more detailed description of the recommendations and how they can be implemented are presented in the Information Management Plan. (Brown and Root, Task 16 Technical Memorandum)

12.2 Public Participation

SRA provides the general public with extensive information about itself, its facilities, water quality conditions, recreational opportunities and general social and economic conditions in the Basin through its Web page, maps and materials on recreational opportunities and quarterly newsletters. SRA is involved with a local GIS consortium that connects it with water planning and civic entities in Orange County. It also provides area schools with the Major Rivers water use education program for fourth grade students. Through the Texas Clean Rivers Program it meets regularly with the public to discuss water quality issues and general operations activities. In addition, the Trans-Texas Water

Program has deepened SRA's communication network extending it to members of the Basin's industrial, civic and environmental communities.

To further community participation, SRA should focus its public involvement efforts on specific issues that impact the public/corporate/civic interests in direct ways. Such issues include the relationship between private actions, public policy and water supply, water conservation, drought contingency planning, water quality programs, and economic development.

The following is a summary of the recommended approach to public involvement. Details of this approach and how to implement the recommendations are presented in a separate technical memorandum. (Brown and Root, Task 13 Technical Memorandum)

- Define goals that focus on specific issues of importance to the Sabine Basin;
- Implement a "Partners in Water Resource Management" program. This program identifies specific water quality or water supply conditions and client or interest groups that impact or are impacted by these conditions. It then enlists these entities in working with SRA to find and implement responses.
- Continue existing public information and education activities;
- Develop policies and internal communications with regard to public notice via the SRA website and/or newsletter. These policies should establish guidelines for types of information that can be made available to the public, who is authorized to release information and how to notify the webmaster or newsletter editor of this information.

13.0 RECOMMENDATIONS

13.1 Water Supply Development Recommendations

Evaluations of the water supply resources within the Sabine Basin indicate the need to develop additional supplies in the Upper Basin for future growth. Presently, there is only a very small amount of supply available in the Upper Basin from existing permits, other than the supply in Panola County (Lake Murvaul). Utilizing the portion of the water contracted to Dallas that must remain in the Sabine Basin, existing supplies can most likely meet the future needs of the Upper Basin until the year 2010. After 2010, a significant increase in water requirements is projected due to manufacturing, mining and power development.

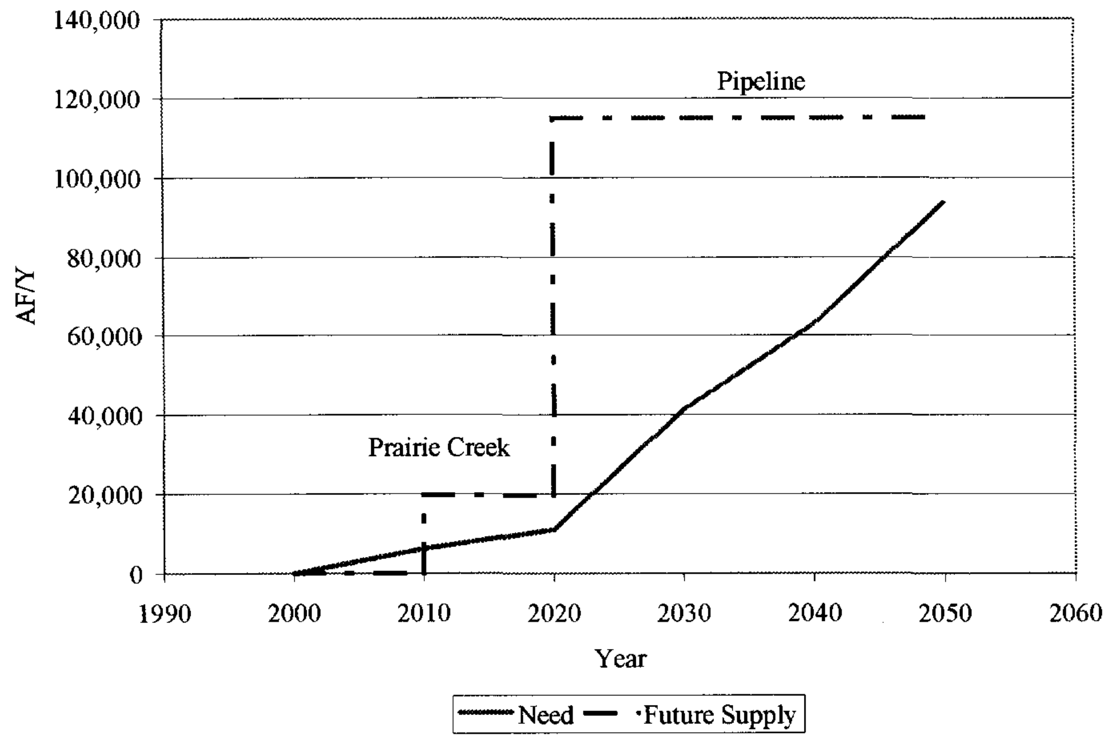
These three industries play an important role in the economy of the Basin. However, it is uncertain whether the growth and water demands will increase at the projected rates. The largest manufacturing industry in the Basin, Eastman Chemical, has indicated that they have no plans for large expansions in the near future. Also, they are currently using less water than the supply they have available through their contracts and water rights. Steam electric power stations are the primary users of water associated with power in the Upper Basin. With deregulation, there is some uncertainty regarding the direction of power development in the Basin. There is, however, a new steam electric facility planned in the Upper Basin in the near future. Tenaska has plans to build a power generating facility in Rusk County. Tenaska has already signed a contract with SRA to purchase Toledo Bend water for use at this facility. SRA, is currently building a pipeline to transport water to this facility in Rusk County. Another uncertainty in water use projections area is the fact that electric companies are currently pursuing options that utilize less water per kilowatt generated (e.g., combined cycle generation). The growth in mining is generally dependent on the local economy and building industries. Lignite mining in the Basin is associated with operating steam electric power stations. If alternate power sources are used, water use for lignite mining will not increase as predicted. Based on this uncertainty in the projected future water requirements in the Upper Basin, it is recommended that additional water supply be developed in stages. A staged plan will allow for adjustments to changing needs and avoid unnecessary commitments of financial resources to a single project.

The potential sources for future water supply include new surface water reservoirs, diversions from the Sabine River, a transmission pipeline from Toledo Bend Reservoir, importation from outside the Basin, and some limited new ground water resources. Additional importation from the Cypress Basin is currently not a viable option since the supply available from Lake O' the Pines Reservoir will most likely be retained for in-Basin use. If new reservoirs are developed in the adjacent Basins, then importation may become more feasible.

Ground water currently provides approximately three percent of the Basin's total water supply. Water availability analyses indicates there is approximately an additional 16,000 acre-feet per year of ground water supply in the Carrizo-Wilcox aquifer and smaller amounts in the other aquifers that could be used for Upper Basin demands. It is unlikely that much of this amount will be developed due to the limitations of the aquifer and the location, amount and concentrations of the future demands. The aquifer is unable to support the large, concentrated future demands of manufacturing, mining and steam electric water uses. Also, based on the experiences of a number of entities in the Upper Basin, future plans should include alternatives to provide water supply if and when well fields fail.

The most viable surface water project is a staged development of Prairie Creek Reservoir. This reservoir site was selected based on its location, cost analysis and assessment of developmental concerns. Prairie Creek is centrally located in the Upper Basin, and its firm yield should provide approximately enough supply to meet projected 2023 demands. When the yield of Prairie Creek Reservoir is fully used, there are two options for further supply. One option is diverting water from the Sabine River near Prairie Creek to supplement the yield of Prairie Creek Reservoir. This option would only increase the yield about 50 percent to about 30,000 AF/Y. This option would only be used if it was fairly certain the large future demands would not develop. The other option would be to build a pipeline from Toledo Bend Reservoir to Prairie Creek Reservoir. As needs increase and larger demands develop, approaching the limit of the Prairie Creek supply, this pipeline should be constructed. This pipeline/reservoir system would be able to provide for all the projected additional demands in the Upper Basin through 2050 as shown on Figure 13.1. This option has become particularly attractive in recent months since SRA is now building a pipeline along the approximate route of this pipeline about half way to Prairie Creek Reservoir, to serve an industrial customer. This represents a substantial cost savings to SRA for a future extension of this pipeline route to Prairie Creek Reservoir. It would decrease the cost of this option even below the amount presented in this report.

Figure 13.1: Recommended Water Resource Development



Based on the considerations discussed above, a summary of the recommended water resource development program is presented below.

- SRA should continue to pursue negotiations with the City of Dallas to allow for selling the water in Dallas's contract that must remain in the Sabine Basin.
- SRA should begin the process of permitting Prairie Creek Reservoir. A new reservoir typically takes 10 to 15 years to permit and construct. Therefore, if Prairie Creek Reservoir is planned to meet the needs in the Upper Basin by 2010, the permitting process should be started by year 2000. SRA should try to get Prairie Creek added into the Texas Water Plan though the Senate Bill 1 regional planning process. Should significant obstacles arise to the development of Prairie Creek Reservoir, SRA should pursue the development of the State Highway 322 Stage II reservoir. SRA should

talk to TXU Electric regarding their plans for the mining operations at the reservoir site.

- Prior to year 2010, SRA should re-evaluate the water use demand projections (the Senate Bill One projections that are accepted by TWDB) to assess changes in growth and future needs.
- SRA should review the results of the Water Availability Model (WAM) of the Sabine River when completed by TNRCC. This model will indicate if there is additional supply available from the Sabine River for future diversions or insufficient water for existing contracts.
- Based on the results of the re-evaluated demand projections and the WAM, SRA should evaluate the need, timing, and sizing of a transmission pipeline from Toledo Bend Reservoir with terminal storage at Prairie Creek. SRA should pursue the design, permitting and construction of the pipeline several years prior to the expected shortage.
- SRA should pursue discussions with various customers regarding reducing their contracted amount if they are not intending to use that water for future use. If a portion of the entity's water contract is released, it could be used for water supply needs elsewhere in the Basin.
- SRA should initiate discussions with Wood County regarding the possibility of converting the Wood County Lakes to water supply. There is a potential 20,000 acre-feet per year of firm yield from these four lakes. However, this would impact the current recreational value of these reservoirs.
- SRA should encourage the Cities of Kilgore and Canton to work with the TWDB regarding the possibility of implementing ASR at their existing well fields to better utilize the surface water supplies during drought and high demand periods.
- SRA should review its current contracting procedures to determine if modifications would result in more accurate allocations of firm yield to its customers. Currently, there are a number of large water contracts in the Upper Basin that are not being fully utilized.
- SRA should conduct volumetric surveys of their existing reservoirs to verify sedimentation rates. If the sedimentation rates are significantly different from those

used in this plan, SRA should re-evaluate the firm yields of the affected reservoirs. The projected firm yield of Lake Tawakoni and Lake Fork in the year 2050 is approximately 18,100 acre-feet per year less than the current contracted amounts. This amount is not reflected in the total 93,000 acre-feet per year of projected water needs in the Upper Basin.

13.2 Environmental Recommendations

Other recommendations from this comprehensive report include the following:

- SRA should continue evaluating potential environmental mitigation areas for future water development projects. This will enable SRA to pursue surface water projects that require mitigation lands.
- Due to the uncertainty surrounding the current Bottomland Hardwoods status in the Sabine Basin and their importance to reservoir development, we recommend that an updated statewide study of Bottomland Hardwoods be conducted. In addition, new studies on flood plain and wildlife within the Sabine Basin should be conducted. SRA should request that the TWDB , TNRCC, and/or the Texas Park and Wildlife Department conduct such studies.
- SRA should continue their current water quality monitoring program to assess water quality in the Basin. We recommend that SRA expand the special studies program to include more high flow or storm sampling studies for non-point source documentation, and SRA should pursue working with the TNRCC to develop regional tolerance values for bioassessment data.
- Train entities within the Sabine Basin that collect water quality data in approved data collection and analysis methods so that this information can be used in the Clean Rivers Program and SRA's Information System and GIS database.
- Use GIS and other data analysis methods to continue monitoring for water quality problems that may be related to wastewater treatment effluent and septic systems, non-point sources, oil and brine spills, construction activities, and specific anthropogenic pollutants.

13.3 Information Management, Economic Development, and Public Participation Recommendations

Specific details on how to improve Sabine River Authority's Information Management System, Economic Development Program and Public Participation Program have been provided to the SRA in separate technical memoranda. The general guidelines are below.

- Continue to evaluate more efficient means of handling data. This should incorporate software that permits data filtering and analysis.
- Improve the information system for collection, storage, retrieval and analysis of watershed planning and environmental data for SRA use, compliance with regulations and dissemination to the interested public.
- Develop a standardized and accessible record control system for SRA documents; expediting document location, preventing storage of multiple document versions, and facilitating migration to an electronic document management system.
- Improve the communications process between SRA divisions, and tie these locations into the SRA data system.
- Create automated tools to analyze Sabine River watershed data for watershed operations and planning.
- Maintain its Internet World Wide Web site to communicate with federal, state, and local agencies, institutions, and SRA field offices and to inform and educate the public.
- SRA should implement an economic development program for traditional economic development utilizing local, regional, and state resources throughout the Sabine Basin. Further, this effort should be expanded to include eco-tourism to fully take advantage of the wealth of natural resources in the Basin. Define goals that focus on specific issues of importance to the Sabine Basin.
- Implement a "Partners in Water Resource Management" program. This program identifies specific water quality or water supply conditions and client or interest

groups that impact or are impacted by these conditions. It then enlists these entities in working with SRA to find and implement responses.

- Continue existing public information and education activities;.
- Develop policies and internal communications with regard to public notice via the SRA website and/or newsletter. These policies should establish guidelines for types of information that can be made available to the public, who is authorized to release information and how to notify the webmaster or newsletter editor of this information.

13.4 Water and Wastewater Treatment Recommendations

Recommendations regarding the assessment of water and wastewater treatment needs throughout the Basin are below.

- SRA should provide a technical assistance program to support water and wastewater providers in the Basin with information such as EPA and TNRCC regulations. Provide recommendations on treatment options to help small water supply entities comply with regulations. Host and/or facilitate any available TWDB and TNRCC seminars or workshops regarding water or wastewater treatment. Facilitate the TNRCC plant optimization program within the Basin. If necessary, hire local consultants on an as needed basis to help with this technical assistance program.
- SRA should host and/or facilitate TWDB drought management and contingency planning seminars to assist all of the water suppliers in the region with their plans.
- SRA should further study the opportunity of implementing regional water and wastewater treatment facilities particularly in the Lower Basin.

APPENDIX A

REFERENCES

Appendix A

REFERENCES

Bauer, Frye and Spain, *A Natural Resource Survey for Proposed Reservoir Sites and Selected Stream Segments in Texas*, prepared for TWDB, August 1991.

Brown & Root, *Canal Improvement Study*, prepared for SRA, September 1987.

Brown and Root, Inc, *Yield Study, Toledo Bend Reservoir*, prepared for Sabine River Authority of Texas and Sabine River Authority, State of Louisiana, July 1991.

Brown & Root, *Federal Energy Regulatory Commission Inspection Reports for the Toledo Bend Dam Project*, prepared for the Toledo Bend Project Joint Resolution, 1988 &1993.

Brown & Root, *Sabine River Flood Study*, prepared for the Sabine Basin Task Force, 1993.

Brown & Root in association with Freese & Nichols, Inc., *Trans-Texas Water Program Southeast Area Phase I Report*, March 1994.

Brown & Root in association with Freese & Nichols, Inc., *Trans-Texas Water Program Planning Information Update*, April 1996.

Brown & Root, *Design of Recreational Facilities at Various Sites within the Lower Sabine Basin*, prepared for SRA, 1996.

Bureau of Economic Geology, University of Texas at Austin, *Shoreline changes Between Sabine Pass and Bolivar Roads: An Analysis of Historical Changes of the Texas Gulf Shoreline*, Geological Circular 75-6, 1975.

Bureau of Economic Geology, University of Texas at Austin, *Land Resources of Texas*, 1977.

Corps of Engineers, *Comprehensive Basin Study Sabine River and Tributaries, Texas & Louisiana, Volumes 1-5*, December 1967.

Corps of Engineers, *Summary Report, Sabine River and Tributaries, Texas & Louisiana*, February 1981.

Espey, Huston & Associates, *Update of the Master Plan for the Sabine River and Tributaries in Texas*, prepared for SRA, March 1985.

Espey, Huston, & Associates, *Lake Fork Reservoir Yield Determination*, prepared for SRA, April 1985.

Espey, Huston, & Associates, *Lake Tawakoni Yield Determination*, prepared for SRA, April 1985.

Espey, Huston & Associates, *Waters Bluff Dam and Reservoir*, prepared for SRA, March 1986.

Forrest & Cotton, *Toledo Bend Dam, Appendix "A" Hydrology,* prepared for SRA, 1954.

Forrest and Cotton, *Master Plan of the Sabine River and Tributaries in Texas*, prepared for SRA, January 1955.

Forrest & Cotton, *Toledo Bend Dam, Design Memo No. 1: Hydrology*, prepared for the SRA Texas and SRA Louisiana, 1961.

Forrest and Cotton, *Supplement to the Master Plan*, prepared for SRA, November 1962.

Forrest & Cotton, *Report on Lake Tawakoni Yield Study*, prepared for SRA, March 1977.

Forrest & Cotton, *Report on Potential Water Supply from Sabine River Basin*, prepared for North Texas Municipal Water District, August 1979.

Freese and Nichols, *Water Supply Study*, prepared for SRA, May 1976.

Freese and Nichols, *Feasibility Report on the Belzora Landing Dam and Reservoir*, prepared for SRA, 1988a.

Freese and Nichols, *Upper Sabine Regional Water Supply Plan*, prepared for SRA, 1988b.

Freese & Nichols, *Preliminary Feasibility Study: Interbasin Water Transfer from the Sabine River to the San Jacinto River Authority Service Area,* prepared for SJRA and SRA, November, 1989a.

Freese & Nichols, *Reconnaissance Study for the Lake Tawakoni Regional Water Supply System*, prepared for SRA, November, 1989b.

Freese and Nichols, *Environmental Impact Analysis of the Proposed Sabine River Channel Reservoir Project*, 1992.

Freese & Nichols, *Sabine River Authority of Texas Water Conservation and Drought Contingency Plan*, prepared for SRA, September 1994.

Frye, R.G., *Wildlife habitat appraisal procedure*. Texas Parks and Wildlife Report PWD-RP-7100-145-9/86. Austin, Texas, 1986.

Frye and Curtis, *Texas Water and Wildlife, An Assessment of Direct Impacts to Wildlife Habitat from Future Water Development Projects*. Texas Parks and Wildlife Department Report No. PWD-BK-7100-147-5/90, Austin, Texas, May 1990.

Galveston Bay National Estuary Program, *The State of the Bay: Characteristics of the Galveston Bay Ecosystem,* March 1994.

Graves, J. Memorandum of Law Re: Sabine River Authority of Texas, To Sam F. Collins, January 11, 1985.

Henningson, Durham, & Richardson, Inc., *A Feasibility Study for Developing a Reservoir on Big Cow Creek, Newton County, Texas*, October, 1976.

John J. Peep, Consulting Engineers, *Preliminary Basin Import Study, Sabine River to Livingston*, prepared for Texas Water Development Board, 1977.

Kindle, Stone, & Associates, Inc., *Water Treatment Facilities Study*, prepared for the City of Carthage, Texas, March 1980.

Kindle, Stone, & Associates, Inc., *Water Supply Study, Addendum No. 1.*, prepared for the City of Marshall, Texas, January 1981.

Kindle, Stone, & Associates, Inc., *Longview Water Supply Study*, prepared for the City of Longview, Texas, May 1982.

Kindle, Stone, & Associates, Inc., *Preliminary Feasibility Study, Little Cypress Reservoir*, prepared for the Cites of Shreveport, Longview, Marshall, Kilgore, Gilmore, and Hallsville, July 1982.

Kindle Stone & Associates, *Preliminary Engineering Report for Prairie Creek Reservoir*, prepared for City of Longview, August 1984.

Kindle Stone & Associates, *Big Sandy Reservoir of Texas*, prepared for SRA, October 1984.

Kindle, Stone, & Associates, Inc. *Comprehensive Plan for the City of Sulphur Springs, Texas.*

Klebba, James M., *Water Rights and Water Policy in Louisiana: Laissez Faire Riparianism, Market Based Approaches, or a New Managerialism?* Louisiana Law Review. 1993.

Levine, Steven J., *Ground Water: Louisiana's Quasi-Fictional and Truly Fugacious Mineral.* Louisiana Law Review. 1984.

Lyons, Barry W., *Existing Reservoir and Stream Management Recommendations - Statewide Minimum Stream Recommendations.* Austin, Texas, October 16, 1979.

Sabine River Authority, *Preplanning Studies for the Upper Sabine Reservoir Projects* (Mineola, Lake Fork, and Big Sandy), July 1, 1972.

Sabine River Authority, *Technical Report No. 79-1, Gulf Coast Division Water Quality Monitoring Program, Lower Sabine River Watershed and Canal System*, 1979.

Sabine River Authority of Louisiana, *Sabine River Diversion Channel and Diversion System*, 1990.

Sabine River Authority, *Environmental Services Division, Water Quality Monitoring Program, 1991 Summary.*

Sabine River Authority, *1992 Regional Assessment of Water Quality, Sabine River Basin, Texas, Volumes I-III*, October 1992.

Sabine River Authority, *Comprehensive Annual Financial Report*, August 1995.

Sabine River Authority, *1996 Regional Assessment of Water Quality, Sabine River Basin, Texas*, October 1996.

Sabine River Authority, *Problems Relating to the Proposed Water Bluff Reservoir and Other Surface Water Supply Projects in Texas*, December 1996.

Sabine River Authority, *Draft Quality Assurance Project Plan for the Sabine River Authority, for Environmental Monitoring and Measurement Activities Relating to Water Quality Monitoring Programs*, revised January 13, 1998.

Sabine River Compact Administration Louisiana and Texas, *Forty First Annual Report*, 1995.

Telephone Conversation with Mr. Joe Benton, Cherokee Water Company Manager, 1998.

Texas Board of Water Engineers, Bulletin 5912, *Inventory and Use of Sedimentation Data in Texas*, prepared by the U. S. Soil Conservation Service, January 1959.

Texas Board of Water Engineers, Bulletin 6108, *Silt Load of Texas Streams, A Compilation Report*, December 1961.

Texas Department of Transportation, *The Anderson Tract Mitigation Project*, October 1995.

Texas Department of Water Resources, Report 268, *Erosion and Sedimentation by Water in Texas*, prepared by the U. S. Soil Conservation Service, February 1982.

Texas Natural Resource Conservation Commission, *1996 State of Texas Water Quality Inventory, 13th Ed.*, Surface Water Quality Monitoring Program, SFR-50, 1996a.

Texas Natural Resource Conservation Commission, *Surface Water Rights in Texas: How They Work and What to Do When They Don't*, GI-228, 1996b. http://www.tnrcc.state.tx.us/admin/topdoc/gi/228/index.html

Texas Natural Resource Conservation Commission, *The Texas Clean Rivers Program 1998–1999 Program Guidance*, 1997.

Texas Natural Resource Conservation Commission, *1998 Draft 303(d) list (March 13, 1998)*, 1998a.

Texas Natural Resource Conservation Commission, *Draft Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data (January 9, 1998)*, 1998b.

Texas Natural Resource Conservation Commission, *State of Texas 1998 Clean Water Act Section 303(d) List*, 1998c.

Texas Natural Resource Conservation Commission,, *WAM: Water Availability Modeling, An Overview*, GI-245, 1998d. http://www.tnrcc.state.tx.us/admin/topdoc/gi/245/index.html

Texas Parks and Wildlife Department, *Annotated County Lists of Rare Species for Shelby, San Augustine, Gregg, Harrison, Hopkins, Jasper, Newton, Orange, Sabine, Panola, Rains, Rusk, Smith, Upshur, Van Zandt, and Wood Counties*, 1998a.

Texas Parks and Wildlife Department, *Analysis of Bottomland Hardwood Areas and Assessment of Wildlife Habitat Quality at the Potential Future Waters Bluff Reservoir Site*, Final Report to TWDB, 1998b.

Texas Parks and Wildlife Department, *Annotated County Lists of Rare Species for Collin, Hunt, Kaufman, and Rockwall Counties*, 1999.

Texas Water Development Board, *Report M111, Water Resources of Harrison County, Texas*, 1943.

Texas Water Development Board, *Report M280, Results of Pumping Test of Municipal Wells at Tyler, Texas*, 1944.

Texas Water Development Board, *Report M096, Ground Water Resources in the Greenville Area, Hunt County, Texas*, 1945a.

Texas Water Development Board, *Report M099, Water Resources of Gregg County, Texas*, 1945b.

Texas Water Development Board, *Suspended-Sediment Load of Texas Streams*, various reports covering the years 1959 through 1982.

Texas Water Development Board, *Report B6302, Availability and Quality of Ground Water in Smith County, Texas*, 1963.

Texas Water Development Board, *Report B6516, Geology and Ground Water Resources of Orange County, Texas*, 1965a.

Texas Water Development Board, *Report B6517, Ground Water Resources of Camp, Franklin, Morris, and Titus Counties, Texas*, 1965b.

Texas Water Development Board, *Report R027, Ground Water Resources of Harrison County, Texas*, 1966.

Texas Water Development Board, *Report R037, Ground Water Resources of Sabine and San Augustine Counties, Texas*, 1967a.

Texas Water Development Board, *Report R059, Ground Water Resources of Jasper and Newton Counties, Texas*, 1967b.

Texas Water Development Board, *Report R079, Ground Water Resources of Wood County, Texas*, 1968.

Texas Water Development Board, *Report R101, Ground Water Resources of Gregg and Upshur Counties, Texas*, 1969.

Texas Water Development Board, *Report R156, Development of Ground Water Resources in Orange County Area, Texas and Louisiana*, 1963 to 1971, 1972.

Texas Water Development Board, *Report R169, Ground Water Resources of Rains and Van Zandt Counties, Texas*, 1973.

Texas Water Development Board, *Report 188, Land-Surface Subsidence in the Houston-Galveston Region, Texas*, February 1975.

Texas Water Development Board, *Preliminary Basin Import Study, Sabine River to Lake Livingston*, 1977.

Texas Water Development Board, *Report 238. Groundwater Availability in Texas, Estimates and Projections Through 2030*, September 1979.

Texas Water Development Board, *Report R297, Ground Water Resources of Rusk County, Texas*, 1987.

Texas Water Development Board, *Report R320, Evaluation of Water Resources of Orange and Eastern Jefferson Counties, Texas*, 1990.

Texas Water Development Board, *Water for Texas, Today and Tomorrow*, 1992.

Texas Water Development Board, *Monthly Reservoir Evaporation Rates for Texas 1940 Through 1990*. Facsimile transmission, July, 1997a.

Texas Water Development Board, *Volumetric Survey of Lake Cherokee, January*, 1997b.

Texas Water Development Board, *Volumetric Survey of Lake Tawakoni*, prepared for Sabine River Authority, August, 1997c.

Texas Water Development Board, Water for Texas, *A Consensus-Based Update to the State Water Plan, Volume II*, 1997d.

Texas Water Resources Institute, Texas A & M, *Water Supply Planning, Using an Expert GIS*, May 1995.

United States Bureau of Reclamation, *Big Cow Creek Project*, June 1982.

United States Bureau of Reclamation, *Plan Formulation Working Document for Texas Big Sandy Study*, September 1986.

United States Fish and Wildlife Service, *Habitat Evaluation Procedures*. Division of Ecological Services, Washington, DC. ESM102, 1980.

United States Fish and Wildlife Service, *Texas Bottomland Hardwood Preservation Program, Category 3; Final Concept Plan*. Department of the Interior, USFWS, Albuquerque, New Mexico, 1984.

United States Fish and Wildlife Service, *Impact in the Sabine River Basin of Water Transfer to Houston*, prepared by Allan J. Mueller, March 1989.

United States Fish and Wildlife Service. Southwest Region Ecological Services Endangered Species Program, [Online] (December 1998). Available URL: http://ifw2es.fws.gov/endspcs/lists/

URS/Forrest and Cotton, *Site H Dam and Reservoir on Cherokee Bayou*, May 1975.

URS, *Upper Sabine Water Supply Study*, prepared for SRA, May 1983.

Vernon's Texas Water Code, 1972 ed. Chapter 25: Regional Waste Disposal Act.

Vernon's Texas Water Code, 1972 ed. Chapter 44: Sabine River Compact.

Wayne Smith & Assoc., Inc., *Preliminary Feasibility Report - Surface Water - Sabine River to Lake Houston*, prepared for SJRA and SRA, 1985.

Wayne Smith & Assoc., Inc., *Feasibility Study Interbasin Transfer Sabine to San Jacinto*, prepared for SJRA and SRA, 1987.

West's Louisiana Statutes Annotated, Volume 22, Chapter 11: Sabine

APPENDIX B

WATER RIGHTS

Table B-1
Water Rights Downstream of Toledo Bend Reservoir

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4657	City of Center	Mill Creek	Shelby	1,460	Mun	446	8/04/22
5207	U S Department of Agriculture	Unnamed	Sabine	0	Recr	222	11/18/88
4658A	Sabine River Authority of TX	Toledo Bend Res.	Newton	**	Hydro	4,477,000	3/05/58
4658A	Sabine River Authority of TX	Toledo Bend Res.	Newton	50,000	Irr	4,477,000	3/05/58
4658A	Sabine River Authority of TX	Toledo Bend Res.	Newton	600,000	Ind	4,477,000	3/05/58
4658A	Sabine River Authority of TX	Toledo Bend Res.	Newton	100,000	Mun	4,477,000	3/05/58
4659	Weirgate Lumber Company	Little Cow Creek	Newton	235	Ind		11/17/69
4660	Temple-Inland Forest Prod Co.	Unnamed	Newton	50	Irr		12/2/74
4661	Louisiana-Pacific Corp	Harve Davis	Newton	0	Recr		11/6/69
4662	Sabine River Authority of TX	Sabine River	Newton	100,400	Mun/Ind		2/24/26
4662	Sabine River Authority of TX	Sabine River	Newton	46,700	Irr		11/13/78
4663	J.A. Heard et al	Orange Co DD	Orange	67	Irr		5/31/38
4664	E.I Dupont de Nemours & Co.	Adams Bayou	Orange	267,000 *	Ind	2,870	6/19/45
4575A	Robert Thomas Perry et al	Unnamed	Smith	0	Ind		
5491	Oxy USA Inc.	Unnamed	Gregg	0	Mining		6/1/94

2 Municipal Right	101,460
1 Mun/Ind Right	100,400
4 Industrial Rights	867,235
4 Irrigation Rights	96,817
1 Mining	0
2 Recreational Rts	0
1 Hydroelectric Rts	0
15 Total Rights	1,165,912

* Much of this water at the downstream end of Adams Bayou is brackish.
** The hydroelectric right is at a rate of 21,000 cubic feet per second, but is non-consumptive.

Table B-2
Water Rights Upstream of Toledo Bend Reservoir and Downstream of Lake Fork & Iron Bridge Dams

Permit/ Cert. Of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4671	City of Wills Point	Magby Creek	Van Zandt	300	Mun	267	12/10/73
4672	Fin & Feather Hunt & Fish Club	Unnamed	Van Zandt	0	Recr		6/1/76
4673	Willow Lake Estates Assoc.	McBees Creek	Van Zandt	10	Ind	6	03/16/27
4673	Willow Lake Estates Assoc.	McBees Creek	Van Zandt	160	Mun	511	03/16/27
4674	Wirt Davis Trusts, TR#49220	Chinquapin	Van Zandt	0	Recr	282	12/6/76
4675	City of Canton	Mill Creek	Van Zandt	1,550	Mun	2,261	04/19/54
4676	City of Canton	Unnamed	Van Zandt	12	Mun	88	07/31/29
4677	William H McRae el al	Elliot	Van Zandt	0	Recr		¾/74
4678	City of Edgewood	Unnamed	Van Zandt	317	Mun	416	12/31/51
4679	City of Grand Saline	Simmons	Van Zandt	399	Mun	399	02/05/26
4557	Clifford L Barlow	Unnamed	Van Zandt	0	Recr	360	4/16/85
4680	Sunset Advertising, Inc.	Unnamed	Wood	0	Recr	54	4/14/75
4681	Dorothy Jean Harvey et al.	Unnamed	Rains	33	Irr	30	06/30/66
4682	Edward C Jones	Unnamed	Van Zandt	27	Irr	400	12/31/64
4684	Jack C Kellam	Unnamed	Van Zandt	27	Irr		11/06/72
4685	Van Zandt Club 20 Inc.	Unnamed	Van Zandt	0	Recr		8/30/76
4686	Unocal Pipline Company	Davis Creek	Van Zandt	0	Recr		2/19/74
4687	B R Darnell	Unnamed	Van Zandt	0	Recr		8/19/74
4688	Industrial Properties Corp.	Unnamed	Van Zandt	20	Irr		01/08/73
4689	Morton Salt Company Inc.	Unnamed	Van Zandt	251	Min		04/21/75
4683	Blount Realty Company	Small Creek	Wood	0	Recr	210	8/7/50
4690	Wood County	Lake Holbrook	Wood	0	Recr	7,990	12/19/60
4691	Mineola Club Lake	Smith Creek	Wood	0	Recr		3/13/72
4692	Lake Country Land Company	Smith Creek	Wood	0	Recr		3/29/76
4693	City of Van	Village Creek	Smith	400	Mun	1,175	02/01/49

Table B-2 (continued)
Water Rights Upstream of Toledo Bend Reservoir and Downstream of Lake Fork & Iron Bridge Dams

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4694	Sky Ranches Inc.	Unnamed	Smith	0	Recr	600	8/1/66
5229	Charles Breedlove	Unnamed	Smith	9	Irr		04/14/89
4695	David Brent Pogue, et al	Unnamed	Van Zandt	0	Recr	350	1/3/77
4696	Holiday Camplands of Texas	Unnamed	Smith	0	Recr	390	5/1/72
4697	Preston Southwest Investments	Rock Creek	Smith	0	Recr		8/24/73
4698	James C Miller & Wife	Old Sabine River	Smith	273	Irr		07/30/62
4707	Paul B. Horton	Turman Creek	Wood	0	Recr	600	1/13/75
4708	Wood County	Lake Quitman	Wood	0	Recr	7,440	12/19/60
4709	North American Coal Corp	Unnamed	Wood	0	Recr	440	2/23/76
4710	Walter L Lengel & Wife	Unnamed	Wood	17	Irr		06/30/48
4713	Wells Land & Cattle Company	Graveyard Creek	Wood	0	Recr		1/13/75
4711	Quitman Club Lake	Glade Creek	Wood	0	Recr	98	1/20/75
4712	Lake Lydia Inc.	Chinquapin	Wood	0	Recr	570	1/27/75
4513	William N Walker	Lake Fork Creek	Wood	750	Irr		11/01/84
4714	Tom E Glover et al.	Four Mile Creek	Wood	10	Ind		08/28/73
4715	Lake Brenda Owners Assoc.	Two Mile Creek	Wood	0	Recr	228	7/1/74
4716	Nations Bank of Texas, Trust	Unnamed	Wood	20	Ind	45	12/31/43
4769	Frank E Elro et al.	Unnamed	Wood	40	Irr	16	12/31/54
4717	Sundowner Property Owners	Unnamed	Wood	0	Recr	389	1/20/75
4718	H L Hobbs	Red Br & Tribs	Wood	30	Irr	49	06/30/62
4719	Salesmanship Club of Dallas	Unnamed	Wood	0	Recr		1/12/76
4720	Rock Falls Fishing Club	Rock Falls Creek	Wood	0	Recr`	237	6/10/74
4721	Jerry Paul Vaughan et al	Lacy Branch	Wood	0	Recr	275	6/30/75
4770	Woodvale Fishing Club	Black Creek	Wood	0	Recr	282	12/31/16
4722	Barney Holmes, Jr	Unnamed	Wood	38	Irr	50	12/31/50
4723	Youth with a Mission Inc.	Unnamed	Smith	0	Recr		6/1/76

Table B-2 (continued)
Water Rights Upstream of Toledo Bend Reservoir and Downstream of Lake Fork & Iron Bridge Dams

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4724	Hide-A-Way Lake Club	Hubbard Creek	Smith	180	Irr	2,816	05/23/67
4725	Smith County Baptist Association	Unnamed	Smith	0	Recr	28	1/7/80
4726	Lindale Hunting & Fishing Club	Unnamed	Smith	0	Recr		11/15/71
4727	James C Miller & Wife	Mac's Creek	Smith	107	Irr	550	06/30/63
4727	James C Miller & Wife	Red Lake	Smith	218	Irr	80	06/30/63
4728	T L Arthur Jr & Wife	Mill Creek	Smith	23	Irr		12/31/1871
4729	Lake Lorraine Club	North Prairie Creek	Smith	0	Recr		2/7/72
4730	Marion B. Shelton Estate et al	Hitt's Creek	Smith	0	Recr	1,214	12/31/1883
4731	Texas Parks & Wildlife	Unnamed	Smith	0	Recr	1,090	12/16/63
4733	Weldon S. Wells et al	Red Branch	Wood	0	Recr	400	5/1/78
4734	West Lakes Club	Little Sandy Creek	Wood	0	Recr	990	1/13/75
4735	Community Centers International	Highland Pond	Wood	0	Recr	100	3/17/75
4736	Wood County	Lake Hawkins	Wood	0	Recr	11,890	12/19/60
4251	Dale A Hipke, et al	Unnamed	Smith	65	Recr	65	10/18/82
4771	Little Sandy Hunting & Fishing	Little Sandy	Wood	10	Ind	4,589	12/31/02
4737	Bo Holmes & Wife	Unnamed	Wood	8	Irr	5	07/31/61
4738	Barney Holmes Jr & Wife	Unnamed	Wood	44	Irr	5	12/31/60
4739	Wayne Moore, et al.	Unnamed	Smith	750	Irr	244	02/27/56
4740	William L Brady et al.	Spring Creek	Smith	8	Irr	15	12/31/56
4741	Pinedale Lake Company	Born Branch	Smith	0	Recr	248	4/22/75
5287	First City Texas-Tyler Trust	Born Branch	Smith	0	Recr	491	3/21/90
4742	Suzette D Shelmire et al.	Born Branch	Smith	25	Irr	207	10/09/52
4575	Charles D & Mary J Wood	Unnamed	Smith	117	Irr	7	06/04/85
4575	Robert Thomas Perry el al	Unnamed	Smith	0	Irr		
4744	Horseshoe Club Lake	Hankins Creek	Smith	0	Recr	291	1/15/73
4745	Edwin B Ashby & Wife	Harris Creek	Smith	15	Irr		07/31/45
4747	William L Brady et al.	Spring Creek	Smith	20	Irr	20	12/31/51

Table B-2 (continued)
Water Rights Upstream of Toledo Bend Reservoir and Downstream of Lake Fork & Iron Bridge Dams

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4746	William L Brady et al.	Spring Creek	Smith	20	Irr	9	12/31/51
4743	William L Brady & Wife	Glade Creek	Smith	5	Irr		12/31/51
4748	Pinehurst Partners, Ltd.	Harris Cr & Trib.	Smith	120	Irr	200	07/31/55
4749	Wood County	Lake Winnsboro	Wood	0	Recr	8,100	12/19/60
4750	Virgil Woodward & Wife	Turkey Creek	Wood	1	Irr	4	07/31/559
4751	Big Woods Springs Imp Assoc.	Turkey Creek	Wood	0	Recr	787	4/22/75
4752	Comy E Bradshaw & Wife	Buck Creek	Wood	30	Irr	4	07/31/56
4267	Louisiana-Pacific Corp.	Unnamed	Wood	200	Irr	8	11/22/82
4753	Gunstream Land Corp	Mill Creek	Wood	0	Recr	2,758	1/6/75
4754	Mill Creek Company	Mill Creek	Wood	500	Irr	698	02/04/80
5419	Silverleaf Resources, Ltd.	Holly Creek	Wood	432	Recr	432	6/1/92
4755	Real Estate Holdings Inc.	Greenbriar Cr	Wood	86	Irr	2,260	01/31/72
4756	A C Musgrave, Jr.	Boggy Creek	Wood	0	Recr	520	9/11/73
4757	Boggy Creek Ranchy	Boggy Creek	Wood	0	Recr		7/28/75
4307	Tyler Sand Company	Big Sandy Cr	Upshur	200	Min		01/24/83
4758	Ambassador College	Big Sandy & Trib.	Upshur	400	Mun		05/03/65
4758	Ambassador College	Big Sandy & Trib.	Upshur	350	Irr	914	05/03/65
4220	Ralph Trimble	Big Sandy Cr.	Upshur	80	Irr		06/07/82
4760	Gladewater Hunting & Fishing Club	Rocky Creek	Upshur	0	Recr		1/13/75
4761	Donald Therneau	Unnamed	Smith	7	Ind	4	07/02/73
4762	City of Gladewater	Lake Gladewater	Upshur	1,679	Mun	6,950	05/17/51
4763	Jack L Phillips & Wife	Glade Creek	Upshur	100	Irr	10	06/30/63
4622	Lake Devernia Hunting & Fishing	Campbells Creek	Gregg	0	Recr	690	11/4/71
4764	Howell Club Lake	Sandy Bottom Creek	Smith	0	Recr	608	7/8/74
4765	Hamrick Lake Association	Sandy Bottom Creek	Smith	0	Recr	306	12/9/74
4732	Edwin Baggett & Wife	Unnamed	Upshur	202	Irr	44	03/31/61
4623	G R Akin et al.	Unnamed	Gregg	5	Min		12/31/31

Table B-2 (continued)
Water Rights Upstream of Toledo Bend Reservoir and Downstream of Lake Fork & Iron Bridge Dams

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
5090	City of Longview	Sabine River	Gregg	13,860	Mun		08/26/86
4759	City of Longview	Big Sandy Creek	Upshur	100	Irr		07/13/45
4759	City of Longview	Big Sandy Creek	Upshur	100	Ind		07/13/45
4759	City of Longview	Big Sandy Creek	Upshur	5,400	Mun	183	04/24/35
4624	City of Longview	Sabine River	Gregg	1,087	Mun	180	07/07/15
4625	City of Overton	Unnamed	Smith	0	Mun	170	4/12/76
4626	M F Glover et al	Unnamed	Gregg	17	Irr	70	06/30/55
4627	Patricia Louise Phillips et al.	Unnamed	Rusk	80	Irr	334	04/12/76
4628	Gino Venitucci et al.	Unnamed	Gregg	37	Irr	100	12/31/63
4629	Carlos B. Griffin, Sr. & Wife	Unnamed	Gregg	28	Irr	240	08/31/53
4630	George D Grogan	Unnamed	Gregg	39	Irr	56	12/31/52
4632	Pinecrest Country Club	Unnamed	Harrison	0	Irr		12/31/36
4632	J L Finch Estate	Unnamed	Harrison	51	Irr	102	12/31/36
4631	Eastman Chemical Company	Sabine River	Harrison	22,500	Ind	8,135	09/19/49
4633	Clarence W Young & Wife	Unnamed	Harrison	3	Ind		12/31/55
4634	E C Johnston, Jr.	Unnamed	Harrison	69	Irr		03/31/63
4635	Gordon C Johnston et al.	Unnamed Trib Mason	Harrison	17	Irr	183	03/31/63
4636	Brown's Lake Fishing Club	Unnamed	Rusk	0	Mun	106	11/3/75
4637	Boral Bricks, Inc.	Unnamed	Rusk	15	Ind		08/18/75
4638	Alex Pope Jr et al.	Mill Creek	Rusk	37	Irr		07/31/63
5578	City of Henderson	Unnamed Trib Beaver Cr	Rusk	10	Mun		03/04/97
5519	Texas Util Mining Co/TU Svcs.	Unnamed	Rusk	245	Min	137	08/16/95
5441	Texas Utilities Mining Company	Boggy Branch	Rusk	1006	Ind		03/23/93
4639	Margene Tuthill et al.	Unnamed	Rusk	50	Irr		05/31/46
4640	C J Bennett & Wife	Unnamed	Rusk	16	Irr	24	12/31/22
4641	E E Brown & Wife	Unnamed	Rusk	0	Ind	21	12/31/44
4643	Long Glade Lake Inc.	Unnamed	Rusk	0	Recr	284	3/3/75

Table B-2 (continued)
Water Rights Upstream of Toledo Bend Reservoir and Downstream of Lake Fork & Iron Bridge Dams

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4642	Cherokee Water Company	Lake Cherokee	Gregg	62,400*	Mun	62,400	10/05/46
4645	James E Utz	Unnamed	Harrison	118	Irr		03/31/60
4644	Highway Lake Company Inc.	Unnamed	Harrison	0	Recr	398	12/31/25
5439	Sabine Mining Company	Rodgers Creek	Harrison	100	Ind	93	12/03/92
5382	Sabine Mining Company	Clark Creek	Harrison	100	Ind	28	09/09/91
5246	Sabine Mining Company	Unnamed	Harrison	100	Ind	45	07/14/89
5177	Sabine Mining Company	Rodgers Creek	Harrison	100	Ind	187	04/28/88
4646	Carolyn Holloway Bicknell	Clark Creek	Harrison	9	Irr	60	12/31/37
5454	The Sabine Mining Company	Unnamed	Harrison	100	Ind	100	03/05/93
5082	The Sabine Mining Company	Unnamed	Harrison	5	Ind	59	08/07/86
5124	Sabine Mining Company	Unnamed	Harrison	15	Ind	50	03/23/87
4647	Southwestern Elec Power Co.	Brandy Branch	Harrison	11,000	Ind	29,513	08/21/78
5468	Norit Americas Inc.	Unnamed Trib	Harrison	7	Ind	7	08/18/93
5158	Norit Americas Inc.	Unnamed	Harrison	0	Other		9/28/87
4648	Philip H Megason & Wife	Unnamed Trib	Rusk	76	Ind	77	03/31/65
5492	Texas Utilities Mining Co/ TU Services	Weir Creek	Panola	164	Other	164	6/17/94
5526	Texas Utilities Mining Co/ TU Services	Unnamed	Panola	0	Mining	50	4/4/95
5504	Texas Utilities Mining Co/ TU Services	Caney Branch	Panola	0	Mining	180	9/14/94
4649	Texas Utilities Mining Co/ TU Services	Martin Lake	Rusk	25,000	Ind	56,500	07/19/71
5219	Texas Utilities Mining Co/ TU Services	Unnamed	Panola	129	Ind	100	03/20/89
4556	James A Burgess	Martin Creek	Panola	77	Irr		04/16/85
4650	3-H Lake Association, Inc.	Unnamed	Panola	0	Recr		11/10/75
4651	Dixie Lake Inc.	Little Six Mile Creek	Panola	0	Recr	740	5/7/73
4652	Hills Lake Fishing Club	Unnamed	Panola	286	Ind	220	01/10/72
5380	Charle R Johnson	Maxwell Branch	Rusk	20	Ind	9	08/23/91
4653	W C Smith Children Trust	Murvaul Bayou	Panola	50	Irr		04/16/64
4654	Panola Co FWSD 1	Murvaul Lake	Panola	1,120	Ind	44,650	07/19/56

Table B-2 (continued)
Water Rights Upstream of Toledo Bend Reservoir and Downstream of Lake Fork & Iron Bridge Dams

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4654	Panola Co FWSD 1	Murvaul Lake	Panola	21,280	Mun	44,650	07/19/56
4655	Cities Service Oil & Gas Corp.	Unnamed	Panola	229	Ind	144	04/26/48
4531	Miriam H & Jeanette Bounds	Unnamed	Panola	70	Irr		01/03/85
4656	Arnold Hooper & Wife	Sabine River	Panola	118	Irr		06/20/55
		17	Municipal Rights	109,254			
		27	Industrial Rights	62,068			
		55	Irrigation Rights	5,456			
		56	Recreation	497			
		6	Mining Rights	701			
		2	Other	164			
		163	Total Rights	178,140			

* The firm yield of Lake Cherokee is less than the permitted water right.

Table B-3
Water Rights Upstream of Lake Fork Dam

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
5046	Robert Carrozza	Brickkiln Branch	Rains	0	Recr	278	2/27/86
4700	Nell Cobb Click	Unnamed	Rains	25	Irr	196	5/30/51
4699	Truman L. Renshaw	Unnamed	Hopkins	19	Irr		5/8/69
4702	Dewey Dickens & Wife	Unnamed	Hopkins	75	Irr		8/30/74
5217	Coy Johnson et at	Unnamed	Hopkins	0	Mun	318	2/10/89
4701	Donald L. Gale el al.	Elm Cr & Lake Fork	Rains	249	Irr		5/31/55
4703	Anita L. Tynes, et al.	Unnamed	Hopkins	1	Irr	1	6/27/77
4704	A.C. McAfee & Wife	Unnamed	Wood	137	Irr	75	4/30/58
4705	Elberta Lake Club Inc.	Running Creek	Hopkins	0	Recr		12/13/71
4669A	Sabine River Authority of TX	Lake Fork Reservoir	Wood	0	Mun	115	4/16/92
4669A	Sabine River Authority of TX	Lake Fork Reservoir	Wood	19,500	Ind		6/26/74
4669A	Sabine River Authority of TX	Lake Fork Reservoir	Wood	131,860	Mun		6/26/74
4669A	Sabine River Authority of TX	Lake Fork Reservoir	Wood	37,300	Mun	675,819	6/26/74
		1	Industrial Rts	19,500			
		4	Municipal Rts	169,160			
		6	Irrigation Rights	506			
		2	Recreation	0			
		13	Total Rights	189,166			

Table B-4
Water Rights Upstream of Iron Bridge Dam (Lake Tawakoni)

Permit/ Cert. of Adjud.	Owner	Stream or Reservoir	County	Annual Permitted Use (AF/Y)	Type of Use	Reservoir Capacity (Ac-Ft)	Priority Date
4665A	City of Greenville	Cowleech Fork	Hunt	4,159	Mun	6,864	6/30/25
4666	Mrs. Edgar Hutchins	Unnamed	Hunt	0	Recr		11/27/72
4667	E.H. Buehring, et al.	Cowleech Fork	Hunt	250	Irr		11/27/56
4668	Greenville Lake & Water Company	Cedar Creek	Hunt	0	Recr	2,170	9/29/75
4670	Sabine River Authority/City of Dallas	Lake Tawakoni	Hunt	238,100	Mun	927,440	9/12/55
			2 Municipal Rights	242,259			
			2 Recreation	0			
			1 Irrigation Right	250			
			5 Total Rights	242,509			

Table B-5
Historical Water Use Associated with Rights over 1,000 AF/Y in the Sabine Basin

Permit/ Cert. of Adjud.	Owner	Annual Right (AF/Y)	Historical Use 1988	1989	1990	1991	1992	1993	1994	1995	1996
	Downstream of Toledo Bend Reservoir										
4657	City of Center	1,460	271	177	374	0	NR	NR	NR	10	1
4658A	SRA (Toledo Bend)-Irrigation	50,000	0	0	0	0	0	0	0	0	0
4658A	SRA (Toledo Bend)-Industrial	600,000	0	0	0	0	0	0	0	0	0
4658A	SRA (Toledo Bend)-Municipal	100,000	1,031	1,068	1,098	1,099	1,179	1,274	1,128	1,234	1,488
4658A	SRA (Toledo Bend)-Hydropower		3,046	4,637	5,190	5,115	5,580	5,333	3,382	5,721	443
4664	DuPont (Brackish)	267,000	123,886	126,905	125,707	121,449	154,690	149,113	97,385	0	0
4664	DuPont (Fresh)						636	709	517	0	0
4662	SRA-Municipal/Industrial	100,400	51,918	51,125	49,219	47,193	51,822	58,431	53,820	52,568	56,079
4662	SRA-Irrigation	46,700	4,596	5,391	3,340	3,550	3,308	3,270	3,619	2,117	2,563
	Between Toledo Bend Reservoir & Lake Fork and Iron Bridge Dams										
4675	City of Canton	1,550	372	282	357	242	370	250	NR	647	627
4762	City of Gladewater	1,679	1,296	1,190	1,242	1,187	1,243	1,254	1,106	1,170	1,191
5090	City of Longview	13,860	0	80	0	826	898	819	1,011	658	197
4759	City of Longview-Municipal	5,400	4,011	4,144	3,594	3,642	4,051	4,027	4,150	3,628	2,527
4759	City of Longview-Irrigation	100	856	777	837	838	852	918	1,060		
4624	City of Longview	1,087	1,088	634	593	716	761	720	768	656	501
4631	Eastman Chemical	22,500	10,440	8,727	12,715	14,273	9,191	9,972	12,210	47,750	12,017
4642*	Cherokee Water Co-Municipal	62,400	14,900	15,164	14,538	17,370	17,100	12,899	13,743	14,208	17,400
4642	Cherokee Water Co-Industrial		8	3	9	8	10	19	24	10	1
4647	SWEPCO	11,000	513	524	490	1,428	1,701	1,558	1,576	NR	NR

Table B-5 (continued)
Historical Water Use Associated with Rights over 1,000 AF/Y in the Sabine Basin

Permit/ Cert of Adjud.	Owner	Annual Right (AF/Y)	Historical Uses 1988	1989	1990	1991	1992	1993	1994	1995	1996
	Between Toledo Bend Reservoir & Lake Fork and Iron Bridge Dams:										
4649	TU Electric	25,000	19,152	18,744	23,830	22,338	21,527	NR	19,721	19,966	NR
4654	Panola Co. FWSD-Industrial	1,120									
4654	Panola Co. FWSD-Municipal	21,280	1,570	1,678	1,610	1,650	1,651	1,896	1,853	2,159	2,182
	Upstream of Lake Fork Dam:										
4669A	SRA (Lake Fork)-Industrial	19,500	0	0	3,491	0	0	0	0	0	0
4669A	SRA (Lake Fork)-Municipal	169,160	10,889	12,187	3,321	4,782	4,588	5,210	5,394	9,739	12,653
	Upstream of Iron Bridge Dam:										
4665A	Greenville	4,159	5,443	5,016	5,302	3,436	4,625	5,382	4,803	4,070	1,240
4670	SRA/City of Dallas (Tawakoni)	238,100	149,461	87,995	122,435	100,035	102,780	122,995	64,978	82,586	145,286

NR- No Record
* The firm yield of Lake Cherokee is less than the permitted water right.

APPENDIX C

POPULATION AND WATER USE DATA

Table C-1
Sabine River Basin Population Projections[1]
Most Likely Migration Rate Scenario
Upper Basin Cities

Year	1990	2000	2010	2020	2030	2040	2050
Big Sandy	1,185	1,334	1,455	1,566	1,657	1,722	1,776
Caddo Mills	1,068	1,305	1,540	1,742	1,859	1,912	1,967
Canton	2,949	3,406	3,685	3,861	3,813	3,666	3,508
Carthage	6,496	6,860	7,102	7,196	7,173	6,943	6,720
Edgewood	1,284	1,477	1,597	1,674	1,653	1,589	1,520
Emory	963	979	994	1,005	1,014	1,029	1,044
Gladewater	6,027	6,832	7,471	8,122	8,710	9,226	9,749
Grand Saline	2,630	2,907	3,145	3,296	3,254	3,129	2,994
Greenville	23,071	24,137	25,075	25,565	26,276	26,476	26,678
Hallsville	2,288	3,081	3,901	4,514	4,859	4,919	4,980
Hawkins	1,309	1,474	1,590	1,663	1,647	1,552	1,386
Henderson	1,115	1,202	1,217	1,188	1,160	1,157	1,154
Kilgore	11,066	12,767	13,705	14,644	15,435	16,270	17,151
Liberty City	1,607	2,177	2,565	2,863	3,073	3,200	3,332
Lindale	1,214	1,372	1,491	1,566	1,626	1,677	1,709
Longview	70,311	78,218	84,498	91,157	97,281	102,956	108,979
Marshall	18,621	20,094	21,612	22,959	23,211	22,143	21,124
Mineola	4,321	4,858	5,239	5,480	5,426	5,115	4,566
Overton[1]	1,954	2,043	2,081	2,048	2,010	2,013	2,015
Quinlan	1,360	1,841	2,322	2,752	2,982	3,089	3,200
Quitman	1,684	1,897	2,046	2,140	2,119	1,998	1,783
Royse City	2,206	3,948	5,827	8,311	11,348	14,920	19,633
Tatum	1,289	1,392	1,443	1,445	1,433	1,427	1,421
Tyler[1]	8	8	8	9	9	10	11
Van	91	105	113	119	117	113	108
White Oak	5,136	5,882	6,466	7,089	7,682	8,246	8,851
Wills Point	1,491	1,671	1,810	1,899	1,876	1,805	1,736
Winnsboro[1]	2,202	2,453	2,652	2,786	2,776	2,634	2,377

1. City population includes only that portion of the population within the Sabine River Basin

Table C-2
Sabine River Basin Population Projections[1]
Most Likely Migration Rate Scenario
Lower Basin Cities

Year	1990	2000	2010	2020	2030	2040	2050
Bessmay-Buna	2,127	2,528	2,629	2,695	2,738	2,828	2,921
Bridge City	4,820	5,578	6,163	6,755	7,354	7,637	7,931
Center	4,950	5,403	5,911	6,301	6,724	7,059	7,411
Hemphill	1,182	1,265	1,335	1,384	1,470	1,555	1,645
Kirbyville	1,871	2,162	2,248	2,306	2,341	2,419	2,419
Newton	1,885	2,267	2,594	2,908	3,185	3,294	3,407
Orange	19,381	20,317	22,300	24,444	26,612	27,632	28,691
Pinehurst	2,682	2,952	3,189	3,351	3,543	3,760	3,960
Tenaha	1,072	1,169	1,213	1,264	1,320	1,370	1,420
Timpson	1,029	1,142	1,178	1,222	1,269	1,313	1,359
Vidor	3,279	3,606	3,758	3,885	3,990	4,067	4,146
West Orange	4,187	4,785	5,289	5,647	6,073	6,558	7,082

1. Population is for that portion of the city within the Sabine River basin.

Table C-3
Sabine River Basin: Lower Basin Population Projections
Most Likely Migration Rate Scenario

COUNTY	1990	2000	2010	2020	2030	2040	2050
Jasper	11,337	12,267	12,941	13,589	14,329	14,964	15,556
Newton	13,556	14,271	14,900	15,172	15,231	14,967	14,567
Orange	54,313	59,943	65,092	68,949	73,382	77,802	81,949
Sabine	6,774	7,592	8,252	8,704	8,864	9,086	9,333
San Augustine	785	787	802	813	830	837	843
Shelby	20,095	21,073	21,914	22,852	23,878	24,796	25,710
Total	**106,860**	**115,933**	**123,901**	**130,079**	**136,514**	**142,452**	**147,958**

Table C-4
Sabine River Basin: Upper Basin Population Projections
Most Likely Migration Rate Scenario

COUNTY	1990	2000	2010	2020	2030	2040	2050
Collin	2,015	3,144	2,646	5,432	9,555	14,759	20,211
Franklin	81	94	109	125	142	151	161
Gregg	103,325	112,188	119,566	127,469	134,662	141,231	148,128
Harrison	37,123	40,283	43,388	45,336	45,169	43,586	42,065
Hopkins	6,257	6,446	6,659	6,804	6,828	6,768	6,669
Hunt	51,714	57,464	62,772	66,990	69,750	70,849	73,395
Kaufman	964	1,135	1,346	1,579	1,782	1,938	2,029
Panola	21,998	23,561	24,716	25,306	25,357	24,650	23,943
Rains	6,715	7,444	8,210	8,870	9,436	9,807	10,506
Rockwall	3,480	5,494	7,711	11,068	15,229	20,162	24,949
Rusk	20,646	22,314	23,783	26,172	28,596	30,131	31,104
Smith	21,554	25,421	27,887	29,018	28,995	28,431	26,973
Upshur	11,139	12,464	13,593	14,630	15,484	16,091	16,593
Van Zandt	20,784	23,291	25,196	26,404	26,072	25,066	23,985
Wood	27,703	31,002	33,434	34,972	34,628	32,641	29,138
Total	**335,498**	**371,745**	**401,016**	**430,175**	**451,685**	**466,261**	**479,849**

Projections are for the portion of each county that lies within the Sabine Basin.

Table C-5
Sabine River Basin "Most Likely" Municipal Use Scenario[1]
(Acre-Feet/Year)

County	1990	2000	2010	2020	2030	2040	2050
Collin	320	485	377	716	1,231	1,994	2,600
Franklin	13	18	20	21	24	25	26
Gregg	17,469	21,438	21,761	22,248	23,048	23,769	24,849
Harrison	5,287	6,338	6,435	6,407	6,222	5,791	5,583
Hopkins	828	1,070	1,053	1,022	995	956	935
Hunt	9,337	9,762	9,879	9,829	9,933	9,826	10,011
Jasper	1,548	1,752	1,737	1,708	1,731	1,752	1,791
Kaufman	109	153	169	186	204	215	223
Newton	1,675	1,764	1,753	1,701	1,663	1,577	1,551
Orange	8,523	9,553	9,828	9,971	10,348	10,646	11,073
Panola	3,010	3,651	3,607	3,488	3,377	3,171	3,072
Rains	1,096	1,317	1,377	1,415	1,463	1,487	1,579
Rockwall	482	1,004	1,280	1,734	2,347	3,084	3,679
Rusk	2,743	3,250	3,252	3,307	3,431	3,490	3,589
Sabine	751	927	927	917	913	912	934
San Augustine	147	98	93	89	87	85	85
Shelby	2,794	3,104	3,052	3,004	3,053	3,071	3,158
Smith	3,348	3,920	4,042	3,976	3,846	3,680	3,469
Upshur	1,700	1,895	1,930	1,954	1,988	2,003	2,041
Van Zandt	3,017	3,368	3,421	3,385	3,234	2,995	2,869
Wood	4,032	4,864	4,934	4,870	4,702	4,264	3,843
TOTAL	**68,229**	**79,731**	**80,927**	**81,948**	**83,840**	**84,793**	**86,960**

1. "Most Likely" Scenario uses "most likely" population series and assumes below average rainfall and expected levels of conservation.

Projections are for the portion of each county that lies within the Sabine Basin.

Table C-6
Sabine River Basin 1.0 Migration Rate Municipal Use Scenario[2]
(Acre-Feet/Year)

County	1990	2000	2010	2020	2030	2040	2050
Collin	320	619	949	1,385	1,872	2,299	2,404
Franklin	13	13	11	9	7	6	5
Gregg	17,469	20,111	19,274	18,147	17,069	15,497	14,017
Harrison	5,287	6,314	6,393	6,358	6,169	5,757	5,535
Hopkins	828	1,098	1,070	1,047	1,008	921	866
Hunt	9,337	10,245	10,706	10,860	11,142	11,299	11,442
Jasper	1,548	1,604	1,477	1,353	1,245	1,061	869
Kaufman	109	170	202	240	283	326	344
Newton	1,675	1,815	1,808	1,714	1,555	1,411	1,274
Orange	8,523	8,751	7,985	7,109	6,167	5,407	4,627
Panola	3,010	3,764	3,701	3,518	3,411	2,968	2,617
Rains	1,096	1,443	1,615	1,758	1,879	1,983	2,040
Rockwall	482	1,003	1,278	1,732	2,344	3,079	3,672
Rusk	2,743	3,170	3,120	2,968	2,799	2,471	2,271
Sabine	751	882	834	773	705	658	625
San Augustine	147	92	80	67	56	46	38
Shelby	2,794	2,941	2,677	2,349	2,030	1,804	1,548
Smith	3,348	3,923	4,016	3,980	3,850	3,684	3,472
Upshur	1,700	1,822	1,766	1,667	1,544	1,484	1,423
Van Zandt	3,017	3,308	3,340	3,315	3,099	2,864	2,698
Wood	4,032	4,799	4,818	4,679	4,430	4,054	3,625
TOTAL	**68,229**	**77,887**	**77,120**	**75,028**	**72,664**	**69,079**	**65,412**

2. 1.0 Migration Rate Scenario assumes 1.0 migration rate population series with Below Average Rainfall and Expected Conservation.

Projections are for the portion of each county that lies within the Sabine Basin.

Table C-7
Sabine River Basin Advanced Conservation Municipal Use Scenario[3]
(Acre-Feet/Year)

County	1990	2000	2010	2020	2030	2040	2050
Collin	320	464	343	639	1,234	1,813	2,354
Franklin	13	17	18	20	22	23	25
Gregg	17,469	20,706	20,290	20,339	21,274	22,199	23,199
Harrison	5,287	6,109	5,968	5,831	5,730	5,433	5,192
Hopkins	828	1,034	986	938	926	903	882
Hunt	9,337	9,360	9,096	8,800	8,974	8,978	9,140
Jasper	1,548	1,681	1,602	1,558	1,600	1,645	1,672
Kaufman	109	147	157	168	188	200	209
Newton	1,675	1,695	1,610	1,531	1,526	1,484	1,446
Orange	8,523	9,234	9,230	9,198	9,680	10,104	10,438
Panola	3,010	3,531	3,344	3,156	3,101	2,958	2,846
Rains	1,096	1,284	1,293	1,314	1,376	1,418	1,504
Rockwall	482	962	1,195	1,581	2,158	2,833	3,400
Rusk	2,743	3,138	3,007	2,995	3,159	3,248	3,316
Sabine	751	889	864	837	849	859	879
San Augustine	147	94	87	81	82	81	80
Shelby	2,794	2,986	2,834	2,734	2,809	2,871	2,951
Smith	3,348	3,749	3,696	3,547	3,481	3,357	3,189
Upshur	1,700	1,829	1,799	1,785	1,845	1,887	1,909
Van Zandt	3,017	3,245	3,161	3,039	2,945	2,779	2,660
Wood	4,032	4,686	4,544	4,377	4,258	3,982	3,533
Total	**68,229**	**76,840**	**75,124**	**74,468**	**77,217**	**79,055**	**80,824**

3. Advanced Conservation Scenario assumes "most likely" population series with below average rainfall and advanced levels of conservation.

Projections are for the portion of each county that lies within the Sabine Basin.

Table C-8

Sabine River Basin Low Oil Price Manufacturing Use Scenario[1]
(Acre-Feet/Year)

County	1990	2000	2010	2020	2030	2040	2050
Collin	0	0	0	0	0	0	0
Franklin	0	0	0	0	0	0	0
Gregg	14,634	16,431	18,276	20,363	22,576	24,931	27,351
Harrison	74,107	115,543	150,737	169,499	190,993	214,392	244,883
Hopkins	2	2	3	3	3	4	4
Hunt	409	434	461	485	509	533	559
Jasper	0	0	0	0	0	0	0
Kaufman	0	0	0	0	0	0	0
Newton	114	125	135	146	156	166	180
Orange	49,169	55,518	62,835	71,073	80,130	91,522	104,257
Panola	641	720	804	888	967	1,046	1,121
Rains	0	0	0	0	0	0	0
Rockwall	0	0	0	0	0	0	0
Rusk	48	54	60	66	72	77	84
Sabine	0	0	0	0	0	0	0
San Augustine	0	0	0	0	0	0	0
Shelby	1,204	1,505	1,856	2,242	2,656	3,099	3,560
Smith	229	280	340	402	465	526	587
Upshur	0	0	0	0	0	0	0
Van Zandt	223	296	385	471	570	648	729
Wood	41	48	55	64	73	82	93
TOTAL	**140,821**	**190,956**	**235,947**	**265,702**	**299,170**	**337,026**	**383,408**

1. Low Oil Price Scenario assumes lower priced oil with no conservation efforts.

Projections are for the portion of each county that lies within the Sabine Basin.

Table C-9

Sabine River Basin "Most Likely" Manufacturing Use Scenario[2]
(Acre-Feet/Year)

County	1990	2000	2010	2020	2030	2040	2050
Collin	0	0	0	0	0	0	0
Franklin	0	0	0	0	0	0	0
Gregg	14,634	16,538	18,576	20,934	23,507	26,515	29,716
Harrison	74,107	109,321	133,587	140,270	146,244	159,506	174,422
Hopkins	2	2	3	3	4	5	5
Hunt	409	426	443	456	466	488	508
Jasper	0	0	0	0	0	0	0
Kaufman	0	0	0	0	0	0	0
Newton	114	122	131	139	146	154	162
Orange	49,169	52,936	56,817	60,388	63,391	69,938	76,790
Panola	641	685	730	762	785	844	897
Rains	0	0	0	0	0	0	0
Rockwall	0	0	0	0	0	0	0
Rusk	48	54	59	65	71	76	83
Sabine	0	0	0	0	0	0	0
San Augustine	0	0	0	0	0	0	0
Shelby	1,204	1,436	1,694	1,944	2,189	2,550	2,928
Smith	229	262	298	325	346	377	403
Upshur	0	0	0	0	0	0	0
Van Zandt	223	280	344	396	451	508	566
Wood	41	48	57	67	77	92	107
TOTAL	**140,821**	**182,110**	**212,739**	**225,749**	**237,677**	**261,053**	**286,587**

2. "Most Likely" scenario assumes base oil price with expected conservation.

Projections are for the portion of each county that lies within the Sabine Basin.

Table C-10

Sabine River Basin Base with No Conservation Manufacturing Use Scenario[3]
(Acre-Feet/Year)

County	1990	2000	2010	2020	2030	2040	2050
Collin	0	0	0	0	0	0	0
Franklin	0	0	0	0	0	0	0
Gregg	14,634	16,637	18,801	21,330	24,108	27,177	30,440
Harrison	74,107	113,211	143,704	157,554	171,951	187,617	205,322
Hopkins	2	2	3	3	4	5	5
Hunt	409	434	458	482	504	530	554
Jasper	0	0	0	0	0	0	0
Kaufman	0	0	0	0	0	0	0
Newton	114	122	131	139	146	154	162
Orange	49,169	54,410	60,337	66,691	73,143	80,903	89,017
Panola	641	712	790	864	935	1,004	1,067
Rains	0	0	0	0	0	0	0
Rockwall	0	0	0	0	0	0	0
Rusk	48	54	59	65	71	76	83
Sabine	0	0	0	0	0	0	0
San Augustine	0	0	0	0	0	0	0
Shelby	1,204	1,492	1,833	2,207	2,613	3,045	3,498
Smith	229	273	324	371	416	455	486
Upshur	0	0	0	0	0	0	0
Van Zandt	223	291	374	453	544	612	682
Wood	41	49	58	69	81	95	111
TOTAL	**140,821**	**187,687**	**226,872**	**250,228**	**274,516**	**301,673**	**331,427**

3. No Conservation Scenario assumes base oil prices with no conservation efforts.

Projections are for the portion of each county that lies within the Sabine Basin.

Table C-11
Total Water Requirements - Year 2000
(Acre-Feet per Year)

County	Municipal [1]	Irrigation [1]	Livestock	Manufac. [2]	Mining	Power [3]	Total
Collin	485	0	38	0	0	0	523
Franklin	18	0	2	0	0	0	20
Gregg	21,438	0	230	16,431	96	2,500	40,695
Harrison	6,338	50	326	115,543	186	5,000	127,443
Hopkins	1,070	0	2,130	2	0	0	3,202
Hunt	9,762	271	896	434	70	800	12,233
Jasper	1,752	0	100	0	2	0	1,854
Kaufman	153	0	72	0	0	0	225
Newton	1,764	2,200	82	125	30	0	4,201
Orange	9,553	3,329	70	55,518	1	6,000	74,471
Panola	3,651	0	2,027	720	3,245	0	9,643
Rains	1,317	20	700	0	0	0	2,037
Rockwall	1,004	0	26	0	0	0	1,030
Rusk	3,250	75	549	54	563	30,000	34,491
Sabine	927	0	337	0	0	0	1,264
San Augustine	98	0	87	0	0	0	185
Shelby	3,104	27	1,635	1,505	0	0	6,271
Smith	3,920	63	453	280	425	0	5,141
Upshur	1,895	0	418	0	0	0	2,313
Van Zandt	3,368	0	1,100	296	1,233	0	5,997
Wood	4,864	235	2,360	48	2,102	0	9,609
TOTALS	**79,731**	**6,270**	**13,638**	**190,956**	**7,953**	**44,300**	**342,848**

1. "Most Likely" Projection Series
2. Low Oil Price without Conservation Series
3. "High" Projection Series

Projections are for the portion of the county that lies within the Sabine Basin.

Table C-12
Total Water Requirements - Year 2010
(Acre-Feet per Year)

County	Municipal [1.]	Irrigation [1.]	Livestock	Manufac. [2.]	Mining	Power [3.]	Total
Collin	377	0	38	0	0	0	415
Franklin	20	0	2	0	0	0	22
Gregg	21,761	0	230	18,276	67	3,000	43,334
Harrison	6,435	50	326	150,737	89	5,000	162,637
Hopkins	1,053	0	2,130	3	0	0	3,186
Hunt	9,879	271	896	461	71	0	11,578
Jasper	1,737	0	100	0	2	0	1,839
Kaufman	169	0	72	0	0	0	241
Newton	1,753	2,200	82	135	30	0	4,200
Orange	9,828	3,014	70	62,835	1	10,000	85,748
Panola	3,607	0	2,027	804	2,645	0	9,083
Rains	1,377	20	700	0	0	0	2,097
Rockwall	1,280	0	26	0	0	0	1,306
Rusk	3,252	75	549	60	314	35,000	39,250
Sabine	927	0	337	0	0	0	1,264
San Augustine	93	0	87	0	0	0	180
Shelby	3,052	27	1,635	1,856	0	0	6,570
Smith	4,042	63	453	340	178	0	5,076
Upshur	1,930	0	418	0	0	0	2,348
Van Zandt	3,421	0	1,100	385	1,073	0	5,979
Wood	4,934	235	2,360	55	17,584	7,500	32,668
TOTALS	**80,927**	**5,955**	**13,638**	**235,947**	**22,054**	**60,500**	**419,021**

1. "Most Likely" Projection Series

2. Low Oil Price without Conservation Series

3. "High" Projection Series

Projections are for the portion of the county that lies within the Sabine Basin.

Table C-13
Total Water Requirements - Year 2020
(Acre-Feet per Year)

County	Municipal [1]	Irrigation [1]	Livestock	Manufac. [2]	Mining	Power [3]	Total
Collin	716	0	38	0	0	0	754
Franklin	21	0	2	0	0	0	23
Gregg	22,248	0	230	20,363	46	3,000	45,887
Harrison	6,407	50	326	169,499	50	5,000	181,332
Hopkins	1,022	0	2,130	3	0	0	3,155
Hunt	9,829	271	896	485	73	0	11,554
Jasper	1,708	0	100	0	2	0	1,810
Kaufman	186	0	72	0	0	0	258
Newton	1,701	2,200	82	146	31	0	4,160
Orange	9,971	3,014	70	71,073	1	15,000	99,129
Panola	3,488	0	2,027	888	8,697	0	15,100
Rains	1,415	20	700	0	0	0	2,135
Rockwall	1,734	0	26	0	0	0	1,760
Rusk	3,307	75	549	66	104	40,000	44,101
Sabine	917	0	337	0	0	0	1,254
San Augustine	89	0	87	0	0	0	176
Shelby	3,004	27	1,635	2,242	0	0	6,908
Smith	3,976	63	453	402	91	0	4,985
Upshur	1,954	0	418	0	0	0	2,372
Van Zandt	3,385	0	1,100	471	1,026	0	5,982
Wood	4,870	235	2,360	64	17,344	7,500	32,373
TOTALS	**81,948**	**5,955**	**13,638**	**265,702**	**27,465**	**70,500**	**465,208**

1. "Most Likely" Projection Series
2. Low Oil Price without Conservation Series
3. "High" Projection Series

Projections are for the portion of the county that lies within the Sabine Basin.

Table C-14
Total Water Requirements - Year 2030
(Acre-Feet per Year)

County	Municipal [1]	Irrigation [1]	Livestock	Manufac. [2]	Mining	Power [3]	Total
Collin	1,231	0	38	0	0	0	1,269
Franklin	24	0	2	0	0	0	26
Gregg	23,048	0	230	22,576	37	3,000	48,891
Harrison	6,222	50	326	190,993	24	10,000	207,615
Hopkins	995	0	2,130	3	0	0	3,128
Hunt	9,933	271	896	509	75	0	11,684
Jasper	1,731	0	100	0	2	0	1,833
Kaufman	204	0	72	0	0	0	276
Newton	1,663	2,200	82	156	32	0	4,133
Orange	10,348	2,940	70	80,130	1	20,000	113,489
Panola	3,377	0	2,027	967	16,912	0	23,283
Rains	1,463	20	700	0	0	0	2,183
Rockwall	2,347	0	26	0	0	0	2,373
Rusk	3,431	75	549	72	89	45,000	49,216
Sabine	913	0	337	0	0	0	1,250
San Augustine	87	0	87	0	0	0	174
Shelby	3,053	27	1,635	2,656	0	0	7,371
Smith	3,846	63	453	465	32	0	4,859
Upshur	1,988	0	418	0	0	0	2,406
Van Zandt	3,234	0	1,100	570	1,014	0	5,918
Wood	4,702	235	2,360	73	17,107	7,500	31,977
TOTALS	**83,840**	**5,881**	**13,638**	**299,170**	**35,325**	**85,500**	**523,354**

1. "Most Likely" Projection Series
2. Low Oil Price without Conservation Series
3. "High" Projection Series

Projections are for the portion of the county that lies within the Sabine Basin.

Table C-15
Total Water Requirements - Year 2040
(Acre-Feet per Year)

County	Municipal [1]	Irrigation [1]	Livestock	Manufac. [2]	Mining	Power [3]	Total
Collin	1,994	0	38	0	0	0	2,032
Franklin	25	0	2	0	0	0	27
Gregg	23,769	0	230	24,931	29	3,000	51,959
Harrison	5,791	50	326	214,392	18	10,000	230,577
Hopkins	956	0	2,130	4	0	0	3,090
Hunt	9,826	271	896	533	77	0	11,603
Jasper	1,752	0	100	0	2	0	1,854
Kaufman	215	0	72	0	0	0	287
Newton	1,577	2,200	82	166	33	0	4,058
Orange	10,646	2,867	70	91,522	1	25,000	130,106
Panola	3,171	0	2,027	1,046	17,179	0	23,423
Rains	1,487	20	700	0	0	0	2,207
Rockwall	3,084	0	26	0	0	0	3,110
Rusk	3,490	75	549	77	60	45,000	49,251
Sabine	912	0	337	0	0	0	1,249
San Augustine	85	0	87	0	0	0	172
Shelby	3,071	27	1,635	3,099	0	0	7,832
Smith	3,680	63	453	526	18	0	4,740
Upshur	2,003	0	418	0	0	0	2,421
Van Zandt	2,995	0	1,100	648	1,025	0	5,768
Wood	4,264	235	2,360	82	16,107	7,500	30,548
TOTALS	**84,793**	**5,808**	**13,638**	**337,026**	**34,549**	**90,500**	**566,314**

1. "Most Likely" Projection Series
2. Low Oil Price without Conservation Series
3. "High" Projection Series

Projections are for the portion of the county that lies within the Sabine Basin.

Table C-15
Total Water Requirements - Year 2050
(Acre-Feet per Year)

County	Municipal [1]	Irrigation [1]	Livestock	Manufac. [2]	Mining	Power [3]	Total
Collin	2,600	0	38	0	0	0	2,638
Franklin	26	0	2	0	0	0	28
Gregg	24,849	0	230	27,351	27	4,000	56,457
Harrison	5,583	50	326	244,883	16	15,000	265,858
Hopkins	935	0	2,130	4	0	0	3,069
Hunt	10,011	271	896	559	79	0	11,816
Jasper	1,791	0	100	0	2	0	1,893
Kaufman	223	0	72	0	0	0	295
Newton	1,551	2,200	82	180	34	0	4,047
Orange	11,073	2,797	70	104,257	1	30,000	148,198
Panola	3,072	0	2,027	1,121	16,912	0	23,132
Rains	1,579	20	700	0	0	0	2,299
Rockwall	3,679	0	26	0	0	0	3,705
Rusk	3,589	75	549	84	7	45,000	49,304
Sabine	934	0	337	0	0	0	1,271
San Augustine	85	0	87	0	0	0	172
Shelby	3,158	27	1,635	3,560	0	0	8,380
Smith	3,469	63	453	587	6	0	4,578
Upshur	2,041	0	418	0	0	0	2,459
Van Zandt	2,869	0	1,100	729	1,055	0	5,753
Wood	3,843	235	2,360	93	4,641	15,000	26,172
TOTALS	**86,960**	**5,738**	**13,638**	**383,408**	**22,780**	**109,000**	**621,524**

1. "Most Likely" Projection Series
2. Low Oil Price without Conservation Series
3. "High" Projection Series

Projections are for the portion of the county that lies within the Sabine Basin.

Table C-16
Sabine River Basin Total Water Demand: Lower Basin
(Acre-Feet/Year)

1990

COUNTY	Municipal	Irrigation	Livestock	Manufact.	Mining	Power	Total
Jasper	1,548	0	128	0	0	0	1,676
Newton	1,675	2,200	97	114	27	0	4,113
Orange	8,523	3,340	50	49,169	1	5,574	66,657
Sabine	751	0	383	0	0	0	1,134
San Augustine	147	0	78	0	0	0	225
Shelby	2,794	28	1,650	1,204	0	0	5,676
Totals	15,438	5,568	2,386	50,487	28	5,574	79,481

2000

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact [2]	Mining	Power [3]	Total
Jasper	1,752	0	100	0	2	0	1,854
Newton	1,764	2,200	82	125	30	0	4,201
Orange	9,553	3,329	70	55,518	1	6,000	74,471
Sabine	927	0	337	0	0	0	1,264
San Augustine	98	0	87	0	0	0	185
Shelby	3,104	27	1,635	1,505	0	0	6,271
Totals	17,198	5,556	2,311	57,148	33	6,000	88,246

2010

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact [2]	Mining	Power [3]	Total
Jasper	1,737	0	100	0	2	0	1,839
Newton	1,753	2,200	82	135	30	0	4,200
Orange	9,828	3,014	70	62,835	1	10,000	85,748
Sabine	927	0	337	0	0	0	1,264
San Augustine	93	0	87	0	0	0	180
Shelby	3,052	27	1,635	1,856	0	0	6,570
Totals	17,390	5,241	2,311	64,826	33	10,000	99,801

2020

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact [2]	Mining	Power [3]	Total
Jasper	1,708	0	100	0	2	0	1,810
Newton	1,701	2,200	82	146	31	0	4,160
Orange	9,971	3,014	70	71,073	1	15,000	99,129
Sabine	917	0	337	0	0	0	1,254
San Augustine	89	0	87	0	0	0	176
Shelby	3,004	27	1,635	2,242	0	0	6,908
Totals	17,390	5,241	2,311	73,461	34	15,000	113,437

Projections are for the portion of the Sabine River basin.

Table C-16
Sabine River Basin Total Water Demand: Lower Basin
(Acre-Feet/Year)

2030

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact [2]	Mining	Power [3]	Total
Jasper	1,731	0	100	0	2	0	1,833
Newton	1,663	2,200	82	156	32	0	4,133
Orange	10,348	2,940	70	80,130	1	20,000	113,489
Sabine	913	0	337	0	0	0	1,250
San Augustine	87	0	87	0	0	0	174
Shelby	3,053	27	1,635	2,656	0	0	7,371
Totals	17,795	5,167	2,311	82,942	35	20,000	128,250

2040

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact [2]	Mining	Power [3]	Total
Jasper	1,752	0	100	0	2	0	1,854
Newton	1,577	2,200	82	166	33	0	4,058
Orange	10,646	2,867	70	91,522	1	25,000	130,106
Sabine	912	0	337	0	0	0	1,249
San Augustine	85	0	87	0	0	0	172
Shelby	3,071	27	1,635	3,099	0	0	7,832
Totals	18,043	5,094	2,311	94,787	36	25,000	145,271

2050

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact [2]	Mining	Power [3]	Total
Jasper	1,791	0	100	0	2	0	1,893
Newton	1,551	2,200	82	180	34	0	4,047
Orange	11,073	2,797	70	104,257	1	30,000	148,198
Sabine	934	0	337	0	0	0	1,271
San Augustine	85	0	87	0	0	0	172
Shelby	3,158	27	1,635	3,560	0	0	8,380
Totals	18,592	5,024	2,311	107,997	37	30,000	163,961

1. "Most Likely" Projection Series

2. "Low Oil Prices without Conservation" Series

3. "High" Projection Series

Projections are for the portion of the Sabine River basin.

Table C-17
Sabine River Basin Total Water Demand: Upper Basin
(Acre-Feet/Year)

1990

COUNTY	Municipal	Irrigation	Livestock	Manufact.	Mining	Power	Total
Collin	320	0	37	0	0	0	357
Franklin	13	0	0	0	0	0	13
Gregg	17,469	0	200	14,634	124	465	32,892
Harrison	5,287	50	420	74,107	170	4,869	84,903
Hopkins	828	0	1,797	2	0	0	2,627
Hunt	9,337	271	817	409	0	834	11,668
Kaufman	109	0	72	0	0	0	181
Panola	3,010	0	2,145	641	3,208	0	9,004
Rains	1,096	20	790	0	0	0	1,906
Rockwall	482	0	34	0	0	0	516
Rusk	2,743	75	563	48	732	28,320	32,481
Smith	3,348	63	495	229	555	0	4,690
Upshur	1,700	0	287	0	0	0	1,987
Van Zandt	3,017	0	1,023	223	785	0	5,048
Wood	4,032	236	1,673	41	3,162	0	9,144
Totals	52,791	715	10,353	90,334	8,736	34,488	197,417

2000

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact. [2]	Mining	Power [3]	Total
Collin	485	0	38	0	0	0	523
Franklin	18	0	2	0	0	0	20
Gregg	21,438	0	230	16,431	96	2,500	40,695
Harrison	6,338	50	326	115,543	186	5,000	127,443
Hopkins	1,070	0	2,130	2	0	0	3,202
Hunt	9,762	271	896	434	70	800	12,233
Kaufman	153	0	72	0	0	0	225
Panola	3,651	0	2,027	720	3,245	0	9,643
Rains	1,317	20	700	0	0	0	2,037
Rockwall	1,004	0	26	0	0	0	1,030
Rusk	3,250	75	549	54	563	30,000	34,491
Smith	3,920	63	453	280	425	0	5,141
Upshur	1,895	0	418	0	0	0	2,313
Van Zandt	3,368	0	1,100	296	1,233	0	5,997
Wood	4,864	235	2,360	48	2,102	0	9,609
Totals	62,533	714	11,327	133,808	7,920	38,300	254,602

Projections are for that portion of the county within the Sabine River basin.

Table C-17
Sabine River Basin Total Water Demand: Upper Basin
(Acre-Feet/Year)

2010

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact. [2]	Mining	Power [3]	Total
Collin	377	0	38	0	0	0	415
Franklin	20	0	2	0	0	0	22
Gregg	21,761	0	230	18,276	67	3,000	43,334
Harrison	6,435	50	326	150,737	89	5,000	162,637
Hopkins	1,053	0	2,130	3	0	0	3,186
Hunt	9,879	271	896	461	71	0	11,578
Kaufman	169	0	72	0	0	0	241
Panola	3,607	0	2,027	804	2,645	0	9,083
Rains	1,377	20	700	0	0	0	2,097
Rockwall	1,280	0	26	0	0	0	1,306
Rusk	3,252	75	549	60	314	35,000	39,250
Smith	4,042	63	453	340	178	0	5,076
Upshur	1,930	0	418	0	0	0	2,348
Van Zandt	3,421	0	1,100	385	1,073	0	5,979
Wood	4,934	235	2,360	55	17,584	7,500	32,668
Totals	63,537	714	11,327	171,121	22,021	50,500	319,220

2020

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact. [2]	Mining	Power [3]	Total
Collin	716	0	38	0	0	0	754
Franklin	21	0	2	0	0	0	23
Gregg	22,248	0	230	20,363	46	3,000	45,887
Harrison	6,407	50	326	169,499	50	5,000	181,332
Hopkins	1,022	0	2,130	3	0	0	3,155
Hunt	9,829	271	896	485	73	0	11,554
Kaufman	186	0	72	0	0	0	258
Panola	3,488	0	2,027	888	8,697	0	15,100
Rains	1,415	20	700	0	0	0	2,135
Rockwall	1,734	0	26	0	0	0	1,760
Rusk	3,307	75	549	66	104	40,000	44,101
Smith	3,976	63	453	402	91	0	4,985
Upshur	1,954	0	418	0	0	0	2,372
Van Zandt	3,385	0	1,100	471	1,026	0	5,982
Wood	4,870	235	2,360	64	17,344	7,500	32,373
Totals	64,558	714	11,327	192,241	27,431	55,500	351,771

Projections are for that portion of the county within the Sabine River basin.

Table C-17
Sabine River Basin Total Water Demand: Upper Basin
(Acre-Feet/Year)

2030

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact. [2]	Mining	Power [3]	Total
Collin	1,231	0	38	0	0	0	1,269
Franklin	24	0	2	0	0	0	26
Gregg	23,048	0	230	22,576	37	3,000	48,891
Harrison	6,222	50	326	190,993	24	10,000	207,615
Hopkins	995	0	2,130	3	0	0	3,128
Hunt	9,933	271	896	509	75	0	11,684
Kaufman	204	0	72	0	0	0	276
Panola	3,377	0	2,027	967	16,912	0	23,283
Rains	1,463	20	700	0	0	0	2,183
Rockwall	2,347	0	26	0	0	0	2,373
Rusk	3,431	75	549	72	89	45,000	49,216
Smith	3,846	63	453	465	32	0	4,859
Upshur	1,988	0	418	0	0	0	2,406
Van Zandt	3,234	0	1,100	570	1,014	0	5,918
Wood	4,702	235	2,360	73	17,107	7,500	31,977
Totals	66,045	714	11,327	216,228	35,290	65,500	395,104

2040

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact. [2]	Mining	Power [3]	Total
Collin	1,994	0	38	0	0	0	2,032
Franklin	25	0	2	0	0	0	27
Gregg	23,769	0	230	24,931	29	3,000	51,959
Harrison	5,791	50	326	214,392	18	10,000	230,577
Hopkins	956	0	2,130	4	0	0	3,090
Hunt	9,826	271	896	533	77	0	11,603
Kaufman	215	0	72	0	0	0	287
Panola	3,171	0	2,027	1,046	17,179	0	23,423
Rains	1,487	20	700	0	0	0	2,207
Rockwall	3,084	0	26	0	0	0	3,110
Rusk	3,490	75	549	77	60	45,000	49,251
Smith	3,680	63	453	526	18	0	4,740
Upshur	2,003	0	418	0	0	0	2,421
Van Zandt	2,995	0	1,100	648	1,025	0	5,768
Wood	4,264	235	2,360	82	16,107	7,500	30,548
Totals	66,750	714	11,327	242,239	34,513	65,500	421,043

Projections are for that portion of the county within the Sabine River basin.

Table C-17
Sabine River Basin Total Water Demand: Upper Basin
(Acre-Feet/Year)

2050

COUNTY	Municipal [1]	Irrigation [1]	Livestock	Manufact. [2]	Mining	Power [3]	Total
Collin	2,600	0	38	0	0	0	2,638
Franklin	26	0	2	0	0	0	28
Gregg	24,849	0	230	27,351	27	4,000	56,457
Harrison	5,583	50	326	244,883	16	15,000	265,858
Hopkins	935	0	2,130	4	0	0	3,069
Hunt	10,011	271	896	559	79	0	11,816
Kaufman	223	0	72	0	0	0	295
Panola	3,072	0	2,027	1,121	16,912	0	23,132
Rains	1,579	20	700	0	0	0	2,299
Rockwall	3,679	0	26	0	0	0	3,705
Rusk	3,589	75	549	84	7	45,000	49,304
Smith	3,469	63	453	587	6	0	4,578
Upshur	2,041	0	418	0	0	0	2,459
Van Zandt	2,869	0	1,100	729	1,055	0	5,753
Wood	3,843	235	2,360	93	4,641	15,000	26,172
Totals	68,368	714	11,327	275,411	22,743	79,000	457,563

1. "Most Likely" Projection Series

2. "Low Oil Prices without Conservation" Projection Series

3. "High" Projection Series

Projections are for that portion of the county within the Sabine River basin.

Table C-18
Sabine River Upper Basin: Municipal Water Demand for Cities
Upper Basin Cities "Most Likely" Migration Rate Scenario (Acre-Feet/Year)[1]

City	1990	2000	2010	2020	2030	2040	2050
Big Sandy	180	220	225	230	236	239	245
Caddo Mills	85	165	181	193	200	201	205
Canton	605	664	681	679	658	612	585
Carthage	1,235	1,629	1,615	1,564	1,527	1,447	1,393
Edgewood	184	200	202	201	191	176	169
Emory	313	194	188	181	179	178	179
Gladewater	1,105	1,194	1,230	1,265	1,326	1,374	1,442
Grand Saline	465	563	578	576	558	522	500
Greenville	5,982	5,894	5,842	5,670	5,710	5,664	5,678
Hallsville	301	418	489	536	561	557	558
Hawkins	229	249	253	250	242	219	197
Henderson	227	246	239	224	212	206	206
Kilgore	2,211	2,731	2,794	2,854	2,940	3,043	3,189
Liberty City	198	410	454	481	506	520	537
Lindale	229	261	267	267	271	274	278
Longview	12,272	15,859	16,279	16,848	17,544	18,221	19,165
Marshall	3,112	3,894	3,970	4,012	3,952	3,671	3,502
Mineola	816	871	892	884	857	779	696
Overton	327	423	413	385	369	361	358
Quinlan	175	221	255	284	301	301	312
Quitman	367	395	408	408	394	363	324
Royse City	313	593	803	1,079	1,450	1,889	2,463
Tatum	160	184	180	169	162	155	152
Tyler	2	2	2	2	2	2	2
Van	22	24	24	25	24	22	21
White Oak	767	824	847	873	912	951	1,011
Wills Point	312	281	288	285	273	255	245
Winnsboro	358	462	476	477	464	431	386

Municipal water demands includes only that portion of the city that lies within the Sabine Basin.

Table C-19
Sabine River Upper Basin: Municipal Water Demand for Cities
Lower Basin Cities "Most Likely" Migration Rate Scenario (Acre-Feet/Year)[1]

City	1990	2000	2010	2020	2030	2040	2050
Bessmay-Buna	321	374	368	356	353	355	360
Bridge City	617	812	849	885	939	950	977
Center	705	938	967	981	1,017	1,044	1,087
Hemphill	279	339	342	341	356	371	391
Kirbyville	342	470	466	457	456	461	458
Newton	356	467	506	541	578	590	607
Orange	4,000	4,438	4,621	4,846	5,157	5,262	5,431
Pinehurst	385	513	522	522	536	556	581
Tenaha	148	153	149	146	146	147	151
Timpson	189	299	297	294	301	306	315
Vidor	470	493	484	474	469	465	469
West Orange	509	649	675	683	707	742	793

Municipal water demands includes only that portion of the city that lies within the Sabine Basin.

APPENDIX D

HYDROLOGIC DATA

Lake Tawakoni

LAKE TAWAKONI OPERATION w/ new TWDB Area Capacity data ADL 8/7/97

SUMMARY OF RUNOFF DATA
(VALUES IN ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	0.	4500.	5250.	47830.	21550.	58460.	28160.	1400.	12190.	820.	33350.	133840.	347350.
1941	29860.	31290.	60800.	26790.	107890.	148580.	16730.	10270.	3660.	4380.	10500.	29240.	479990.
1942	3720.	19070.	13690.	258910.	208870.	49970.	10.	5080.	6910.	4890.	10740.	18660.	600520.
1943	21070.	3240.	15600.	41060.	19590.	194300.	91530.	0.	0.	11620.	210.	5550.	403770.
1944	27360.	51670.	108630.	27830.	227790.	49990.	1870.	0.	1390.	380.	7650.	54050.	558610.
1945	72170.	36470.	180080.	430280.	9550.	65240.	208620.	2530.	510.	35050.	13300.	7320.	1061120.
1946	72220.	136390.	43460.	26050.	63340.	199260.	1880.	2120.	6360.	1760.	222610.	48720.	824170.
1947	38590.	4640.	20760.	56380.	18310.	11420.	6640.	560.	13720.	200.	17890.	77170.	266280.
1948	99570.	52300.	81340.	6190.	93760.	2320.	3090.	980.	0.	0.	750.	1390.	341690.
1949	13330.	73860.	96140.	17540.	30900.	19610.	10680.	5060.	850.	28340.	34390.	1830.	332530.
1950	68650.	224020.	20940.	24480.	127400.	30690.	4800.	27910.	15740.	270.	700.	360.	545960.
1951	4250.	26020.	21510.	1810.	15120.	55950.	19000.	0.	0.	100.	390.	760.	144910.
1952	1890.	3210.	9940.	55810.	112910.	30860.	100.	0.	0.	0.	590.	25520.	240830.
1953	38850.	2730.	21580.	19160.	259900.	0.	9690.	20.	1100.	0.	2820.	17650.	373500.
1954	48880.	12270.	1260.	14560.	22980.	4550.	0.	0.	0.	1470.	54140.	2310.	162420.
1955	3100.	23920.	27990.	31170.	2470.	830.	580.	1610.	1790.	0.	0.	140.	93600.
1956	580.	13620.	700.	290.	31350.	0.	0.	0.	0.	0.	3390.	670.	50600.
1957	1570.	17980.	16840.	169380.	440460.	89180.	520.	70.	70.	69020.	122910.	13310.	941310.
1958	49440.	4390.	47590.	40660.	334220.	11610.	21420.	0.	4900.	2590.	2660.	2070.	521550.
1959	1440.	37510.	17610.	45680.	35240.	3330.	7110.	13490.	220.	98000.	24890.	101660.	386180.
1960	67540.	39120.	9240.	22830.	18070.	5230.	24100.	4900.	4330.	19290.	920.	174900.	390470.
1961	62580.	36890.	84990.	3070.	5740.	20430.	1910.	1060.	5140.	1760.	27480.	50320.	301370.
1962	13240.	17720.	16770.	83270.	17220.	64750.	17560.	3580.	87380.	29260.	62660.	4240.	417650.
1963	7160.	1320.	5160.	70210.	63210.	1820.	27370.	1920.	1600.	1880.	1070.	1150.	183870.
1964	1290.	1340.	25270.	22810.	49830.	14230.	870.	2530.	56090.	1300.	51210.	2380.	229150.
1965	32690.	151730.	13750.	3190.	211890.	3570.	2450.	2150.	7190.	1440.	2720.	1590.	434360.
1966	2750.	36300.	7280.	316800.	60970.	3520.	3000.	5750.	6890.	11440.	1400.	1780.	457880.
1967	1510.	1210.	2750.	48330.	138990.	19570.	2670.	1950.	41170.	106190.	20560.	55560.	440460.
1968	69770.	24090.	152650.	49510.	192120.	39150.	35310.	3730.	9520.	4400.	13740.	24530.	618520.
1969	66300.	68110.	99010.	25360.	227660.	1930.	1910.	1900.	1390.	10170.	1480.	46910.	552130.

LAKE TAWAKONI OPERATION w/ new TWDB Area Capacity data ADL 8/7/97

SUMMARY OF RUNOFF DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	6860.	132190.	128850.	80840.	22790.	12810.	1760.	4840.	46730.	75210.	1640.	1430.	515950.
1971	240.	7830.	2610.	0.	330.	0.	1490.	18320.	4480.	238560.	970.	306470.	581300.
1972	10110.	980.	590.	3570.	460.	460.	220.	290.	360.	4320.	17640.	8050.	47050.
1973	47070.	58020.	49590.	143760.	20140.	147470.	13450.	2120.	116930.	244210.	72150.	52390.	967300.
1974	124650.	5740.	18530.	113230.	24740.	107210.	2280.	32680.	176980.	59300.	126810.	41600.	833750.
1975	27920.	152290.	25090.	43780.	100530.	71030.	12540.	1860.	1890.	1930.	1650.	1690.	442200.
1976	1730.	1690.	15170.	117030.	73230.	9770.	41890.	2220.	2310.	19020.	2150.	54650.	340860.
1977	22160.	103940.	286780.	107750.	9750.	2970.	2030.	30650.	2530.	1430.	14590.	3960.	588540.
1978	10410.	70950.	29920.	3970.	9160.	30300.	3440.	2710.	2230.	1900.	3150.	15190.	183330.
1979	125330.	63450.	207470.	17730.	341020.	64230.	5810.	8780.	7660.	2170.	1820.	41010.	886480.
1980	109000.	41660.	1890.	11230.	44010.	2880.	2550.	2570.	13730.	3910.	1680.	33460.	268570.
AVG.	34313.	43797.	48660.	64150.	93060.	40231.	15538.	5064.	16242.	26780.	24180.	35743.	447758.

LAKE TAWAKONI OPERATION w/ new TWDB Area Capacity data ADL 8/7/97

SUMMARY OF NET EVAPORATION DATA
(VALUES IN FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	.07	.00	.21	.01	.08	.13	.35	.49	.50	.29	-.27	-.09	1.77
1941	.08	-.05	.05	-.06	.17	-.12	.34	.40	.37	.04	.14	.01	1.37
1942	.10	.13	.18	-.39	.14	.16	.54	.34	.22	.17	.16	-.06	1.69
1943	.09	.22	.03	.24	-.04	.25	.57	.72	.31	.16	.23	-.05	2.73
1944	-.06	-.14	.03	.13	-.24	.44	.50	.45	.43	.35	-.06	-.15	1.68
1945	.03	-.18	-.46	.08	.27	.07	.14	.37	.37	.09	.19	.12	1.09
1946	-.14	-.02	.04	.08	-.22	.32	.56	.28	.30	.29	-.33	.04	1.20
1947	-.01	.15	.02	-.04	.16	.27	.64	.43	.40	.31	.06	-.14	2.25
1948	-.05	-.10	.05	.26	-.07	.44	.51	.66	.60	.32	.19	.08	2.89
1949	-.35	-.11	.03	-.02	.16	.28	.37	.42	.37	-.25	.29	-.01	1.18
1950	-.19	-.23	.22	-.03	-.12	.32	.10	.39	.07	.33	.31	.22	1.39
1951	.06	-.12	.21	.21	.21	.03	.50	.70	.07	.23	.16	.09	2.35
1952	.11	.04	.04	-.19	.05	.47	.50	.83	.67	.59	-.16	-.12	2.83
1953	.10	.06	-.03	-.10	.00	.60	.22	.41	.38	.25	.04	-.02	1.91
1954	-.08	.20	.24	.07	-.08	.47	.85	.89	.63	-.04	.15	.14	3.44
1955	.07	-.08	.06	.06	.12	.38	.47	.17	.19	.45	.37	.16	2.42
1956	.05	-.11	.29	.20	.21	.45	.86	.84	.71	.37	.14	.13	4.14
1957	.05	-.01	-.08	-.62	-.25	.17	.56	.34	.17	.03	-.19	.12	.29
1958	.00	.11	-.02	-.18	.09	.29	.40	.40	.00	.24	.15	.14	1.62
1959	.21	-.02	.18	.06	-.01	.01	.13	.40	.32	-.02	.27	-.12	1.41
1960	-.06	.02	.12	.23	.27	.19	.30	.30	.30	.11	.17	-.36	1.59
1961	-.08	-.03	-.05	.28	.19	-.01	.34	.50	.26	.30	-.05	.00	1.65
1962	.01	.03	.14	-.04	.34	-.05	.33	.54	-.02	.06	.02	.12	1.48
1963	.11	.15	.11	-.11	.11	.34	.43	.66	.45	.58	.26	.08	3.17
1964	.13	.05	-.02	.03	.07	.37	.74	.45	.03	.41	.02	.12	2.40
1965	.04	-.20	.06	.23	-.32	.25	.63	.55	.14	.29	.07	.04	1.78
1966	.00	-.04	.13	-.20	.09	.35	.41	.22	.03	.28	.24	.10	1.61
1967	.12	.08	.16	-.10	-.06	.39	.30	.43	.03	.13	.13	.03	1.64
1968	.01	.04	-.02	.00	-.02	.22	.30	.54	.19	.25	.14	.11	1.76
1969	.00	-.02	.02	-.02	-.22	.36	.66	.52	.28	.28	.19	.02	2.07

LAKE TAWAKONI OPERATION w/ new TWDB Area Capacity data ADL 8/7/97

SUMMARY OF NET EVAPORATION DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	.05	-.10	-.03	-.17	.05	.41	.60	.57	.15	.10	.23	.06	1.92
1971	.18	.05	.27	.25	.25	.56	.45	.26	.32	.07	.16	-.12	2.70
1972	.01	.18	.26	.21	.34	.36	.56	.53	.28	.16	.00	.03	2.92
1973	-.08	-.02	.05	-.03	.27	.17	.33	.59	.10	.08	.07	.12	1.65
1974	-.08	.15	.22	.22	.22	.31	.65	.27	.00	.12	.00	-.01	2.07
1975	.02	-.04	.03	.10	.09	.28	.43	.55	.44	.42	.21	.06	2.59
1976	.18	.21	.10	.06	.12	.28	.26	.55	.12	.09	.16	.04	2.17
1977	-.08	.04	.09	.12	.32	.43	.66	.43	.44	.39	.07	.20	3.11
1978	-.05	-.07	.12	.26	.19	.47	.77	.59	.37	.49	-.03	.05	3.16
1979	-.09	-.05	.06	.13	.14	.40	.39	.38	.33	.36	.21	.01	2.27
1980	-.04	.07	.18	.18	.19	.49	.83	.80	.43	.33	.16	.07	3.69
AVG.	.01	.01	.08	.03	.08	.29	.48	.49	.29	.23	.10	.03	2.12

LAKE TAWAKONI OPERATION w/ new TWDB Area Capacity data ADL 8/7/97

THERE ARE 63 AREA/CAPACITY/ELEVATION POINTS.

AREA (ACRES)	CAPACITY (ACRE-FEET)	ELEVATION (FEET)
0.	0.	373.0
1.	1.	374.0
2.	2.	375.0
3.	5.	376.0
4.	9.	377.0
6.	14.	378.0
8.	21.	379.0
11.	31.	380.0
14.	43.	381.0
22.	61.	382.0
50.	94.	383.0
169.	197.	384.0
434.	476.	385.0
797.	1097.	386.0
1191.	2075.	387.0
1669.	3503.	388.0
2336.	5486.	389.0
2941.	8138.	390.0
3522.	11364.	391.0
4089.	15170.	392.0
4654.	19539.	393.0
5336.	24545.	394.0
5911.	30174.	395.0
6453.	36360.	396.0
6987.	43073.	397.0
7502.	50310.	398.0
8159.	58133.	399.0
8862.	66627.	400.0
9542.	75839.	401.0
11025.	96387.	403.0
11621.	107736.	404.0
12125.	119608.	405.0
12640.	131983.	406.0
13199.	144901.	407.0
13758.	158385.	408.0
14324.	172430.	409.0
14940.	187050.	410.0
15658.	202338.	411.0
16483.	218407.	412.0
17279.	235291.	413.0
18034.	252947.	414.0
18784.	271359.	415.0
19500.	290508.	416.0
20181.	310359.	417.0
20823.	330855.	418.0
21427.	350985.	419.0
22000.	373691.	420.0
22650.	396006.	421.0
24104.	442733.	423.0
24913.	467244.	424.0
25785.	492587.	425.0
26669.	518811.	426.0
27472.	545886.	427.0
28265.	573743.	428.0
29164.	602452.	429.0
30280.	632162.	430.0
32176.	694633.	432.0
33140.	727299.	433.0
34132.	760930.	434.0
35154.	795619.	435.0
36244.	831809.	436.0
37334.	869088.	437.0
37879.	888137.	437.5

Lake Fork Reservoir

LAKE FORK OPERATION w/ 2000 Area Capacity data sfk 10/29/98
1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF RUNOFF DATA
(VALUES IN ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	0.	379.	2717.	26615.	26207.	36170.	18083.	1676.	4383.	164.	16859.	76281.	209534.
1941	14026.	25453.	45808.	28802.	41090.	52712.	11903.	3773.	1005.	235.	3353.	8474.	236634.
1942	4230.	9200.	13070.	131400.	106820.	8800.	140.	1560.	1710.	600.	1800.	13950.	293280.
1943	10300.	3000.	6390.	14980.	18400.	111520.	52540.	0.	0.	2220.	0.	1890.	221240.
1944	11350.	29150.	44630.	23500.	134060.	23420.	1630.	170.	3170.	20.	5420.	28260.	304780.
1945	44610.	26110.	180550.	297930.	11140.	33000.	116230.	1530.	120.	43370.	11250.	6400.	772240.
1946	85750.	102030.	49490.	14590.	78420.	131390.	970.	1350.	1480.	570.	113220.	33540.	612800.
1947	33615.	5031.	19907.	50694.	23405.	4478.	2099.	476.	1409.	0.	8752.	51073.	200939.
1948	60837.	54009.	60485.	11583.	83454.	917.	3621.	132.	0.	0.	396.	698.	276132.
1949	16002.	48252.	59660.	32633.	18498.	3137.	4731.	229.	809.	41903.	41392.	6040.	273286.
1950	57480.	153230.	31450.	14490.	87770.	28200.	17850.	23100.	7180.	1000.	440.	690.	422880.
1951	5487.	31750.	26375.	2361.	6153.	9255.	1543.	0.	0.	0.	272.	1080.	84276.
1952	6090.	6158.	13905.	93359.	66253.	6044.	73.	0.	0.	0.	890.	18236.	211008.
1953	31580.	6790.	14960.	31870.	164740.	230.	7690.	760.	10040.	10.	850.	14790.	284310.
1954	42816.	20927.	2682.	8259.	14458.	1052.	0.	0.	0.	1194.	27738.	1674.	120800.
1955	4435.	10697.	18027.	24907.	1662.	515.	0.	1356.	2563.	136.	0.	0.	64298.
1956	256.	13065.	886.	777.	12045.	104.	0.	0.	0.	0.	1222.	166.	28521.
1957	1610.	10600.	10200.	104410.	261220.	61100.	90.	170.	3500.	34430.	88380.	16140.	591850.
1958	49000.	6030.	40500.	50340.	249740.	14580.	4430.	0.	7020.	1660.	5950.	4040.	433290.
1959	2030.	41893.	39766.	34516.	23619.	2009.	5599.	3863.	1909.	23625.	6530.	86545.	271904.
1960	89837.	32754.	24328.	2525.	4448.	6659.	4523.	159.	4133.	3275.	7299.	91177.	271117.
1961	48501.	45871.	50788.	22209.	3485.	26418.	5947.	508.	2039.	109.	9921.	28759.	244555.
1962	17521.	22613.	25009.	27622.	22995.	6586.	6209.	2231.	24045.	1908.	16524.	16683.	189946.
1963	13536.	1776.	5411.	15512.	31204.	6773.	358.	1.	142.	0.	0.	0.	74713.
1964	133.	1067.	3111.	14896.	954.	693.	0.	15.	105.	195.	477.	90.	21736.
1965	1280.	42372.	7260.	1548.	93856.	16973.	89.	0.	1045.	8.	165.	45.	164641.
1966	1750.	28490.	2370.	131140.	119740.	1230.	690.	2470.	12160.	4650.	330.	5190.	310210.
1967	3181.	3324.	3349.	24381.	45937.	23866.	1117.	0.	1213.	11105.	41828.	44684.	203985.
1968	49000.	29930.	71670.	37750.	140500.	24240.	3140.	240.	6980.	890.	9040.	33500.	406880.
1969	6880.	73500.	89080.	38170.	120230.	1380.	0.	0.	0.	120.	2110.	5770.	337240.

LAKE FORK OPERATION w/ 2000 Area Capacity data sfk 10/29/98
1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF RUNOFF DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	15969.	30987.	91009.	38090.	8996.	17305.	759.	689.	4762.	19261.	3530.	1336.	232693.
1971	1630.	12010.	6570.	1210.	9240.	110.	2960.	2650.	1880.	29220.	3750.	174010.	245240.
1972	43995.	8388.	4410.	1453.	643.	10647.	167.	0.	0.	3547.	19403.	21095.	113748.
1973	29660.	35570.	96870.	120070.	9830.	50830.	1870.	50.	7600.	25970.	75560.	48790.	502670.
1974	83370.	11700.	13270.	56250.	10890.	40750.	210.	730.	37580.	6410.	160190.	66780.	488130.
1975	22120.	108850.	47580.	47280.	62050.	39840.	3640.	1360.	720.	600.	400.	770.	335210.
1976	457.	915.	7180.	75612.	76966.	4496.	18933.	212.	965.	1510.	1451.	10355.	199052.
1977	10627.	58220.	72551.	52030.	2478.	5696.	2621.	1280.	272.	0.	1665.	500.	207940.
1978	3281.	10920.	28417.	3364.	10857.	629.	0.	0.	0.	0.	1538.	311.	59317.
1979	18222.	20299.	35150.	52153.	92927.	8906.	1490.	27041.	2760.	2064.	4003.	56660.	321675.
1980	71759.	38599.	18467.	59621.	87143.	7633.	217.	0.	806.	1146.	821.	9022.	295234.
AVG.	24737.	29803.	33788.	44412.	58159.	20251.	7419.	1946.	3793.	6418.	16944.	24036.	271706.

LAKE FORK OPERATION w/ 2000 Area Capacity data sfk 10/29/98
1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF NET EVAPORATION DATA
(VALUES IN FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	.06	-.02	.15	.03	.05	.10	.33	.36	.42	.23	-.33	-.13	1.25
1941	.04	-.05	.02	-.08	.17	-.14	.26	.37	.26	.01	.09	-.03	.92
1942	.09	.11	.13	-.35	.15	.12	.47	.26	.20	.21	.13	-.12	1.40
1943	.04	.21	.02	.19	-.08	.22	.47	.61	.26	.06	.17	-.07	2.10
1944	-.09	-.17	-.06	.06	-.34	.35	.46	.29	.36	.36	-.14	-.24	.84
1945	-.01	-.16	-.59	.07	.23	.02	.10	.32	.31	.02	.17	.09	.57
1946	-.23	-.05	-.03	.04	-.31	.25	.49	.15	.29	.24	-.36	.03	.51
1947	-.05	.12	-.06	-.10	.08	.26	.54	.38	.29	.29	.00	-.16	1.59
1948	-.10	-.12	.02	.15	-.10	.42	.53	.59	.56	.27	.10	.01	2.33
1949	-.43	-.13	.01	-.11	.19	.26	.24	.32	.32	-.37	.26	-.06	.50
1950	-.20	-.29	.16	-.08	-.20	.29	.13	.39	-.03	.27	.26	.20	.90
1951	.01	-.15	.15	.16	.21	.06	.38	.61	-.07	.19	.12	-.02	1.65
1952	.05	-.03	-.02	-.22	.02	.37	.40	.77	.65	.56	-.18	-.16	2.21
1953	.05	.03	-.09	-.14	-.10	.47	.08	.33	.31	.29	.03	-.10	1.16
1954	-.11	.15	.18	.03	-.16	.44	.77	.83	.61	-.14	.11	.08	2.79
1955	.02	-.11	-.03	-.01	.07	.36	.33	-.02	.12	.39	.33	.14	1.59
1956	.02	-.16	.23	.15	.13	.36	.75	.66	.62	.34	.13	.14	3.37
1957	.02	-.05	-.10	-.63	-.21	.05	.48	.34	.14	-.08	-.21	.10	-.15
1958	-.02	.08	.00	-.22	.06	.13	.27	.29	-.10	.19	.09	.15	.92
1959	.19	-.06	.10	-.02	-.15	-.03	.04	.29	.25	.07	.24	-.16	.76
1960	-.08	-.01	.08	.17	.24	.06	.24	.29	.21	.09	.13	-.38	1.04
1961	-.09	-.05	-.08	.23	.17	-.10	.23	.39	.21	.27	-.10	-.06	1.02
1962	-.07	-.04	.09	-.06	.27	-.10	.30	.46	.00	.00	.00	.10	.95
1963	.09	.13	.04	-.14	.09	.27	.31	.59	.39	.54	.22	.06	2.59
1964	.13	-.01	-.04	-.05	-.04	.29	.62	.37	.08	.38	.05	.08	1.86
1965	.01	-.25	.00	.18	-.41	.21	.52	.47	.08	.26	.09	.00	1.16
1966	-.03	-.05	.08	-.22	-.03	.23	.26	.19	.07	.23	.17	.10	1.00
1967	.09	.05	.07	-.22	-.18	.35	.19	.27	.06	.08	.15	.04	.95
1968	.08	.07	-.01	-.02	-.11	.19	.16	.49	.15	.25	.20	.10	1.55
1969	-.04	-.04	.01	-.16	-.33	.30	.52	.53	.28	.33	.17	.01	1.58

LAKE FORK OPERATION w/ 2000 Area Capacity data sfk 10/29/98
1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF NET EVAPORATION DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	.03	-.10	-.06	-.23	.01	.27	.53	.56	.24	.10	.14	-.05	1.44
1971	.18	.02	.17	.22	.22	.51	.38	.26	.30	.06	.10	-.14	2.28
1972	-.02	.17	.18	.19	.32	.27	.43	.47	.24	.14	-.01	.02	2.40
1973	-.08	-.02	.01	-.03	.22	.14	.32	.54	.08	.05	.02	.08	1.33
1974	-.12	.11	.17	.16	.18	.24	.56	.23	-.05	.12	-.02	-.03	1.55
1975	.01	-.05	.03	.08	.10	.22	.46	.53	.44	.35	.19	.05	2.41
1976	.12	.15	.05	.07	.11	.24	.23	.51	.12	.07	.14	.02	1.83
1977	-.08	.01	.08	.11	.31	.40	.59	.37	.37	.36	.03	.15	2.70
1978	-.08	-.07	.09	.24	.20	.42	.68	.58	.36	.44	-.04	.02	2.84
1979	-.11	-.04	.06	.13	.17	.37	.35	.40	.29	.34	.17	.01	2.14
1980	-.07	.06	.13	.14	.16	.38	.75	.70	.38	.26	.12	.09	3.10
AVG.	-.02	-.02	.03	-.01	.03	.23	.39	.42	.25	.20	.07	.00	1.57

LAKE FORK OPERATION w/ 2000 Area Capacity data sfk 10/29/98
1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

THERE ARE 15 AREA/CAPACITY/ELEVATION POINTS.

AREA (ACRES)	CAPACITY (ACRE-FEET)	ELEVATION (FEET)
0.	0.	335.0
16.	39.	340.0
656.	1717.	345.0
1706.	7621.	350.0
3176.	19824.	355.0
4776.	39702.	360.0
6456.	67780.	365.0
8316.	104709.	370.0
10906.	152762.	375.0
13886.	214740.	380.0
16056.	289593.	385.0
18416.	375772.	390.0
21706.	476075.	395.0
25306.	593603.	400.0
27626.	673000.	403.0

Wood County Lakes

Lake Winnsboro
Lake Hawkins
Lake Quitman
Lake Holbrook

LAKE QUITMAN Firm yield calculations
SRA96425 ADK 9/22/98

SUMMARY OF RUNOFF DATA
(VALUES IN ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	1.	27.	176.	1705.	1680.	2317.	1160.	110.	283.	13.	1081.	4882.	13435.
1941	899.	1629.	2931.	1844.	2630.	3373.	764.	245.	67.	18.	217.	544.	15161.
1942	273.	591.	837.	8400.	6829.	566.	12.	103.	111.	41.	118.	894.	18775.
1943	666.	196.	413.	966.	1187.	7176.	3383.	0.	2.	146.	2.	124.	14261.
1944	728.	1865.	2854.	1504.	8569.	1499.	107.	14.	205.	4.	349.	1808.	19506.
1945	2836.	1661.	11471.	18926.	711.	2099.	7386.	100.	10.	2757.	717.	409.	49083.
1946	5456.	6491.	3150.	930.	4991.	8359.	65.	89.	97.	39.	7203.	2136.	39006.
1947	2178.	328.	1291.	3283.	1518.	293.	139.	34.	94.	2.	569.	3308.	13037.
1948	3932.	3491.	3909.	751.	5393.	62.	237.	12.	0.	0.	28.	48.	17863.
1949	1030.	3100.	3832.	2097.	1191.	204.	307.	18.	55.	2692.	2659.	390.	17575.
1950	3680.	9806.	2014.	930.	5619.	1807.	1145.	1481.	462.	67.	30.	46.	27087.
1951	374.	2150.	1786.	162.	420.	629.	108.	0.	0.	0.	21.	76.	5726.
1952	400.	405.	911.	6101.	4331.	398.	8.	0.	0.	0.	60.	1194.	13808.
1953	2040.	441.	968.	2059.	10634.	18.	500.	53.	650.	4.	57.	957.	18381.
1954	2897.	1417.	184.	561.	981.	75.	0.	0.	0.	83.	1878.	116.	8192.
1955	309.	742.	1248.	1724.	118.	39.	1.	97.	180.	12.	0.	3.	4473.
1956	22.	964.	68.	60.	890.	11.	0.	0.	0.	0.	93.	15.	2123.
1957	105.	678.	653.	6655.	16648.	3896.	9.	14.	226.	2196.	5634.	1031.	37745.
1958	3142.	389.	2597.	3228.	16003.	938.	287.	2.	452.	109.	384.	261.	27792.
1959	134.	2710.	2572.	2233.	1530.	133.	365.	253.	126.	409.	510.	3049.	14024.
1960	5722.	2122.	2402.	821.	750.	479.	497.	310.	416.	403.	643.	5094.	19659.
1961	3214.	3120.	3665.	2332.	722.	1402.	1071.	345.	533.	317.	1154.	3375.	21250.
1962	1975.	2381.	2722.	1908.	1708.	546.	594.	248.	415.	474.	673.	923.	14567.
1963	926.	665.	1073.	1657.	1694.	271.	215.	148.	193.	161.	292.	394.	7689.
1964	414.	638.	981.	842.	509.	206.	101.	125.	173.	202.	305.	296.	4792.
1965	555.	1814.	1011.	575.	2250.	978.	134.	93.	120.	136.	182.	255.	8103.
1966	359.	635.	445.	6490.	5322.	358.	146.	226.	508.	297.	373.	496.	15655.
1967	697.	505.	485.	1187.	1165.	1930.	180.	110.	172.	198.	479.	964.	8072.
1968	2246.	1511.	2785.	2385.	6571.	1685.	684.	251.	572.	444.	794.	1862.	21790.
1969	922.	3731.	5728.	3387.	3566.	544.	181.	152.	152.	213.	876.	1181.	20633.

LAKE QUITMAN Firm yield calculations
SRA96425 ADK 9/22/98

SUMMARY OF RUNOFF DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	1371.	1452.	3379.	1914.	984.	946.	227.	161.	238.	664.	632.	543.	12511.
1971	585.	757.	693.	486.	435.	152.	553.	353.	147.	239.	588.	2852.	7840.
1972	3073.	1169.	1011.	496.	499.	480.	249.	144.	179.	336.	1128.	1086.	9850.
1973	1451.	1910.	5415.	8526.	1584.	4089.	558.	304.	923.	1397.	3750.	3281.	33188.
1974	3562.	1815.	1415.	3279.	1480.	3242.	375.	462.	3524.	990.	7060.	4331.	31535.
1975	2626.	4934.	4011.	2944.	4876.	1880.	727.	361.	262.	293.	445.	755.	24114.
1976	949.	933.	2213.	2056.	2736.	800.	2622.	221.	703.	648.	582.	1771.	16234.
1977	1120.	3849.	3872.	4603.	744.	471.	256.	509.	331.	231.	512.	781.	17279.
1978	1184.	1195.	2099.	719.	1164.	230.	204.	238.	238.	127.	243.	260.	7901.
1979	1868.	1283.	2421.	3528.	4928.	2484.	1890.	1412.	2944.	783.	1315.	2110.	26966.
1980	4269.	3264.	2212.	3581.	4435.	568.	119.	117.	181.	271.	386.	551.	19954.
AVG.	1712.	1921.	2290.	2874.	3415.	1406.	672.	217.	389.	425.	1074.	1328.	17723.

LAKE QUITMAN Firm yield calculations
SRA96425 ADK 9/22/98

SUMMARY OF NET EVAPORATION DATA
(VALUES IN FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	.06	-.01	.15	.01	.03	.11	.32	.38	.42	.24	-.31	-.12	1.28
1941	.05	-.04	.03	-.09	.17	-.13	.25	.37	.28	.01	.10	-.02	.98
1942	.10	.11	.13	-.35	.15	.13	.48	.27	.21	.21	.13	-.12	1.45
1943	.02	.21	.02	.19	-.05	.22	.48	.62	.28	.08	.17	-.06	2.18
1944	-.08	-.17	-.06	.07	-.32	.36	.46	.29	.37	.36	-.14	-.23	.91
1945	.00	-.17	-.58	.08	.23	.02	.11	.32	.30	.03	.18	.10	.62
1946	-.22	-.05	-.02	.04	-.30	.26	.49	.18	.29	.25	-.36	.03	.59
1947	-.04	.13	-.06	-.10	.09	.27	.54	.38	.29	.29	.00	-.16	1.63
1948	-.10	-.12	.02	.16	-.12	.42	.52	.59	.56	.27	.11	.02	2.33
1949	-.43	-.13	.01	-.10	.20	.25	.25	.33	.32	-.35	.26	-.05	.56
1950	-.21	-.29	.16	-.07	-.21	.30	.11	.38	-.05	.27	.26	.20	.85
1951	.01	-.15	.16	.16	.21	.04	.38	.58	-.07	.18	.12	.00	1.62
1952	.05	-.02	-.03	-.23	.02	.37	.40	.77	.65	.56	-.18	-.15	2.21
1953	.05	.04	-.08	-.15	-.08	.49	.08	.34	.32	.29	.04	-.09	1.25
1954	-.11	.15	.19	.03	-.17	.44	.77	.83	.61	-.13	.13	.09	2.83
1955	.03	-.09	-.03	-.01	.09	.38	.34	-.01	.13	.38	.33	.14	1.68
1956	.03	-.17	.24	.16	.15	.36	.76	.68	.63	.34	.14	.15	3.47
1957	.02	-.04	-.10	-.60	-.23	.06	.48	.35	.13	-.04	-.21	.10	-.08
1958	-.02	.09	-.01	-.21	.06	.14	.27	.29	-.07	.20	.09	.15	.98
1959	.20	-.05	.10	.00	-.12	-.03	.03	.29	.25	.06	.25	-.16	.82
1960	-.07	.00	.09	.18	.24	.08	.24	.29	.20	.10	.15	-.37	1.13
1961	-.06	-.04	-.08	.23	.17	-.08	.23	.40	.23	.28	-.10	-.05	1.13
1962	-.06	-.03	.09	-.05	.28	-.11	.33	.47	.01	.00	.01	.11	1.05
1963	.09	.14	.03	-.14	.10	.27	.29	.59	.41	.54	.23	.07	2.62
1964	.14	.00	-.04	-.07	-.02	.29	.64	.36	.08	.39	.05	.09	1.91
1965	.02	-.25	.01	.19	-.38	.21	.54	.48	.09	.27	.09	.02	1.29
1966	-.02	-.04	.10	-.21	-.02	.24	.26	.20	.06	.24	.17	.10	1.08
1967	.10	.05	.08	-.20	-.17	.35	.17	.28	.06	.08	.15	.04	.99
1968	.08	.07	-.01	-.01	-.12	.18	.17	.47	.13	.25	.19	.11	1.51
1969	-.03	-.04	.01	-.14	-.31	.29	.52	.53	.26	.32	.18	.01	1.60

LAKE QUITMAN Firm yield calculations
SRA96425 ADK 9/22/98

THERE ARE 5 AREA/CAPACITY/ELEVATION POINTS.

AREA (ACRES)	CAPACITY (ACRE-FEET)	ELEVATION (FEET)
0.	0.	375.0
94.	235.	380.0
288.	1190.	385.0
510.	3185.	390.0
756.	6350.	395.0

LAKE HOLBROOK Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF RUNOFF DATA
(VALUES IN ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	0.	13.	85.	825.	813.	1121.	561.	53.	137.	6.	523.	2362.	6499.
1941	435.	788.	1418.	892.	1273.	1632.	370.	118.	32.	9.	105.	263.	7335.
1942	132.	286.	405.	4064.	3304.	274.	6.	50.	54.	20.	57.	432.	9084.
1943	322.	95.	200.	468.	574.	3472.	1637.	0.	1.	70.	1.	60.	6900.
1944	352.	903.	1381.	728.	4146.	726.	52.	7.	99.	2.	169.	875.	9440.
1945	1372.	804.	5550.	9158.	344.	1016.	3574.	48.	5.	1334.	347.	198.	23750.
1946	2640.	3141.	1524.	450.	2415.	4044.	31.	43.	47.	19.	3485.	1033.	18872.
1947	1054.	159.	625.	1589.	734.	142.	67.	17.	45.	1.	275.	1600.	6308.
1948	7902.	1689.	1891.	363.	2609.	30.	115.	6.	0.	0.	14.	23.	14642.
1949	498.	1500.	1854.	1015.	576.	99.	149.	9.	26.	1303.	1287.	189.	8505.
1950	1781.	4745.	975.	450.	2719.	874.	554.	717.	224.	32.	15.	22.	13108.
1951	181.	1040.	864.	78.	203.	304.	52.	0.	0.	0.	10.	37.	2769.
1952	194.	196.	441.	2952.	2096.	193.	4.	0.	0.	0.	29.	578.	6683.
1953	987.	213.	468.	996.	5145.	9.	242.	25.	315.	2.	28.	463.	8893.
1954	1402.	686.	89.	271.	475.	36.	0.	0.	0.	40.	909.	56.	3964.
1955	150.	359.	604.	834.	57.	19.	0.	47.	87.	6.	0.	1.	2164.
1956	10.	467.	33.	29.	431.	6.	0.	0.	0.	0.	45.	7.	1028.
1957	51.	328.	316.	3220.	8055.	1885.	4.	7.	109.	1063.	2726.	499.	18263.
1958	1520.	188.	1257.	1562.	7743.	454.	139.	1.	219.	53.	186.	127.	13449.
1959	65.	1311.	1245.	1081.	740.	64.	177.	122.	61.	198.	247.	1475.	6786.
1960	2767.	1026.	1162.	397.	363.	232.	240.	150.	201.	195.	311.	2464.	9508.
1961	1554.	1509.	1772.	1128.	349.	678.	518.	167.	258.	153.	558.	1632.	10276.
1962	955.	1151.	1316.	923.	826.	264.	288.	120.	201.	230.	326.	447.	7047.
1963	448.	322.	520.	802.	820.	131.	104.	72.	94.	78.	142.	191.	3724.
1964	201.	309.	475.	408.	246.	100.	49.	61.	84.	98.	148.	143.	2322.
1965	269.	878.	490.	279.	1090.	474.	65.	45.	58.	66.	88.	123.	3925.
1966	174.	307.	215.	3142.	2574.	173.	71.	109.	246.	144.	181.	240.	7576.
1967	337.	245.	235.	574.	564.	934.	87.	53.	84.	96.	232.	466.	3907.
1968	1086.	732.	1347.	1154.	3178.	815.	331.	122.	277.	215.	384.	900.	10541.
1969	446.	1804.	2770.	1638.	1724.	264.	88.	73.	74.	103.	424.	572.	9980.

LAKE HOLBROOK Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF RUNOFF DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	664.	703.	1634.	926.	476.	458.	110.	78.	115.	322.	306.	263.	6055.
1971	283.	367.	336.	236.	211.	74.	268.	171.	71.	116.	285.	1379.	3797.
1972	1486.	565.	489.	240.	241.	233.	120.	70.	87.	163.	546.	525.	4765.
1973	702.	924.	2619.	4123.	766.	1978.	270.	147.	447.	676.	1813.	1587.	16052.
1974	1723.	878.	684.	1586.	716.	1568.	182.	224.	1704.	479.	3414.	2094.	15252.
1975	1270.	2386.	1940.	1424.	2358.	909.	352.	175.	127.	142.	216.	366.	11665.
1976	459.	452.	1070.	994.	1323.	388.	1268.	107.	340.	314.	282.	858.	7855.
1977	542.	1861.	1872.	2226.	360.	228.	124.	247.	160.	112.	248.	378.	8358.
1978	573.	579.	1016.	348.	564.	112.	99.	115.	115.	61.	118.	126.	3826.
1979	905.	621.	1171.	1706.	2383.	1201.	914.	684.	1426.	379.	636.	1020.	13046.
1980	2065.	1579.	1070.	1732.	2145.	275.	58.	56.	87.	131.	187.	267.	9652.
AVG.	975.	929.	1108.	1391.	1652.	680.	325.	105.	188.	206.	520.	642.	8721.

LAKE HOLBROOK Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF NET EVAPORATION DATA
(VALUES IN FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	.06	-.02	.14	.04	.06	.09	.34	.34	.42	.23	-.35	-.14	1.21
1941	.04	-.05	.02	-.07	.17	-.14	.27	.37	.25	.01	.09	-.03	.93
1942	.09	.11	.13	-.34	.15	.11	.47	.25	.20	.20	.13	-.12	1.38
1943	.05	.21	.02	.19	-.11	.21	.47	.61	.25	.04	.17	-.07	2.04
1944	-.10	-.18	-.07	.06	-.35	.35	.47	.29	.36	.36	-.15	-.25	.79
1945	-.01	-.14	-.60	.06	.23	.03	.08	.31	.32	.00	.17	.08	.53
1946	-.24	-.05	-.04	.04	-.32	.25	.50	.13	.29	.24	-.37	.04	.47
1947	-.06	.11	-.07	-.09	.08	.25	.54	.38	.29	.29	-.01	-.16	1.55
1948	-.11	-.11	.02	.14	-.08	.42	.54	.60	.56	.28	.09	.00	2.35
1949	-.42	-.13	.00	-.12	.18	.28	.24	.32	.31	-.39	.26	-.07	.46
1950	-.19	-.29	.15	-.10	-.19	.29	.15	.40	-.02	.26	.25	.20	.91
1951	.01	-.14	.13	.17	.22	.09	.38	.64	-.08	.20	.11	-.04	1.69
1952	.05	-.05	-.02	-.20	.02	.37	.40	.77	.65	.56	-.18	-.17	2.20
1953	.06	.03	-.09	-.12	-.12	.46	.08	.32	.31	.28	.03	-.12	1.12
1954	-.11	.14	.17	.03	-.15	.45	.76	.82	.62	-.15	.10	.08	2.76
1955	.01	-.12	-.04	.00	.05	.35	.33	-.03	.12	.40	.33	.13	1.53
1956	.02	-.15	.23	.15	.11	.36	.73	.64	.61	.33	.12	.14	3.29
1957	.02	-.06	-.10	-.65	-.19	.05	.47	.33	.14	-.11	-.21	.10	-.21
1958	-.02	.07	.01	-.23	.07	.13	.28	.29	-.12	.18	.10	.15	.91
1959	.19	-.07	.10	-.04	-.18	-.04	.06	.30	.24	.07	.24	-.17	.70
1960	-.09	-.01	.07	.16	.25	.04	.24	.29	.21	.09	.12	-.40	.97
1961	-.11	-.06	-.08	.23	.17	-.13	.23	.38	.20	.27	-.10	-.06	.94
1962	-.07	-.05	.09	-.08	.25	-.09	.28	.46	-.01	.00	-.02	.09	.85
1963	.08	.12	.05	-.14	.09	.27	.34	.58	.38	.54	.21	.06	2.58
1964	.12	-.01	-.04	-.04	-.05	.29	.60	.38	.08	.37	.04	.08	1.82
1965	.00	-.24	-.01	.18	-.44	.21	.51	.46	.07	.26	.09	-.01	1.08
1966	-.04	-.05	.07	-.22	-.04	.23	.26	.19	.07	.21	.16	.10	.94
1967	.09	.04	.07	-.24	-.19	.34	.20	.26	.05	.08	.15	.05	.90
1968	.08	.08	-.01	-.03	-.09	.21	.15	.51	.17	.26	.22	.10	1.65
1969	-.05	-.04	.01	-.17	-.36	.30	.53	.53	.29	.34	.15	.01	1.54

LAKE HOLBROOK Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF NET EVAPORATION DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	.03	-.10	-.07	-.21	.01	.25	.53	.56	.27	.11	.13	-.07	1.44
1971	.18	.02	.19	.22	.22	.51	.39	.26	.31	.08	.10	-.12	2.36
1972	-.02	.17	.17	.18	.32	.27	.42	.47	.24	.15	-.01	.02	2.38
1973	-.07	-.01	.02	-.04	.21	.14	.31	.54	.09	.06	.03	.08	1.36
1974	-.12	.11	.17	.16	.17	.25	.56	.24	-.04	.12	-.02	-.03	1.57
1975	.02	-.05	.03	.07	.10	.22	.46	.53	.45	.33	.20	.05	2.41
1976	.11	.15	.05	.07	.10	.23	.22	.50	.12	.08	.15	.01	1.79
1977	-.08	.01	.08	.10	.31	.39	.60	.37	.36	.36	.03	.14	2.67
1978	-.08	-.06	.10	.24	.20	.42	.67	.57	.34	.43	-.04	.02	2.81
1979	-.11	-.03	.06	.14	.18	.37	.36	.41	.30	.36	.17	.00	2.21
1980	-.08	.06	.12	.13	.16	.39	.75	.69	.38	.26	.11	.09	3.06
AVG.	-.02	-.02	.03	-.01	.03	.23	.39	.42	.25	.20	.07	-.01	1.56

LAKE HOLBROOK Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

THERE ARE 9 AREA/CAPACITY/ELEVATION POINTS.

AREA (ACRES)	CAPACITY (ACRE-FEET)	ELEVATION (FEET)
0.	0.	338.0
4.	4.	340.0
44.	124.	345.0
100.	484.	350.0
173.	1167.	355.0
273.	2282.	360.0
397.	3957.	365.0
554.	6334.	370.0
631.	7519.	372.0

LAKE HAWKINS Firm yield calculations
SRA96425 JSA 4/30/97

SUMMARY OF RUNOFF DATA
(VALUES IN ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	286.	578.	566.	988.	761.	1813.	854.	141.	550.	139.	1229.	3513.	11418.
1941	1595.	1472.	3028.	1649.	1123.	3180.	967.	263.	248.	392.	651.	1658.	16226.
1942	1189.	1195.	1371.	3917.	5453.	943.	280.	796.	428.	353.	452.	1779.	18156.
1943	2326.	889.	475.	1685.	633.	2918.	1641.	132.	160.	1206.	269.	987.	13321.
1944	2478.	3799.	3608.	2658.	6793.	1154.	200.	208.	271.	171.	428.	2318.	24086.
1945	3208.	1137.	10021.	20992.	1682.	2222.	6079.	382.	253.	2275.	1099.	1745.	51095.
1946	5871.	4028.	3753.	2173.	4506.	9836.	603.	314.	683.	458.	5225.	2623.	40073.
1947	2869.	1505.	2446.	3058.	1886.	496.	459.	97.	378.	258.	445.	2893.	16790.
1948	4652.	3117.	4132.	1530.	3814.	559.	292.	173.	147.	193.	321.	434.	19364.
1949	628.	2268.	3666.	2022.	2412.	586.	1849.	385.	442.	1842.	2708.	1038.	19846.
1950	4788.	6543.	1682.	1780.	6922.	1527.	705.	1793.	794.	439.	546.	578.	28097.
1951	1366.	2165.	2728.	934.	1238.	631.	255.	139.	203.	226.	392.	429.	10706.
1952	641.	1028.	1413.	2263.	4402.	1188.	206.	124.	103.	127.	112.	1100.	12707.
1953	2218.	988.	1757.	1637.	7788.	292.	913.	345.	533.	219.	467.	1463.	18620.
1954	1873.	1171.	709.	648.	1345.	611.	147.	87.	73.	13.	609.	565.	7851.
1955	638.	1042.	2195.	1598.	494.	213.	196.	276.	248.	155.	153.	270.	7478.
1956	397.	1267.	557.	353.	645.	108.	66.	60.	71.	73.	153.	220.	3970.
1957	125.	1168.	425.	4177.	9005.	3302.	303.	342.	354.	1998.	4079.	1659.	26937.
1958	3023.	1275.	2383.	2333.	11428.	1888.	1108.	285.	880.	519.	1186.	968.	27276.
1959	678.	2291.	2441.	2633.	2819.	635.	387.	711.	478.	396.	494.	2951.	16914.
1960	5539.	2054.	2325.	795.	726.	464.	481.	300.	403.	390.	622.	4931.	19030.
1961	3111.	3020.	3548.	2258.	699.	1358.	1037.	334.	516.	307.	1117.	3267.	20572.
1962	1912.	2304.	2634.	1847.	1654.	529.	575.	240.	402.	459.	652.	893.	14101.
1963	896.	643.	1039.	1604.	1639.	262.	208.	143.	187.	156.	283.	381.	7441.
1964	401.	617.	950.	814.	492.	200.	98.	121.	167.	195.	295.	286.	4636.
1965	538.	1756.	979.	557.	2178.	947.	130.	90.	116.	132.	176.	246.	7845.
1966	348.	614.	430.	6280.	5151.	346.	141.	218.	492.	288.	361.	480.	15149.
1967	674.	489.	470.	1149.	1128.	1867.	174.	106.	167.	192.	464.	933.	7813.
1968	2174.	1463.	2696.	2309.	6360.	1631.	662.	243.	554.	430.	768.	1802.	21092.
1969	893.	3611.	5544.	3279.	3452.	527.	175.	147.	148.	206.	847.	1143.	19972.

LAKE HAWKINS Firm yield calculations
SRA96425 JSA 4/30/97

SUMMARY OF RUNOFF DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	1327.	1405.	3271.	1853.	952.	915.	219.	155.	230.	643.	612.	525.	12107.
1971	566.	733.	671.	471.	421.	147.	536.	341.	143.	231.	569.	2760.	7589.
1972	2975.	1131.	978.	480.	483.	465.	241.	139.	173.	325.	1092.	1051.	9533.
1973	1404.	1849.	5242.	8253.	1533.	3958.	540.	294.	893.	1352.	3629.	3176.	32123.
1974	3448.	1756.	1369.	3174.	1432.	3138.	363.	447.	3411.	958.	6834.	4192.	30522.
1975	2542.	4776.	3883.	2850.	4720.	1820.	704.	349.	254.	283.	431.	731.	23343.
1976	918.	903.	2142.	1990.	2648.	775.	2538.	214.	680.	627.	564.	1714.	15713.
1977	1084.	3726.	3748.	4456.	720.	456.	247.	493.	321.	224.	496.	756.	16727.
1978	1146.	1156.	2032.	696.	1126.	223.	197.	231.	231.	123.	235.	252.	7648.
1979	1808.	1242.	2343.	3415.	4770.	2404.	1829.	1367.	2849.	758.	1273.	2042.	26100.
1980	4133.	3159.	2141.	3467.	4293.	550.	115.	113.	175.	262.	374.	533.	19315.
AVG.	1919.	1886.	2385.	2708.	2969.	1392.	700.	320.	483.	488.	1042.	1495.	17787.

LAKE HAWKINS Firm yield calculations
SRA96425 JSA 4/30/97

SUMMARY OF NET EVAPORATION DATA
(VALUES IN FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	.05	-.03	.12	.02	.07	.07	.31	.30	.40	.22	-.38	-.17	.98
1941	.01	-.06	-.01	-.07	.13	-.13	.26	.35	.22	.00	.06	-.05	.71
1942	.08	.10	.11	-.31	.13	.09	.43	.17	.19	.18	.13	-.12	1.18
1943	.05	.21	.02	.19	-.09	.23	.44	.59	.24	.05	.17	-.09	2.01
1944	-.14	-.22	-.10	.00	-.40	.32	.46	.26	.34	.35	-.16	-.31	.40
1945	-.04	-.14	-.59	.04	.22	.02	.08	.32	.34	-.02	.15	.05	.43
1946	-.28	-.06	-.04	.03	-.33	.21	.48	.14	.29	.22	-.38	.04	.32
1947	-.08	.09	-.10	-.08	.04	.26	.52	.38	.28	.28	-.02	-.17	1.40
1948	-.14	-.14	.00	.13	-.09	.40	.51	.58	.54	.27	.03	.00	2.09
1949	-.41	-.12	-.01	-.13	.17	.26	.15	.29	.29	-.39	.25	-.07	.28
1950	-.22	-.28	.13	-.10	-.20	.26	.15	.35	-.07	.24	.22	.19	.67
1951	-.03	-.14	.10	.16	.21	.10	.37	.64	-.11	.22	.09	-.05	1.56
1952	.01	-.07	-.03	-.19	.00	.35	.37	.73	.63	.53	-.18	-.17	1.98
1953	.03	.01	-.11	-.13	-.17	.44	.05	.32	.30	.29	.02	-.14	.91
1954	-.13	.13	.16	.03	-.20	.44	.73	.79	.62	-.13	.07	.06	2.57
1955	-.01	-.16	-.04	-.02	.02	.34	.31	-.04	.11	.39	.31	.12	1.33
1956	.01	-.18	.20	.13	.07	.33	.68	.59	.57	.31	.12	.12	2.95
1957	.01	-.08	-.11	-.67	-.14	.01	.44	.32	.15	-.18	-.23	.09	-.39
1958	-.04	.05	.01	-.26	.05	.10	.28	.27	-.14	.17	.09	.15	.73
1959	.17	-.09	.09	-.06	-.21	-.02	.04	.29	.22	.09	.21	-.18	.55
1960	-.10	-.03	.06	.16	.25	.06	.26	.29	.18	.10	.10	-.41	.92
1961	-.11	-.07	-.09	.22	.18	-.17	.19	.38	.18	.24	-.10	-.08	.77
1962	-.11	-.05	.08	-.09	.23	-.07	.30	.47	.02	.02	-.02	.08	.86
1963	.07	.11	.04	-.16	.10	.25	.33	.55	.35	.53	.19	.02	2.38
1964	.12	-.02	-.05	-.06	-.03	.30	.58	.34	.10	.36	.05	.04	1.73
1965	-.03	-.25	-.03	.18	-.42	.19	.51	.45	.09	.28	.11	-.03	1.05
1966	-.06	-.03	.08	-.13	-.05	.29	.30	.22	.08	.20	.13	.07	1.10
1967	.05	.05	.09	-.18	-.14	.34	.26	.31	.07	.10	.11	.05	1.11
1968	.08	.06	-.01	-.02	-.03	.25	.23	.47	.18	.20	.20	.10	1.71
1969	-.04	-.06	.01	-.20	-.29	.35	.53	.51	.26	.31	.14	.01	1.53

LAKE HAWKINS Firm yield calculations
SRA96425 JSA 4/30/97

SUMMARY OF NET EVAPORATION DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	.01	-.08	-.03	-.25	.03	.28	.52	.53	.30	.13	.13	-.09	1.48
1971	.17	.01	.18	.22	.22	.49	.37	.27	.29	.10	.09	-.10	2.31
1972	-.04	.16	.15	.17	.30	.25	.39	.46	.24	.14	-.03	.01	2.20
1973	-.08	-.01	.02	-.04	.22	.13	.29	.53	.10	.05	.03	.06	1.30
1974	-.14	.09	.15	.15	.18	.23	.54	.23	-.02	.13	-.02	-.03	1.49
1975	.01	-.06	.02	.06	.10	.22	.46	.49	.43	.31	.17	.05	2.26
1976	.10	.13	.04	.08	.10	.22	.21	.48	.12	.07	.13	.00	1.68
1977	-.08	.01	.07	.10	.32	.38	.57	.35	.33	.36	.03	.12	2.56
1978	-.08	-.05	.11	.23	.21	.43	.64	.56	.32	.41	-.05	.01	2.74
1979	-.12	-.02	.06	.13	.18	.37	.36	.41	.29	.36	.14	.00	2.16
1980	-.09	.05	.10	.12	.15	.39	.74	.68	.38	.26	.10	.10	2.98
AVG.	-.04	-.03	.02	-.01	.03	.23	.38	.41	.24	.19	.05	-.02	1.45

LAKE HAWKINS Firm yield calculations
SRA96425 JSA 4/30/97

THERE ARE 8 AREA/CAPACITY/ELEVATION POINTS.

AREA (ACRES)	CAPACITY (ACRE-FEET)	ELEVATION (FEET)
0.	0.	312.0
72.	117.	315.0
161.	823.	320.0
266.	2005.	325.0
390.	3646.	330.0
518.	4926.	335.0
656.	8830.	340.0
776.	11794.	343.8

LAKE WINNSBORO Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF RUNOFF DATA
(VALUES IN ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	259.	523.	511.	892.	688.	1637.	772.	127.	497.	126.	1111.	3174.	10317.
1941	1441.	1330.	2736.	1490.	1014.	2873.	873.	237.	224.	354.	588.	1498.	14658.
1942	1075.	1079.	1238.	3538.	4926.	852.	253.	719.	387.	320.	408.	1607.	16402.
1943	2101.	804.	429.	1522.	571.	2636.	1483.	119.	145.	1090.	243.	891.	12034.
1944	2238.	3432.	3259.	2401.	6136.	1043.	181.	188.	245.	154.	387.	2094.	21758.
1945	2898.	1027.	9052.	18963.	1520.	2007.	5492.	345.	228.	2055.	993.	1576.	46156.
1946	5303.	3639.	3390.	1963.	4070.	8885.	545.	284.	618.	414.	4720.	2369.	36200.
1947	2591.	1359.	2210.	2762.	1704.	448.	415.	87.	341.	234.	402.	2614.	15167.
1948	4202.	2815.	3732.	1383.	3446.	505.	263.	157.	132.	174.	290.	392.	17491.
1949	568.	2049.	3311.	1826.	2179.	530.	1670.	348.	399.	1663.	2446.	937.	17926.
1950	4325.	5910.	1520.	1608.	6252.	1379.	637.	1620.	717.	396.	493.	522.	25379.
1951	1234.	1955.	2465.	844.	1118.	570.	230.	126.	184.	204.	354.	388.	9672.
1952	579.	928.	1277.	2044.	3976.	1073.	186.	113.	94.	114.	101.	994.	11479.
1953	2003.	892.	1587.	1478.	7034.	263.	824.	311.	481.	198.	421.	1322.	16814.
1954	1692.	1057.	641.	585.	1215.	552.	133.	78.	66.	11.	551.	510.	7091.
1955	577.	941.	1983.	1444.	446.	192.	177.	249.	224.	140.	138.	244.	6755.
1956	359.	1144.	503.	318.	583.	98.	60.	54.	64.	65.	138.	199.	3585.
1957	113.	1055.	384.	3773.	8134.	2983.	274.	309.	320.	1805.	3685.	1499.	24334.
1958	2731.	1152.	2153.	2107.	10323.	1706.	1002.	257.	795.	469.	1071.	874.	24640.
1959	613.	2069.	2205.	2379.	2546.	574.	349.	642.	433.	358.	446.	2665.	15279.
1960	5002.	1855.	2100.	718.	656.	419.	434.	271.	364.	352.	562.	4453.	17186.
1961	2809.	2727.	3204.	2039.	631.	1226.	936.	302.	466.	277.	1009.	2950.	18576.
1962	1727.	2081.	2379.	1668.	1493.	477.	520.	217.	363.	415.	589.	807.	12736.
1963	810.	581.	939.	1449.	1481.	237.	188.	130.	169.	141.	255.	345.	6725.
1964	362.	558.	858.	736.	445.	180.	88.	110.	151.	176.	267.	259.	4190.
1965	486.	1586.	884.	503.	1968.	855.	117.	81.	105.	119.	159.	223.	7086.
1966	314.	555.	389.	5674.	4651.	313.	127.	197.	444.	260.	326.	434.	13684.
1967	609.	442.	424.	1037.	1019.	1687.	157.	96.	151.	173.	419.	843.	7057.
1968	1963.	1321.	2434.	2085.	5743.	1472.	598.	220.	500.	388.	694.	1627.	19045.
1969	806.	3261.	5006.	2961.	3117.	476.	158.	133.	133.	186.	766.	1033.	18036.

LAKE WINNSBORO Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF RUNOFF DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	1199.	1269.	2954.	1673.	860.	827.	198.	140.	208.	581.	553.	475.	10937.
1971	512.	662.	606.	425.	380.	133.	484.	309.	129.	209.	514.	2493.	6856.
1972	2686.	1022.	883.	433.	436.	420.	217.	126.	156.	294.	986.	949.	8608.
1973	1268.	1669.	4733.	7452.	1384.	3574.	488.	266.	807.	1221.	3277.	2868.	29007.
1974	3113.	1586.	1236.	2866.	1293.	2833.	328.	404.	3080.	865.	6171.	3785.	27560.
1975	2295.	4313.	3506.	2573.	4262.	1644.	636.	316.	229.	256.	389.	660.	21079.
1976	829.	816.	1934.	1797.	2391.	700.	2292.	194.	615.	567.	509.	1548.	14192.
1977	980.	3364.	3384.	4023.	650.	412.	223.	445.	290.	202.	448.	683.	15104.
1978	1035.	1045.	1835.	629.	1018.	202.	178.	208.	208.	111.	213.	227.	6909.
1979	1633.	1122.	2116.	3084.	4307.	2171.	1652.	1235.	2574.	684.	1150.	1844.	23572.
1980	3732.	2853.	1933.	3130.	3877.	497.	104.	102.	158.	237.	338.	481.	17442.
AVG.	1733.	1704.	2154.	2446.	2682.	1258.	633.	290.	436.	440.	941.	1350.	16067.

LAKE WINNSBORO Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF NET EVAPORATION DATA
(VALUES IN FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	.06	-.02	.13	-.01	.02	.10	.28	.36	.42	.23	-.31	-.13	1.13
1941	.04	-.04	.01	-.10	.14	-.12	.24	.36	.27	.01	.08	-.03	.86
1942	.10	.11	.11	-.33	.13	.12	.47	.22	.21	.20	.14	-.12	1.36
1943	.02	.20	.02	.19	-.03	.24	.47	.61	.28	.10	.17	-.07	2.20
1944	-.10	-.20	-.07	.04	-.34	.34	.46	.26	.36	.35	-.15	-.26	.69
1945	-.01	-.18	-.58	.06	.21	.00	.12	.32	.31	.03	.16	.09	.53
1946	-.24	-.05	-.02	.02	-.31	.24	.47	.20	.29	.24	-.36	.03	.51
1947	-.05	.12	-.07	-.10	.06	.27	.53	.38	.28	.28	-.02	-.17	1.51
1948	-.11	-.13	.00	.16	-.14	.40	.49	.58	.54	.25	.07	.02	2.13
1949	-.43	-.12	.00	-.10	.20	.23	.20	.31	.32	-.35	.25	-.05	.46
1950	-.23	-.29	.14	-.07	-.24	.28	.10	.35	-.10	.25	.25	.19	.63
1951	-.01	-.16	.14	.15	.21	.04	.37	.58	-.09	.19	.11	.01	1.54
1952	.02	-.02	-.04	-.23	.01	.36	.37	.74	.64	.55	-.19	-.14	2.07
1953	.02	.03	-.08	-.16	-.11	.48	.05	.33	.31	.30	.03	-.10	1.10
1954	-.13	.14	.18	.03	-.20	.43	.74	.81	.61	-.11	.12	.07	2.69
1955	.02	-.11	-.03	-.02	.08	.38	.32	-.02	.13	.35	.32	.14	1.56
1956	.03	-.20	.22	.15	.14	.34	.72	.66	.61	.33	.14	.14	3.28
1957	.01	-.06	-.11	-.59	-.21	.03	.45	.35	.13	-.06	-.23	.09	-.20
1958	-.03	.08	-.01	-.25	.05	.12	.26	.27	-.06	.20	.08	.15	.86
1959	.19	-.07	.09	-.01	-.11	-.02	.02	.29	.24	.07	.24	-.17	.76
1960	-.08	-.01	.08	.19	.24	.10	.26	.29	.18	.11	.15	-.36	1.15
1961	-.05	-.04	-.09	.22	.17	-.09	.20	.40	.22	.27	-.10	-.06	1.05
1962	-.08	-.03	.09	-.06	.29	-.10	.36	.48	.04	.01	.01	.12	1.13
1963	.08	.13	.02	-.14	.11	.25	.27	.58	.40	.53	.22	.05	2.50
1964	.15	.00	-.05	-.09	.00	.30	.63	.33	.08	.39	.05	.07	1.86
1965	.00	-.26	.00	.19	-.34	.20	.54	.47	.10	.28	.10	.02	1.30
1966	-.03	-.03	.12	-.16	.00	.29	.29	.23	.08	.24	.16	.07	1.26
1967	.07	.05	.10	-.16	-.13	.35	.20	.32	.07	.10	.13	.03	1.13
1968	.06	.06	-.02	.00	-.09	.19	.22	.45	.13	.21	.16	.10	1.47
1969	-.03	-.05	.00	-.13	-.24	.31	.52	.52	.24	.29	.16	.01	1.60

LAKE WINNSBORO Firm yield calculations
SRA96425 ADK 9/22/98 1997 A/C Data

SUMMARY OF NET EVAPORATION DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	.01	-.11	-.03	-.27	.04	.33	.53	.54	.23	.09	.14	-.05	1.45
1971	.15	.01	.19	.22	.22	.50	.36	.26	.29	.06	.10	-.15	2.21
1972	-.02	.16	.18	.19	.31	.27	.43	.47	.23	.12	-.03	.01	2.32
1973	-.08	-.02	.00	-.04	.23	.13	.30	.53	.07	.04	.01	.05	1.22
1974	-.13	.10	.17	.15	.18	.22	.53	.23	-.06	.11	-.03	-.04	1.43
1975	.01	-.06	.02	.08	.09	.21	.46	.51	.42	.36	.17	.04	2.31
1976	.12	.14	.04	.07	.10	.23	.23	.52	.13	.07	.13	.02	1.80
1977	-.08	.01	.08	.11	.31	.40	.56	.35	.36	.36	.03	.14	2.63
1978	-.08	-.06	.09	.23	.20	.42	.67	.59	.36	.44	-.05	.01	2.82
1979	-.11	-.04	.05	.11	.15	.35	.33	.37	.28	.31	.15	.01	1.96
1980	-.07	.06	.12	.14	.15	.36	.74	.70	.38	.25	.11	.09	3.03
AVG.	-.02	-.02	.03	-.01	.04	.23	.38	.42	.24	.20	.07	.00	1.56

LAKE WINNSBORO Firm yield calculations
SRA96425   ADK 9/22/98   1997 A/C Data

THERE ARE 5 AREA/CAPACITY/ELEVATION POINTS.

AREA (ACRES)	CAPACITY (ACRE-FEET)	ELEVATION (FEET)
0.	0.	400.0
163.	163.	405.0
358.	2247.	410.0
558.	4537.	415.0
734.	7121.	419.0

Lake Murvaul

LAKE MURVAUL OPERATION w/ 2000 Area Capacity data adk 9/85/98
Inflow from 1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF RUNOFF DATA
(VALUES IN ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	3200.	19400.	1800.	5800.	6100.	7900.	2600.	200.	2500.	600.	19800.	45800.	115700.
1941	36500.	12600.	21000.	8800.	17400.	12200.	18100.	100.	1800.	5100.	19600.	10100.	163300.
1942	8400.	4900.	15700.	5300.	33100.	14200.	2700.	0.	5400.	400.	600.	500.	91200.
1943	6900.	2600.	1900.	2600.	100.	0.	900.	300.	100.	300.	600.	2300.	18600.
1944	20400.	11400.	20800.	25500.	51800.	13400.	600.	200.	400.	100.	0.	1300.	145900.
1945	42700.	13200.	31300.	34400.	3900.	0.	1500.	2600.	600.	8300.	2100.	9200.	149800.
1946	30100.	33900.	37500.	10300.	15400.	25300.	2300.	0.	1600.	700.	0.	10600.	167700.
1947	22100.	13400.	19600.	16800.	11100.	2200.	1000.	100.	0.	0.	200.	0.	86500.
1948	10800.	22500.	20500.	7600.	1200.	11200.	300.	0.	100.	100.	400.	1200.	75900.
1949	9700.	9100.	10300.	8800.	3800.	2400.	1500.	2700.	700.	12000.	2400.	5000.	68400.
1950	24000.	18000.	23300.	1700.	13800.	20600.	5000.	200.	600.	1300.	800.	700.	110000.
1951	3200.	8200.	6400.	4900.	100.	0.	400.	100.	300.	0.	0.	2300.	25900.
1952	3300.	22900.	14200.	14600.	6400.	3300.	400.	300.	100.	0.	0.	160.	65660.
1953	2866.	20472.	24584.	4208.	48668.	22632.	536.	644.	106.	0.	0.	1928.	126644.
1954	1672.	2499.	2846.	1482.	12009.	2607.	203.	0.	28.	1262.	0.	2056.	26664.
1955	4514.	12500.	10527.	19711.	9718.	2771.	715.	2389.	338.	0.	0.	228.	63411.
1956	3719.	5081.	8040.	17475.	2051.	0.	95.	0.	236.	0.	0.	0.	36697.
1957	437.	3869.	4873.	4616.	29062.	7850.	2592.	196.	584.	5851.	7209.	11626.	78765.
1958	8177.	9760.	7165.	15374.	10293.	13508.	625.	1028.	11986.	4133.	38.	1016.	83103.
1959	1834.	10093.	1356.	9208.	3856.	5383.	803.	184.	95.	1427.	650.	7991.	42880.
1960	11886.	15378.	15237.	4588.	1611.	337.	382.	26.	3233.	3418.	5438.	20606.	82140.
1961	31670.	12442.	20668.	2261.	1222.	4720.	1541.	323.	377.	0.	1357.	19007.	95588.
1962	24981.	5075.	7587.	7862.	13288.	2235.	352.	0.	161.	4080.	770.	2818.	69209.
1963	2700.	2638.	408.	1291.	0.	377.	532.	0.	271.	0.	1718.	1143.	11078.
1964	2089.	2001.	5437.	3734.	1528.	895.	162.	174.	321.	274.	491.	866.	17972.
1965	1259.	4978.	13654.	5822.	7169.	1754.	354.	311.	793.	394.	634.	2948.	40070.
1966	2780.	4665.	2249.	18442.	15888.	1470.	662.	1601.	822.	624.	675.	1310.	51188.
1967	1310.	1237.	1470.	2052.	1208.	1667.	560.	135.	162.	154.	356.	961.	11272.
1968	8581.	2365.	3661.	18195.	14614.	3006.	10604.	1332.	3836.	2438.	4010.	14687.	87329.
1969	4891.	11114.	25298.	19221.	14076.	1710.	616.	317.	533.	638.	1907.	2780.	83101.

LAKE MURVAUL OPERATION w/ 2000 Area Capacity data adk 9/85/98
Inflow from 1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF RUNOFF DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	4119.	4760.	7111.	3937.	1339.	655.	406.	356.	462.	1135.	1470.	1172.	26922.
1971	1303.	1987.	2009.	2322.	8945.	640.	371.	464.	417.	440.	689.	3173.	22760.
1972	6579.	3093.	2263.	1419.	721.	573.	566.	310.	360.	1608.	4374.	7045.	28911.
1973	13770.	6514.	10757.	16194.	4214.	8093.	6718.	2336.	9774.	9964.	6572.	15866.	110772.
1974	27511.	8311.	5822.	3282.	3013.	1426.	830.	576.	4367.	3923.	10466.	7831.	77358.
1975	9971.	17467.	6630.	6310.	13392.	8566.	2911.	1674.	961.	1361.	2795.	2991.	75029.
1976	3552.	4476.	9265.	4891.	6849.	9010.	6980.	1143.	902.	1041.	1550.	6201.	55860.
1977	5080.	7977.	6921.	3035.	2358.	1652.	381.	697.	477.	384.	771.	1128.	30861.
1978	3806.	4498.	2889.	2627.	2227.	658.	294.	191.	4425.	678.	6405.	5582.	34280.
1979	21441.	14949.	13559.	11201.	18413.	18049.	4680.	3064.	4505.	1929.	8151.	8188.	128129.
1980	13166.	11405.	5757.	29461.	17089.	2438.	910.	580.	644.	808.	1419.	1608.	85285.
AVG.	10902.	9846.	11033.	9447.	10464.	5790.	2041.	655.	1595.	1875.	2839.	5900.	72387.

LAKE MURVAUL OPERATION w/ 2000 Area Capacity data adk 9/85/98
Inflow from 1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF NET EVAPORATION DATA
(VALUES IN FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1940	.01	-.17	.09	-.08	.07	.00	.25	.11	.34	.22	-.63	-.34	-.13
1941	-.04	-.11	-.05	-.05	-.09	-.10	.09	.32	.04	-.22	-.02	-.06	-.29
1942	.06	.06	.03	-.18	.02	.01	.31	.01	.22	.18	.13	-.09	.76
1943	-.04	.19	.04	.19	.07	.27	.31	.50	.23	.17	.10	-.12	1.91
1944	-.31	-.25	-.14	-.12	-.64	.23	.44	.21	.28	.33	-.22	-.46	-.65
1945	-.15	-.15	-.31	-.07	.10	.05	.08	.27	.29	-.13	.10	-.05	.03
1946	-.40	-.17	-.08	.02	-.29	.04	.33	.18	.23	.15	-.39	-.02	-.40
1947	-.23	.03	-.18	-.01	-.15	.24	.40	.41	.35	.27	-.08	-.18	.87
1948	-.19	-.22	-.01	.06	-.08	.33	.35	.48	.37	.24	-.22	-.03	1.08
1949	-.37	-.11	-.08	-.15	.12	.11	-.02	.22	.23	-.41	.22	-.17	-.41
1950	-.35	-.28	.07	-.09	-.25	.01	.13	.25	-.18	.19	.10	.06	-.34
1951	-.11	-.15	-.05	.16	.17	.14	.30	.58	-.14	.29	.05	-.10	1.14
1952	-.08	-.16	-.07	-.20	-.09	.30	.16	.55	.52	.48	-.15	-.09	1.17
1953	-.04	-.12	-.20	-.28	-.42	.28	-.03	.29	.29	.29	.04	-.15	-.05
1954	-.14	.16	.14	.01	-.25	.40	.55	.64	.56	.00	.01	.06	2.14
1955	-.07	-.24	.04	-.09	-.01	.32	.25	.04	.15	.36	.24	.07	1.06
1956	-.05	-.26	.08	.04	.01	.21	.50	.45	.45	.24	.12	.06	1.85
1957	-.05	-.13	-.16	-.60	.00	-.12	.29	.31	.09	-.25	-.35	.03	-.94
1958	-.16	-.01	.02	-.18	.02	.05	.33	.17	-.32	.18	.05	.12	.27
1959	.12	-.14	.09	-.13	-.09	.05	-.08	.23	.19	.08	.10	-.22	.20
1960	-.10	-.11	.06	.13	.28	.06	.29	.14	.14	.07	-.04	-.38	.54
1961	-.18	-.08	-.14	.19	.21	-.16	.03	.36	.05	.21	-.06	-.17	.26
1962	-.18	.02	.09	-.15	.18	.02	.40	.47	.11	.15	-.06	-.04	1.01
1963	.02	-.01	.09	-.12	.17	.09	.22	.45	.20	.43	.04	-.08	1.50
1964	.04	-.01	-.08	-.20	.08	.33	.53	.27	.19	.34	.08	-.10	1.47
1965	-.08	-.24	-.11	.18	-.31	.13	.47	.39	.12	.31	.10	-.19	.77
1966	-.06	.04	.13	.06	-.05	.32	.31	.24	.14	.16	.09	.05	1.43
1967	-.03	.02	.08	.02	-.08	.27	.31	.39	.23	.26	.06	.07	1.60
1968	.05	.02	-.01	-.03	.06	.21	.36	.31	.09	.01	.15	.09	1.31
1969	.05	-.07	.00	-.17	-.10	.41	.52	.43	.23	.25	.18	.04	1.77

LAKE MURVAUL OPERATION w/ 2000 Area Capacity data adk 9/85/98
Inflow from 1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

SUMMARY OF NET EVAPORATION DATA (CONTINUED)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1970	-.09	-.07	.08	-.26	.04	.34	.41	.35	.31	.13	.15	-.06	1.33
1971	.14	.02	.16	.23	.16	.33	.34	.30	.20	.14	.08	-.06	2.04
1972	-.06	.12	.09	.11	.20	.19	.23	.34	.19	.11	-.04	-.05	1.43
1973	-.09	.01	.02	-.03	.22	.11	.23	.38	.09	.04	.04	-.01	1.01
1974	-.21	.06	.09	.14	.15	.24	.44	.22	.02	.14	.00	-.03	1.26
1975	-.01	-.07	.01	.04	.08	.19	.41	.38	.35	.20	.07	.04	1.69
1976	.07	.06	.01	.13	.09	.22	.17	.43	.15	.10	.07	-.04	1.46
1977	-.08	.02	.05	.12	.30	.31	.48	.23	.25	.36	.05	.06	2.15
1978	-.10	-.01	.15	.22	.24	.40	.50	.49	.15	.36	-.03	-.03	2.34
1979	-.15	-.05	.05	.07	.16	.31	.28	.38	.23	.28	.06	-.01	1.61
1980	-.10	.03	.02	.07	.09	.42	.65	.62	.38	.26	.04	.12	2.60
AVG.	-.09	-.06	.00	-.02	.01	.18	.31	.34	.20	.17	.01	-.06	.99

LAKE MURVAUL OPERATION w/ 2000 Area Capacity data adk 9/85/98
Inflow from 1985 UPDATE OF SRA MASTER PLAN - ESPEY, HUSTON, & ASSOC

THERE ARE 8 AREA/CAPACITY/ELEVATION POINTS.

AREA (ACRES)	CAPACITY (ACRE-FEET)	ELEVATION (FEET)
0.	0.	237.0
1.	2.	240.0
401.	1007.	245.0
1171.	4938.	250.0
2031.	12943.	255.0
3111.	25799.	260.0
3721.	42879.	265.0
3751.	44000.	265.3

APPENDIX E

EXISTING WATER SUPPLY

Appendix E: Water Supply Distribution by County

County	Basin	Entity	Surface Supply (AF/Y)	Groundwater Supply (AF/Y)	Source of Surface Supply	Comment
Collin	Upper		2,638	11	NTMWD	Assume NTMWD will provide all of future need for Sabine portion of Collin County
Franklin	Upper		28		FCFWD1	Assume to be met by Franklin Co. Freshwater Supply Dist #1 in Cypress Basin
Gregg	Upper	Longview	20,547		Sabine & Big Sandy	
Gregg	Upper	Longview	19,000		Lake Fork	
Gregg	Upper	Longview	10,500		Lake Cherokee	
Gregg	Upper	Longview	20,000		Lake O' the Pines	System to be on in 2002; would like to get more from LOP if available.
Gregg	Upper	Kilgore	6,721		Lake Fork	
Gregg	Upper	SWEPCO	2,000		Lake Cherokee	Knox Power Plant
Gregg	Upper	Various	334		Misc Run-of-River	
Gregg	Upper	Total County	79,102	1,936		TWDB projected year 2000 Groundwater Use
Harrison	Upper	Longview	1,000		Lake Fork	
Harrison	Upper	Longview	5,500		Lake Cherokee	
Harrison	Upper	Marshall	16,000		Cypress Bayou	Interbasin Transfer from Cypress Basin
Harrison	Upper	SWEPCO	18,000		Brandy Branch	Interbasin transfer from Lake O' the Pines
Harrison	Upper	Eastman Chem	3,500		Lake Fork	
Harrison	Upper	Eastman Chem	134,500		Run-of-River Rt	Diversion amount is 134,500 AF/Y, but consumption amount is 22,500 AF/Y
Harrison	Upper	Various	793		Misc Run-of-River	
Harrison	Upper	Total County	179,293	2,606		TWDB projected year 2000 Groundwater Use
Hopkins	Upper	Various	95		Misc Run-of-River	
Hopkins	Upper					
Hopkins	Upper	Total County	95	876		
Hunt	Upper	Greenville	21,283		Lake Tawakoni	
Hunt	Upper	Greenville	4,159		Cowleech Fork	

Appendix E: Water Supply Distribution by County

County	Basin	Entity	Surface Supply (AF/Y)	Groundwater Supply (AF/Y)	Source of Surface Supply	Comment
Hunt	Upper	West Tawakoni	1,120		Lake Tawakoni	
Hunt	Upper	Cash WSC	3,004		Lake Tawakoni & Lk Fork	1680 AF/Y from Tawakoni & 1324 AF/Y Option from Lake Fork
Hunt	Upper	Community WC	92		Lake Tawakoni	
Hunt	Upper	Unassigned	11,860		Lake Tawakoni	Dallas' portion that is not available for interbasin transfer; currently not contracted to
Hunt	Upper	Various	250		Misc Run-of-River	
Hunt	Upper	Total County	41,768	352		TWDB projected year 2000 Groundwater Use
Kaufman	Upper	Able Springs WSC	1,120	5	Lake Fork	280 AF/Y Contract w/ 840 AF/Y Option
Panola	Upper	PCFWD1	22,400		Lake Murvaul	
Panola	Upper	PCFWD1	4,650		Lake Murvaul	Unpermitted additional yield
Panola	Upper	Various	1,123		Misc Run-of-River	
Panola	Upper	Total County	28,173	3,661		TWDB projected year 2000 Groundwater Use
Rains	Upper	Emory	1,120		Lake Tawakoni	
Rains	Upper	Emory	896		Lake Fork	
Rains	Upper	Combined Consumers WSC	1,500		Lake Fork & Tawakoni	Assumed 2/3 of service area, 1680 AF/Y Tawakoni & 560 AF/Y Lake Fork
Rains	Upper	Point	448		Lake Fork &	224 AF/Y from Tawakoni, 224 AF/Y Option
Rains	Upper	Various	307		Misc Run-of-River	
Rains	Upper	Total County	4,271	114		TWDB projected year 2000 Groundwater Use
Rockwall	Upper		3,705	50	NTMWD	Assume NTMWD will provide all of future need for Sabine portion of Rockwall County
Rusk	Upper	Henderson	5,041		Lake Fork	
Rusk	Upper	TU	25,000		Lake Martin	
Rusk	Upper	TU	5,000		Lake Fork	TU reserves its portion of its contract in Lake Fork for future use at Lake Martin

Appendix E: Water Supply Distribution by County

County	Basin	Entity	Surface Supply (AF/Y)	Groundwater Supply (AF/Y)	Source of Surface Supply	Comment
Rusk	Upper	Various	1,555		Misc Run-of-River	
Rusk	Upper	Total County	36,596	3,393		TWDB projected year 2000 Groundwater Use
Smith	Upper	Various	2,362		Misc Run-of-River	
Smith	Upper	Total County	2,362	5,058		TWDB projected year 2000 Groundwater Use
Upshur	Upper	Gladewater	3,358		Lake Gladewater	Current right is 1679 AF/Y; applying to increase use to 3358 AF (twice current right)
Upshur	Upper	Gladewater	1,081		Lake Gladewater	Additional yield; assume only 67% of total yield is available for future water supply.
Upshur	Upper	Various	1,130		Misc Run-of-River	
Upshur	Upper	Total County	5,569	1,250		Sabine portion of Upshur Co (33%) estimated 1995 pumpage (TWDB East TX model)
Van Zandt	Upper	Wills Point	2,240		Lake Tawakoni	
Van Zandt	Upper	Quitman	1,120		Lake Fork	
Van Zandt	Upper	Edgewood	840		Lake Fork	
Van Zandt	Upper	MacBee WSC	2,240		Lake Fork	
Van Zandt	Upper	South Tawakoni WSC	560		Lake Fork	
Van Zandt	Upper	Canton	1,562		Mill Creek &	
Van Zandt	Upper	Wills Point	300		Magby Creek	
Van Zandt	Upper	Edgewood	317		Unnamed trib,	
Van Zandt	Upper	Grand Saline	399		Simmons	
Van Zandt	Upper	Tawakoni Plant	184		Lake Tawakoni	
Van Zandt	Upper	Various	494		Misc Run-of-River	
Van Zandt	Upper	Total County	10,256	3,714		TWDB projected year 2000 Groundwater Use
Wood	Upper	Unassigned	169		Lake Fork	Unpermitted additional yield
Wood	Upper	Combined Consumers WSC	740		Lake Fork & Tawakoni	Assumed 1/3 of service area, 1680 AF/Y Tawakoni & 560 AF/Y Lake Fork

Appendix E: Water Supply Distribution by County

County	Basin	Entity	Surface Supply (AF/Y)	Groundwater Supply (AF/Y)	Source of Surface Supply	Comment
Wood	Upper	TU	7,000		Lake Fork	TU portion of its contract in Lake Fork assigned for power in Wood Co.
Wood	Upper	Various	2,353		Misc Run-of-River	
Wood	Upper	Total County	10,262	6,551		Sabine portion of Wood Co (85%) estimated 1995 pumpage (TWDB East TX model)
Jasper	Lower	Portion of Co.		1,838		TWDB projected year 2000 Groundwater Use
Newton	Lower	SRA	750,000		Toledo Bend	
Newton	Lower	SRA	147,100		SRA Canal	
Newton	Lower	Various	285		Misc Run-of-River	
Newton	Lower	Total County	897,385	4,144		TWDB projected year 2000 Groundwater Use
Orange	Lower	DuPont	267,000		Run-of-River Rt	
Orange	Lower	Various	67		Misc Run-of-River	
Orange	Lower	Portion of County		9,243		TWDB projected year 2000 Groundwater Use
Orange	Lower	Total County	267,067	9,243		
Sabine	Lower	Portion of County		368		TWDB projected year 2000 Groundwater Use
San Augustine	Lower	Portion of County		103		TWDB projected year 2000 Groundwater Use
Shelby	Lower	City of Center	1,460		Lake Center on Mill	
Shelby	Lower	Portion of County		2,793		Sabine portion of Shelby Co (80%) estimated 1995 pumpage (TWDB East TX model)

APPENDIX F

COST ESTIMATES

FREESE • NICHOLS

OPINION OF PROBABLE CONSTRUCTION COST

CARL L. ESTES RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
COST SUMMARY					
1	CONSTRUCTION COST	1	LS	$109,844,700.00	$109,844,700.00
2	LAND ACQUISITION COST	1	LS	$71,587,500.00	$71,587,500.00
3	CONFLICT RESOLUTION COST	1	LS	$36,681,620.00	$36,681,620.00
4	ENVIRONMENTAL MITIGATION COST	1	LS	$71,587,500.00	$71,587,500.00
5	PERMIT AND STUDIES	1	LS	$13,086,829.20	$13,086,829.20
6	ENGINEERING FEES (4% OF ITEMS 1, 2, &3)	1	LS	$8,724,552.80	$8,724,552.80
		SUBTOTAL:			$311,512,702.00
		CONTINGENCY:		20%	$62,302,500.00
PROJECT TOTAL					$373,815,202.00

R:\@CS\ESTIMATE\FILES\RESERVOIRS\CARL ESTES

FREESE • NICHOLS

CONSTRUCTION COST DETAILS

CARL L. ESTES RESERVOIR

SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
DAM EMBANKMENT					$56,845,274.72
1	DIVERSION AND CARE OF WATER	1	LS	$720,000.00	$720,000.00
2	CLEARING AND GRUBBING	600	AC	$864.00	$518,400.00
3	EXCAVATION	3,303,333	CY	$2.88	$9,513,599.04
4	COMPACTED FILL	7,448,999	CY	$2.88	$21,453,117.12
5	IMPERVIOUS FILL (CORE)	2,194,332	CY	$2.88	$6,319,676.16
6	RIPRAP BEDDING	68,206	CY	$21.60	$1,473,249.60
7	RIPRAP	227,354	TON	$43.20	$9,821,692.80
8	SLURRY TRENCH	130,500	SF	$5.76	$751,680.00
9	EMBANKMENT DRAINAGE AND INSTRUMENTATION	1	LS	$950,000.00	$950,000.00
10	TOPSOIL	110,700	CY	$14.40	$1,594,080.00
11	HYDROMULCH	5,977,800	SF	$0.10	$597,780.00
12	ROADWAY	783,000	SF	$4.00	$3,132,000.00
SPILLWAY					$34,123,380.00
1	CLEARING AND GRUBBING	5	AC	$864.00	$4,320.00
2	EXCAVATION	205,000	CY	$2.88	$590,400.00
3	PILES	260	EA	$864.00	$224,640.00
4	CONCRETE WEIR	30,000	CY	$300.00	$9,000,000.00
5	CONCRETE SLAB	900	CY	$250.00	$225,000.00
6	CONCRETE WALLS	2,300	CY	$325.00	$747,500.00
7	CONCRETE STILLING BASIN	2,500	CY	$250.00	$625,000.00
8	TAINTER GATES (40' x 35')	5	EA	$924,000.00	$4,620,000.00
9	SUPERSTRUCTURE AND HOISTS	1	LS	$500,000.00	$500,000.00
10	NON-OVERFLOW SECTION	52,600	CY	$325.00	$17,095,000.00
11	DRAINAGE SYSTEM	1	LS	$70,000.00	$70,000.00
12	RIPRAP BEDDING	1,200	CY	$21.60	$25,920.00
13	RIPRAP	8,200	TON	$43.20	$354,240.00
14	HYDROMULCH	44,000	SF	$0.10	$4,400.00
15	FENCING	600	LF	$21.60	$12,960.00
16	4'-0" x 8'-0" SLUICE GATES	2	EA	$12,000.00	$24,000.00
		SUBTOTAL:			$90,968,654.72
		MOBILIZATION:		5%	$4,548,400.00
		SUBTOTAL:			$95,517,100.00
		OH & P:		15%	$14,327,600.00
CONSTRUCTION COST TOTAL					$109,844,700.00

FREESE • NICHOLS

LAND ACQUISITION COST DETAILS

CARL L. ESTES RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
LAND ACQUISITION COST					$71,587,500.00
1	LAND ACQUISITION COST- 31125 AC	31,125	AC	$2,300.00	$71,587,500.00

FREESE • NICHOLS

CONFLICT RESOLUTION COST DETAILS

CARL L. ESTES RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
CONFLICT RESOLUTION COST					$36,681,620.00
1	MAIN HIGHWAYS	1	LS	$21,848,000.00	$21,848,000.00
2	LIGHT-DUTY ROADS	1	LS	$5,322,500.00	$5,322,500.00
	(ASSUME 75% ABANDONED)				
3	UNIMPROVED ROADS	1	LS	$0.00	$0.00
	(ASSUME ALL ABANDONED)				
4	PIPELINES	1	LS	$5,275,000.00	$5,275,000.00
5	POWER LINES	1	LS	$3,498,600.00	$3,498,600.00
6	OIL WELLS	1	LS	$168,760.00	$168,760.00
7	GAS WELLS	1	LS	$168,760.00	$168,760.00
8	DWELLINGS	1	LS	$400,000.00	$400,000.00

ENVIRONMENTAL MITIGATION COST DETAILS

FREESE • NICHOLS

CARL L. ESTES RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
ENVIRONMENTAL MITIGATION COST					$71,587,500.00
1	ENVIRONMENTAL MITIGATION COST	1	LS	$71,587,500.00	$71,587,500.00
	(ASSUME EQUAL TO LAND ACQUISITION COST 1:1 RATIO)				

FREESE • NICHOLS

PERMIT AND STUDIES COST DETAILS

CARL L. ESTES RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PERMIT AND STUDIES					$13,086,829.20
1	PERMIT AND STUDIES				
	MEDIUM CLASSIFICATION	1	LS	$13,086,829.20	$13,086,829.20
	(6% OF ITEMS 1, 2, & 3 ON SUMMARY SHEET)				

OPINION OF PROBABLE CONSTRUCTION COST

FREESE • NICHOLS

BIG SANDY RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
COST SUMMARY					
1	CONSTRUCTION COST	1	LS	$14,145,800.00	$14,145,800.00
2	LAND ACQUISITION COST	1	LS	$12,663,800.00	$12,663,800.00
3	CONFLICT RESOLUTION COST	1	LS	$21,768,800.00	$21,768,800.00
4	ENVIRONMENTAL MITIGATION COST	1	LS	$12,663,800.00	$12,663,800.00
5	PERMIT AND STUDIES	1	LS	$2,914,704.00	$2,914,704.00
6	ENGINEERING FEES (10% OF ITEMS 1, 2, &3)	1	LS	$4,857,840.00	$4,857,840.00
		SUBTOTAL:			$69,014,744.00
		CONTINGENCY:		20%	$13,802,900.00
PROJECT TOTAL					$82,817,644.00

R:\@CS\ESTIMATE\FILES\RESERVOIRS\BIG SANDY_ESTIMATE.XLS

FREESE • NICHOLS

CONSTRUCTION COST DETAILS

BIG SANDY RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
DAM EMBANKMENT					$5,600,918.64
1	DIVERSION AND CARE OF WATER	1	LS	$720,000.00	$720,000.00
2	CLEARING AND GRUBBING	50	AC	$864.00	$43,200.00
3	EXCAVATION	273,944	CY	$2.88	$788,958.72
4	COMPACTED FILL	669,844	CY	$2.88	$1,929,150.72
5	RIPRAP BEDDING	5,647	CY	$21.60	$121,975.20
6	RIPRAP	18,824	TON	$43.20	$813,196.80
7	SLURRY TRENCH	10,900	SF	$5.76	$62,784.00
8	SOIL CEMENT	11,000	CY	$28.80	$316,800.00
9	EMBANKMENT DRAINAGE AND INSTRUMENTATION	1	LS	$330,000.00	$330,000.00
10	TOPSOIL	9,153	CY	$14.40	$131,803.20
11	HYDROMULCH	494,250	SF	$0.10	$49,425.00
12	ROADWAY	65,250	SF	$4.50	$293,625.00
SPILLWAY					$5,183,952.00
1	CLEARING AND GRUBBING	5	AC	$864.00	$4,320.00
2	EXCAVATION	38,000	CY	$2.88	$109,440.00
3	PILES	308	EA	$864.00	$266,112.00
4	CONCRETE WEIR	950	CY	$300.00	$285,000.00
5	CONCRETE SLAB	460	CY	$250.00	$115,000.00
6	CONCRETE WALLS	2,280	CY	$325.00	$741,000.00
7	TAINTER GATES (45'x 23.6')	4	EA	$715,000.00	$2,860,000.00
8	SUPERSTRUCTURE AND HOISTS	1	LS	$288,000.00	$288,000.00
9	DRAINAGE SYSTEM	1	LS	$73,000.00	$73,000.00
10	RIPRAP BEDDING	1,700	CY	$21.60	$36,720.00
11	RIPRAP	9,000	TON	$43.20	$388,800.00
12	HYDROMULCH	36,000	SF	$0.10	$3,600.00
13	FENCING	600	LF	$21.60	$12,960.00
OUTLET WORKS					$930,088.00
1	CONCRETE INTAKE STRUCTURE	130	CY	$504.00	$65,520.00
2	66" CONDUIT	500	LF	$324.00	$162,000.00
3	CONCRETE STILLING BASIN	2,300	CY	$250.00	$575,000.00
4	RIPRAP	120	TON	$43.20	$5,184.00
5	EXCAVATION	4,300	CY	$2.88	$12,384.00
6	GATES AND ACCESS BRIDGE	1	LS	$110,000.00	$110,000.00
		SUBTOTAL:			$11,714,958.64
		MOBILIZATION:		5%	$585,700.00
		SUBTOTAL:			$12,300,700.00
		OH & P:		15%	$1,845,100.00
CONSTRUCTION COST TOTAL					$14,145,800.00

LAND ACQUISITION COST DETAILS

FREESE • NICHOLS

BIG SANDY RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
LAND ACQUISITION COST					$12,663,800.00
1	LAND ACQUISITION COST- 5506 AC	5,506	LS	$2,300.00	$12,663,800.00

CONFLICT RESOLUTION COST DETAILS

FREESE • NICHOLS

BIG SANDY RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
CONFLICT RESOLUTION COST					$21,768,800.00
1	MAIN HIGHWAYS	1	LS	$15,048,000.00	$15,048,000.00
2	LIGHT-DUTY ROADS	1	LS	$3,352,000.00	$3,352,000.00
	(ASSUME 75% ABANDONED)				
3	UNIMPROVED ROADS	1	LS	$0.00	$0.00
	(ASSUME ALL ABANDONED)				
4	PIPELINES	1	LS	$2,125,000.00	$2,125,000.00
5	OIL WELLS	1	LS	$843,800.00	$843,800.00
6	DWELLINGS	1	LS	$400,000.00	$400,000.00

FREESE • NICHOLS

ENVIRONMENTAL MITIGATION COST DETAILS

BIG SANDY RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
ENVIRONMENTAL MITIGATION COST					$12,663,800.00
1	ENVIRONMENTAL MITIGATION COST	1	LS	$12,663,800.00	$12,663,800.00
	(ASSUME EQUAL TO LAND ACQUISITION COST 1:1 RATIO)				

FREESE • NICHOLS

PERMIT AND STUDIES COST DETAILS

BIG SANDY RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PERMIT AND STUDIES					$2,914,704.00
1	PERMIT AND STUDIES				
	MEDIUM CLASSIFICATION	1	LS	$2,914,704.00	$2,914,704.00
	(6% OF ITEMS 1, 2, & 3 ON SUMMARY SHEET)				

FREESE • NICHOLS

OPINION OF PROBABLE CONSTRUCTION COST

WATERS BLUFF RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
COST SUMMARY					
1	CONSTRUCTION COST	1	LS	$71,974,600.00	$71,974,600.00
2	LAND ACQUISITION COST	1	LS	$104,638,500.00	$104,638,500.00
3	CONFLICT RESOLUTION COST	1	LS	$89,443,640.00	$89,443,640.00
4	ENVIRONMENTAL MITIGATION COST	1	LS	$104,638,500.00	$104,638,500.00
5	PERMIT AND STUDIES	1	LS	$26,605,674.00	$26,605,674.00
6	ENGINEERING FEES (4% OF ITEMS 1, 2, & 3)	1	LS	$10,642,269.60	$10,642,269.60
		SUBTOTAL:			$407,943,183.60
		CONTINGENCY:		20%	$81,588,600.00
PROJECT TOTAL					$489,531,783.60

R:\@CS\ESTIMATE\FILES\RESERVOIRS\WATERS BLUFF

FREESE • NICHOLS

CONSTRUCTION COST DETAILS

WATERS BLUFF RESERVOIR

SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
DAM EMBANKMENT					$7,790,404.00
1	DIVERSION AND CARE OF WATER	1	LS	$1,278,000.00	$1,278,000.00
2	CLEARING AND GRUBBING	90	AC	$532.50	$47,925.00
3	EXCAVATION	860,200	CY	$2.84	$2,442,968.00
4	RANDOM FILL	716,400	CY	$0.85	$610,372.80
5	IMPERVIOUS EMBANKMENT CORE	329,100	CY	$0.85	$280,393.20
6	SOIL CEMENT	55,450	CY	$24.14	$1,338,563.00
7	FILTER MATERIAL	78,500	CY	$17.04	$1,337,640.00
8	ACCESS ROAD AND ROAD ON DAM	32,200	SY	$6.39	$205,758.00
9	STRIPPING AND INSPECTION TRENCH	116,800	CY	$2.13	$248,784.00
SPILLWAY					$51,815,921.80
1	SILL CONCRETE	24,850	CY	$200.00	$4,970,000.00
2	PIER CONCRETE	19,300	CY	$250.00	$4,825,000.00
3	BASIN CONCRETE	22,340	CY	$250.00	$5,585,000.00
4	TRAINING WALL CONCRETE	18,800	CY	$325.00	$6,110,000.00
5	CEMENT	24,740	TON	$106.50	$2,634,810.00
6	REINFORCING STEEL	5,700	TON	$1,136.00	$6,475,200.00
7	TAINTER GATES (40' x 28') **	11	EA	$742,500.00	$8,167,500.00
8	GATE ANCHORAGE	1	LS	$976,960.00	$976,960.00
9	GATE MACHINERY	1	LS	$2,577,300.00	$2,577,300.00
9	MAINTENANCE BULKHEADS	110,000	LB	$4.26	$468,600.00
10	MISC. METALS AND EMBEDS	233,450	LB	$5.68	$1,325,996.00
11	SPILLWAY BRIDGE	1	LS	$535,340.00	$535,340.00
12	FOUNDATION DRAINAGE	1	LS	$1,299,300.00	$1,299,300.00
13	APPROACH SLAB	9,450	CY	$250.00	$2,362,500.00
14	STONE PROTECTION	31,850	TON	$65.32	$2,080,442.00
15	GRADED FILTER RIPRAP	4,950	CY	$17.04	$84,348.00
16	UPSTREAM IMPERVIOUS BLANKET	11,650	CY	$0.85	$9,925.80
17	NON-OVERFLOW SECTION	1	LS	$1,327,700.00	$1,327,700.00
		SUBTOTAL:			$59,606,325.80
		MOBILIZATION:		5%	$2,980,300.00
		SUBTOTAL:			$62,586,600.00
		OH & P:		15%	$9,388,000.00
CONSTRUCTION COST TOTAL					$71,974,600.00

NOTE: COST ADJUSTED FROM OCTOBER 1985 TO DECEMBER 1998

** PRICE QUOTE FROM SUPPLIER

LAND ACQUISITION COST DETAILS

FREESE • NICHOLS

WATERS BLUFF RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
LAND ACQUISITION COST					$104.638.500.00
1	LAND ACQUISITION COST- 45,495 AC	45,495	AC	$2,300.00	$104,638,500.00

FREESE • NICHOLS

CONFLICT RESOLUTION COST DETAILS

WATERS BLUFF RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
CONFLICT RESOLUTION COST					$89,443,640.00
1	MAIN HIGHWAYS	1	LS	$38,008,000.00	$38,008,000.00
2	LIGHT-DUTY ROADS	1	LS	$9,582,500.00	$9,582,500.00
	(ASSUME 75% ABANDONED)				
3	UNIMPROVED ROADS	1	LS	$0.00	$0.00
	(ASSUME ALL ABANDONED)				
4	PIPELINES	1	LS	$17,175,000.00	$17,175,000.00
5	POWER LINES	1	LS	$1,500,000.00	$1,500,000.00
6	RAILROADS	1	LS	$9,250,000.00	$9,250,000.00
7	OIL WELLS	1	LS	$253,140.00	$253,140.00
8	DWELLINGS	1	LS	$1,000,000.00	$1,000,000.00
9	FISH HATCHERY	1	LS	$750,000.00	$750,000.00
10	PUMP STATION	1	LS	$1,250,000.00	$1,250,000.00
11	AQUADUCT	1	LS	$1,850,000.00	$1,850,000.00
12	WATER / WASTEWATER PLANT	1	LS	$8,750,000.00	$8,750,000.00
13	GAGING STATION	1	LS	$75,000.00	$75,000.00

FREESE • NICHOLS

ENVIRONMENTAL MITIGATION COST DETAILS

WATERS BLUFF RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
ENVIRONMENTAL MITIGATION COST					$104,638,500.00
1	ENVIRONMENTAL MITIGATION COST	1	LS	$104,638,500.00	$104,638,500.00
	(ASSUME EQUAL TO LAND ACQUISITION COST 1:1 RATIO)				

PERMIT AND STUDIES COST DETAILS

FREESE - NICHOLS

WATERS BLUFF RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PERMIT AND STUDIES					$26.605.674.00
1	PERMIT AND STUDIES				
	HIGH CLASSIFICATION	1	LS	$26,605,674.00	$26,605,674.00
	(10% OF ITEMS 1, 2, & 3 ON SUMMARY SHEET)				

OPINION OF PROBABLE CONSTRUCTION COST

FREESE • NICHOLS

PRAIRIE CREEK RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
COST SUMMARY					
1	CONSTRUCTION COST	1	LS	$18,184,400.00	$18,184,400.00
2	LAND ACQUISITION COST	1	LS	$6,555,000.00	$6,555,000.00
3	CONFLICT RESOLUTION COST	1	LS	$10,848,540.00	$10,848,540.00
4	ENVIRONMENTAL MITIGATION COST	1	LS	$6,555,000.00	$6,555,000.00
5	PERMIT AND STUDIES	1	LS	$711,758.80	$711,758.80
6	ENGINEERING FEES (10% OF ITEMS 1, 2, & 3)	1	LS	$3,558,794.00	$3,558,794.00
		SUBTOTAL:			$46,413,492.80
		CONTINGENCY		20%	$9,282,700.00
PROJECT TOTAL					$55,696,192.80

CONSTRUCTION COST DETAILS

PRAIRIE CREEK RESERVOIR
SABINE RIVER AUTHORITY

FREESE • NICHOLS

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
DAM EMBANKMENT					$8,462,016.00
1	DIVERSION AND CARE OF WATER	1	LS	$720,000.00	$720,000.00
2	CLEARING AND GRUBBING	33	AC	$864.00	$28,512.00
3	EXCAVATION	53,200	CY	$2.88	$153,216.00
4	COMPACTED FILL	1,362,000	CY	$2.88	$3,922,560.00
5	SLURRY TRENCH	173,000	SF	$5.76	$996,480.00
6	SOIL CEMENT	65,800	CY	$28.80	$1,895,040.00
7	EMBANKMENT DRAINAGE AND INSTRUMENTATION	1	LS	$423,360.00	$423,360.00
8	TOPSOIL	10,100	CY	$14.40	$145,440.00
9	HYDROMULCH	660,000	SF	$0.10	$66,528.00
10	ROADWAY	1	LS	$110,880.00	$110,880.00
SPILLWAY					$6,144,590.00
1	CLEARING AND GRUBBING	10	AC	$864.00	$8,640.00
2	EXCAVATION	356,000	CY	$2.88	$1,025,280.00
3	PILES	590	EA	$864.00	$509,760.00
4	CONCRETE WEIR	1,330	CY	$300.00	$399,000.00
5	CONCRETE SLAB	2,200	CY	$250.00	$550,000.00
6	CONCRETE WALLS	7,190	CY	$325.00	$2,336,750.00
7	TAINTER GATES (24' x 20') **	2	EA	$319,000.00	$638,000.00
8	SUPERSTRUCTURE AND HOISTS	1	LS	$144,000.00	$144,000.00
9	DRAINAGE SYSTEM	1	LS	$72,000.00	$72,000.00
10	RIPRAP BEDDING	960	CY	$21.60	$20,736.00
11	RIPRAP	9,620	TON	$43.20	$415,584.00
12	HYDROMULCH	75,000	SF	$0.10	$7,560.00
13	FENCING	800	LF	$21.60	$17,280.00
OUTLET WORKS					$452,848.00
1	CONCRETE INTAKE STRUCTURE	250	CY	$504.00	$126,000.00
2	66" CONDUIT	500	LF	$324.00	$162,000.00
3	CONCRETE STILLING BASIN	160	CY	$250.00	$40,000.00
4	RIPRAP	110	TON	$43.20	$4,752.00
5	EXCAVATION	4,200	CY	$2.88	$12,096.00
6	GATES AND ACCESS BRIDGE	1	LS	$108,000.00	$108,000.00
		SUBTOTAL:			$15,059,454.00
		MOBILIZATION:		5%	$753,000.00
		SUBTOTAL:			$15,812,500.00
		OH & P:		15%	$2,371,900.00
CONSTRUCTION COST TOTAL					$18,184,400.00

NOTE: COST ADJUSTED FROM JUNE 1984 TO DECEMBER 1998.
** PRICE QUOTE FROM SUPPLIER

FREESE • NICHOLS

LAND ACQUISITION COST DETAILS

PRAIRIE CREEK RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
LAND	ACQUISITION COST				$6,555,000.00
1	LAND ACQUISITION COST- 2850 AC	2,850	AC	$2,300.00	$6,555,000.00

FREESE • NICHOLS

CONFLICT RESOLUTION COST DETAILS

PRAIRIE CREEK RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
CONFLICT RESOLUTION COST					$10,848,540.00
1	MAIN HIGHWAYS	1	LS	$8,452,500.00	$8,452,500.00
2	LIGHT-DUTY ROADS	1	LS	$1,546,000.00	$1,546,000.00
	(ASSUME 75% ABANDONED)				
3	UNIMPROVED ROADS	1	LS	$0.00	$0.00
	(ASSUME ALL ABANDONED)				
4	OIL WELLS	1	LS	$675,040.00	$675,040.00
5	DWELLINGS	1	LS	$175,000.00	$175,000.00

FREESE • NICHOLS

ENVIRONMENTAL MITIGATION COST DETAILS

PRAIRIE CREEK RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
ENVIRONMENTAL MITIGATION COST					$6.555.000.00
1	ENVIRONMENTAL MITIGATION COST	1	LS	$6,555,000.00	$6,555,000.00
	(ASSUME EQUAL TO LAND ACQUISITION COST 1:1 RATIO)				

FREESE • NICHOLS

PERMIT AND STUDIES COST DETAILS

PRAIRIE CREEK RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PERMIT AND STUDIES					$711,758.80
1	PERMIT AND STUDIES				
	LOW CLASSIFICATION	1	LS	$711,758.80	$711,758.80
	(2% OF ITEMS 1, 2, & 3 ON SUMMARY SHEET)				

OPINION OF PROBABLE CONSTRUCTION COST

FREESE • NICHOLS

STATE HWY 322 (STAGE I & II)
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
COST SUMMARY					
1	CONSTRUCTION COST	1	LS	$43,844,200.00	$43,844,200.00
2	LAND ACQUISITION COST	1	LS	$18,715,100.00	$18,715,100.00
3	CONFLICT RESOLUTION COST	1	LS	$15,574,380.00	$15,574,380.00
4	ENVIRONMENTAL MITIGATION COST	1	LS	$18,715,100.00	$18,715,100.00
5	PERMIT AND STUDIES	1	LS	$1,562,673.60	$1,562,673.60
6	ENGINEERING FEES (10% OF ITEMS 1, 2, &3)	1	LS	$7,813,368.00	$7,813,368.00
		SUBTOTAL:			$106,224,821.60
		CONTINGENCY:		20%	$21,245,000.00
PROJECT TOTAL					$127,469,821.60

R:\@CS\ESTIMATE\FILES\RESERVOIRS\STATE HWY 322_ESTIMATE.XLS

CONSTRUCTION COST DETAILS

FREESE • NICHOLS

STATE HWY 322 (STAGE I & II)
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
DAM EMBANKMENT					$16,517,859.44
1	DIVERSION AND CARE OF WATER	1	LS	$720,000.00	$720,000.00
2	CLEARING AND GRUBBING	214	AC	$864.00	$184,896.00
3	EXCAVATION	863,516	CY	$2.88	$2,486,926.08
4	COMPACTED FILL	1,781,657	CY	$2.88	$5,131,172.16
5	RIPRAP BEDDING	12,300	CY	$21.60	$265,680.00
6	RIPRAP	41,000	TON	$43.20	$1,771,200.00
7	SLURRY TRENCH	550,000	SF	$5.76	$3,168,000.00
8	SOIL CEMENT	54,600	CY	$28.80	$1,572,480.00
9	EMBANKMENT DRAINAGE AND INSTRUMENTATION	1	LS	$423,360.00	$423,360.00
10	TOPSOIL	27,708	CY	$14.40	$398,995.20
11	HYDROMULCH	1,496,300	SF	$0.10	$149,630.00
12	ROADWAY	186,000	SF	$1.32	$245,520.00
SPILLWAY					$12,375,480.00
1	CLEARING AND GRUBBING	10	AC	$864.00	$8,640.00
2	EXCAVATION	50,000	CY	$2.88	$144,000.00
3	CONCRETE WEIR	1,950	CY	$300.00	$585,000.00
4	CONCRETE SLAB	22,400	CY	$250.00	$5,600,000.00
5	CONCRETE WALLS	13,400	CY	$325.00	$4,355,000.00
6	RIPRAP BEDDING	5,400	CY	$21.60	$116,640.00
7	RIPRAP	36,000	TON	$43.20	$1,555,200.00
8	HYDROMULCH	110,000	SF	$0.10	$11,000.00
OUTLET WORKS					$7,416,560.00
1	CONCRETE INTAKE STRUCTURE (42" CONDUIT)	130	CY	$504.00	$65,520.00
2	42" CONDUIT	420	LF	$324.00	$136,080.00
3	CONCRETE INTAKE STRUCTURE (36" CONDUIT)	115	CY	$504.00	$57,960.00
4	36" CONDUIT	350	LF	$324.00	$113,400.00
5	CONCRETE STILLING BASIN	26,800	CY	$250.00	$6,700,000.00
6	RIPRAP	1,500	TON	$43.20	$64,800.00
7	EXCAVATION	10,000	CY	$2.88	$28,800.00
8	GATES AND ACCESS BRIDGE	1	LS	$250,000.00	$250,000.00
		SUBTOTAL:			$36,309,899.44
		MOBILIZATION:		5%	$1,815,500.00
		SUBTOTAL:			$38,125,400.00
		OH & P:		15%	$5,718,800.00
CONSTRUCTION COST TOTAL					$43,844,200.00

FREESE • NICHOLS

LAND ACQUISITION COST DETAILS

STATE HWY 322 (STAGE I & II)
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
LAND ACQUISITION COST					$18.715.100.00
1	LAND ACQUISITION COST- 8137 AC	8,137	AC	$2,300.00	$18,715,100.00
	(STAGE I AND STAGE II)				

FREESE • NICHOLS

CONFLICT RESOLUTION COST DETAILS

STATE HWY 322 (STAGE I & II)
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
CONFLICT RESOLUTION COST					$15,574,380.00
1	MAIN HIGHWAYS	1	LS	$11,902,500.00	$11,902,500.00
2	LIGHT-DUTY ROADS	1	LS	$3,187,500.00	$3,187,500.00
	(ASSUME 75% ABANDONED)				
3	UNIMPROVED ROADS	1	LS	$0.00	$0.00
	(ASSUME ALL ABANDONED)				
4	PIPELINES	1	LS	$275,000.00	$275,000.00
5	GAS WELLS	1	LS	$84,380.00	$84,380.00
6	DWELLINGS	1	LS	$125,000.00	$125,000.00

FREESE • NICHOLS

ENVIRONMENTAL MITIGATION COST DETAILS

STATE HWY 322 (STAGE I & II)
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
ENVIRONMENTAL MITIGATION COST					$18,715,100.00
1	ENVIRONMENTAL MITIGATION COST	1	LS	$18,715,100.00	$18,715,100.00
	(ASSUME EQUAL TO LAND ACQUISITION COST 1:1 RATIO)				

FREESE • NICHOLS

PERMIT AND STUDIES COST DETAILS

STATE HWY 322 (STAGE I & II)

SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PERMIT AND STUDIES					$1,562,673.60
1	PERMIT AND STUDIES				
	LOW CLASSIFICATION	1	LS	$1,562,673.60	$1,562,673.60
	(2% OF ITEMS 1, 2, & 3 ON SUMMARY SHEET)				

OPINION OF PROBABLE CONSTRUCTION COST

FREESE • NICHOLS

CARTHAGE RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
COST SUMMARY					
1	CONSTRUCTION COST	1	LS	$42,309,200.00	$42,309,200.00
2	LAND ACQUISITION COST	1	LS	$118,450,000.00	$118,450,000.00
3	CONFLICT RESOLUTION COST	1	LS	$97,791,620.00	$97,791,620.00
4	ENVIRONMENTAL MITIGATION COST	1	LS	$118,450,000.00	$118,450,000.00
5	PERMIT AND STUDIES	1	LS	$25,855,082.00	$25,855,082.00
6	ENGINEERING FEES (4% OF ITEMS 1, 2, &3)	1	LS	$10,342,032.80	$10,342,032.80
		SUBTOTAL:			$413,197,934.80
		CONTINGENCY:		20%	$82,639,600.00
PROJECT TOTAL					$495,837,534.80

R:\@CS\ESTIMATE\FILES\RESERVOIRS\Carthage

CONSTRUCTION COST DETAILS

FREESE • NICHOLS

CARTHAGE RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
DAM EMBANKMENT					$24,967,341.92
1	DIVERSION AND CARE OF WATER	1	LS	$720,000.00	$720,000.00
2	CLEARING AND GRUBBING	420	AC	$864.00	$362,880.00
3	EXCAVATION	1,483,258	CY	$2.88	$4,271,783.04
4	COMPACTED FILL	2,863,406	CY	$2.88	$8,246,609.28
5	RIPRAP BEDDING	30,951	CY	$21.60	$668,541.60
6	RIPRAP	103,172	TON	$43.20	$4,457,030.40
7	SLURRY TRENCH	91,600	SF	$5.76	$527,616.00
8	SOIL CEMENT	82,300	CY	$28.80	$2,370,240.00
9	EMBANKMENT DRAINAGE AND INSTRUMENTATION	1	LS	$700,000.00	$700,000.00
10	TOPSOIL	50,194	CY	$14.40	$722,793.60
11	HYDROMULCH	2,710,480	SF	$0.10	$271,048.00
12	ROADWAY	366,400	SF	$4.50	$1,648,800.00
SPILLWAY					$10,071,352.00
1	CLEARING AND GRUBBING	11	AC	$864.00	$9,504.00
2	EXCAVATION	53,600	CY	$2.88	$154,368.00
3	PILES	650	EA	$864.00	$561,600.00
4	CONCRETE WEIR	1,680	CY	$300.00	$504,000.00
5	CONCRETE SLAB	1,230	CY	$250.00	$307,500.00
6	CONCRETE WALLS	2,040	CY	$325.00	$663,000.00
6	CONCRETE STILLING BASIN	5,500	CY	$250.00	$1,375,000.00
7	TAINTER GATES (40' x 20')	10	EA	$528,000.00	$5,280,000.00
8	SUPERSTRUCTURE AND HOISTS	1	LS	$800,000.00	$800,000.00
9	DRAINAGE SYSTEM	1	LS	$130,000.00	$130,000.00
10	RIPRAP BEDDING	1,250	CY	$21.60	$27,000.00
11	RIPRAP	5,400	TON	$43.20	$233,280.00
12	HYDROMULCH	1,800	SF	$0.10	$180.00
13	FENCING	1,200	LF	$21.60	$25,920.00
		SUBTOTAL:			$35,038,693.92
		MOBILIZATION:		5%	$1,751,900.00
		SUBTOTAL:			$36,790,600.00
		OH & P:		15%	$5,518,600.00
CONSTRUCTION COST TOTAL					$42,309,200.00

FREESE • NICHOLS

LAND ACQUISITION COST DETAILS

CARTHAGE RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
LAND ACQUISITION COST					$118,450,000.00
1	LAND ACQUISITION COST- 51,500 AC	51,500	AC	$2,300.00	$118,450,000.00

FREESE • NICHOLS

CONFLICT RESOLUTION COST DETAILS

CARTHAGE RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	CONFLICT RESOLUTION COST				$97,791,620.00
1	MAIN HIGHWAYS	1	LS	$49,208,000.00	$49,208,000.00
2	LIGHT-DUTY ROADS	1	LS	$16,370,000.00	$16,370,000.00
	(ASSUME 75% ABANDONED)				
3	UNIMPROVED ROADS	1	LS	$0.00	$0.00
	(ASSUME ALL ABANDONED)				
4	PIPELINES	1	LS	$9,637,500.00	$9,637,500.00
5	POWER LINES	1	LS	$15,351,000.00	$15,351,000.00
6	RAILROADS	1	LS	$1,700,000.00	$1,700,000.00
7	OIL WELLS	1	LS	$1,181,320.00	$1,181,320.00
8	GAS WELLS	1	LS	$843,800.00	$843,800.00
9	DWELLINGS	1	LS	$450,000.00	$450,000.00
10	CEMETERIES	1	LS	$750,000.00	$750,000.00
11	FISH FARM	1	LS	$300,000.00	$300,000.00
12	POWER PLANT	1	LS	$2,000,000.00	$2,000,000.00

FREESE • NICHOLS

ENVIRONMENTAL MITIGATION COST DETAILS

CARTHAGE RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
ENVIRONMENTAL MITIGATION COST					$118,450,000.00
1	ENVIRONMENTAL MITIGATION COST	1	LS	$118,450,000.00	$118,450,000.00
	(ASSUME EQUAL TO LAND ACQUISITION COST 1:1 RATIO)				

PERMIT AND STUDIES COST DETAILS

FREESE • NICHOLS

CARTHAGE RESERVOIR
SABINE RIVER AUTHORITY

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	December 14, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
PERMIT AND STUDIES					\$25,855,082.00
1	PERMIT AND STUDIES				
	HIGH CLASSIFICATION	1	LS	\$25,855,082.00	\$25,855,082.00
	(10% OF ITEMS 1, 2, & 3 ON SUMMARY SHEET)				

FREESE • NICHOLS

OPINION OF PROBABLE CONSTRUCTION COST

TOLEDO BEND PIPELINE

SABINE RIVER AUTHORITY

, TEXAS

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	November 12, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
OPTION 1 - 60" PIPELINE					
	PIPELINE	1	LS	$0.00	$0.00
	PUMP STATION	1	LS	$0.00	$0.00
	LIFT STATIONS	1	LS	$0.00	$0.00
		SUBTOTAL:			$0.00
		MOBILIZATION:		5%	$0.00
		SUBTOTAL:			$0.00
		OH & P:		15%	$0.00
		SUBTOTAL:			$0.00
		CONTINGENCY:		20%	$0.00
PROJECT TOTAL (OPTION 1)					**$0.00**
OPTION 2 - 72" PIPELINE					
	PIPELINE	1	LS	$0.00	$0.00
	PUMP STATION	1	LS	$0.00	$0.00
	LIFT STATIONS	1	LS	$0.00	$0.00
		SUBTOTAL:			$0.00
		MOBILIZATION:		5%	$0.00
		SUBTOTAL:			$0.00
		OH & P:		15%	$0.00
		SUBTOTAL:			$0.00
		CONTINGENCY:		20%	$0.00
PROJECT TOTAL (OPTION 2)					**$0.00**

R:\@CS\ESTIMATE\FILES\RESERVOIRS\TOLEDO BEND PIPELINE

FREESE • NICHOLS

OPINION OF PROBABLE CONSTRUCTION COST

TOLEDO BEND PIPELINE - OPTION 1

SABINE RIVER AUTHORITY

, TEXAS

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	November 12, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
60" PIPELINE					$0.00
	TRENCH SAFETY		LF	$1.50	$0.00
	60" LINE		LF		$0.00
	2000 PSI CONCRETE ENCASEMENT		LF	$80.00	$0.00
	COARSE AGGREGATE EMBEDMENT		CY	$25.00	$0.00
	GATE VALVES		EA		$0.00
PUMP STATION					$0.00
	PUMPS & MOTORS		EA		$0.00
	CONCRETE ENCASEMENT		CY		$0.00
	ACCESS MANHOLE		EA		$0.00
	FLOW METER AND VAULT	1	LS		$0.00
			LS		$0.00
LIFT STATIONS					$0.00
	SUMP PUMPS		EA		$0.00
	CONCRETE ENCASEMENT		CY		$0.00
	ACCESS MANHOLE		EA		$0.00
			LS		$0.00
			LS		$0.00

FREESE • NICHOLS

OPINION OF PROBABLE CONSTRUCTION COST

TOLEDO BEND PIPELINE - OPTION 2

SABINE RIVER AUTHORITY

, TEXAS

ACCOUNT NO.	ESTIMATOR	CHECKED BY	DATE
SRA96425	JSV/JMC	JMN	November 12, 1998

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
72" PIPELINE					$0.00
	TRENCH SAFETY	1	LS		$0.00
	60" LINE		LS		$0.00
			LS		$0.00
			LS		$0.00
			LS		$0.00
PUMP STATION					$0.00
			LS		$0.00
			LS		$0.00
			LS		$0.00
			LS		$0.00
			LS		$0.00
LIFT STATIONS					$0.00
			LS		$0.00
			LS		$0.00
			LS		$0.00
			LS		$0.00
			LS		$0.00

CONFLICTS FOR PROPOSED RESERVOIRS FOR SRA
PROJECT: SURFACE WATER PROJECTS FOR SRA
PROJECT NO.: SRA96425

	RESERVOIR					
CONFLICT	CARTHAGE	BIG SANDY	CARL ESTES	PRAIRIE CREEK	STATE HWY 322	WATERS BLUFF
MAIN HIGHWAYS (FT)	49,300	52,100	54,900	4,900	6,900	35,300
LIGHT-DUTY ROADS (FT)	94,000	51,000	114,000	6,600	13,600	39,700
UNIMPROVED ROADS (FT)	230,000	113,500	244,500	11,000	15,050	111,500
PIPELINES (FT)	77,000	4,000	110,000		2,100	137,300
POWER LINES (FT)	43,000		16,000			4,200
RAILROAD (FT)	6,800		4,500			37,000
OLD RAILROAD GRADE (FT)			21,500			
NUMBER OF OIL WELLS	14	61	2	8		3
NUMBER OF GAS WELLS	10		2		1	
NUMBER OF DWELLINGS	18	47	99	7	5	40
NUMBER OF CEMETERIES	1		1			
FISH FARM (AC)	139					
NUMBER OF FISH HATCHERIES						1
POWER PLANT (AC)	9					
NUMBER OF ARTESIAN WELLS			1			
PUMP STATION						1
AQUADUCT (FT)						14,700
WATER / WASTEWATER PLANT						1
GAGING STATION						1

APPENDIX G

TWDB COMMENTS ON DRAFT REPORT AND RESPONSES

September 23, 1999

Mr. Jerry Clark
Executive Vice President
Sabine River Authority
P.O. Box 579
Orange, Texas 77630

Re: Regional Water Supply Planning Contract Between the Sabine River Authority of Texas (SRA) and the Texas Water Development Board (Board), Review Comments on "Comprehensive Sabine Watershed Management Plan", TWDB Contract No. 97-483-214

Dear Mr. Clark: Jerry

Staff members of the Texas Water Development Board have completed a review of the draft report under TWDB Contract No. 97-483-214 and offer comments shown in Attachment 1.

However, the items in Attachment 2 were not included or addressed in the Draft Final Report and as submitted does not meet contractual requirements. Therefore, please submit these items for review prior to delivery of the Final Report.

After review comments have been transmitted to SRA regarding the above referenced items, SRA will consider incorporating all comments from the EXECUTIVE ADMINISTRATOR and other commentors on the draft final report into the Final Report.

Please contact Mr. Randy Williams, the Board's designated Contract Manager, at (512) 936-0879, if you have any questions about the Board's comments.

Sincerely,

Tommy

Tommy Knowles, Ph.D., P.E.
Deputy Executive Administrator
Office of Planning

cc: Randy Williams, TWDB

ATTACHMENT 1
TEXAS WATER DEVELOPMENT BOARD

REVIEW COMMENTS: SABINE RIVER AUTHORITY
"Comprehensive Sabine Watershed Management Plan"
Contract No. 97-483-214

1. Review Comments by Report Section

1.1 **Background**: Figure 1.1 does not identify the reservoirs pictured.

1.2 **Sabine Watershed Hydrology**: The 12 stream gages, referenced in the text on page 1-5 are not located in Figure 1.2. The text should contain a justification of the selection of the 5 key gage locations currently shown in Figure 1.2. The maps describing the average annual evaporation and average annual runoff as required in the scope of work were not included in this section. The tables showing time histories of reservoir contents at SRA reservoirs, time histories of rainfall at 4 key rain gages, and seasonal distribution of rainfall and runoff at key locations as required in the scope of work were not included in this section. The text of this section was lacking description of the maps and tables noted as missing.

1.3 **Water Rights**: On page 1-7 the reference in the text to Iron Bridge Dam does not provide a location. The Sabine Basin Annual Permitted Use total described in Table 1.1 does not distinguish between annual use permitted volumes committed inside and outside of the Sabine Basin. Of the volume permitted for annual use outside of the Sabine Basin, a distinction should be made in Table 1.1 between volumes permitted to the City of Dallas and other users. The text on pages 1-8 and 1-9 describes water from the Louisiana portion of the Sabine Basin as potentially available; the potentially available volumes should be tabulated in a format similar to Tables 1.1 and 3.3. The point of Louisiana-Texas water sales described on page 1-9 should be located on a map.

1.4 **Mineral Resource Evaluation**: Figures 1.4, 1.5 and 1.6 lack the inclusion of county lines. The first paragraph on page 1-10, references water quality issues associated with mining and energy generating facilities. Chapter 10 should offer greater detail on these issues.

2.2 **Water Use**: As noted on pages 2-2 and 2-3, the scenario for manufacturing water use projections differs from the one used in the Consensus-Based State Water Plan. Note that any projections to be used for SB 1 planning purposes must be approved by the appropriate Regional Water Planning Group (s). Additionally, any proposed changes to the state consensus projections will be reviewed based on the criteria and data requirements described in *Guidelines and Data Requirements for Addressing Revisions of the Consensus-Based Population and Water Demand Projections.*

3.0 **Existing Surface Water Supplies**: Figure 3.1 and Table 3.1 do not indicate which reservoirs are used for water supply and which are used for recreation as reference in the text on page 3-1.

3.2.1 **SRA Reservoirs and Canal System**: Table 3.2 does not indicate the out of basin portion of allocations for lakes Fork and Tawakoni. It should be clarified whether the demand increase in the Upper Basin which is projected to exceed supply, described on page 1-8 and shown in Table 5.1, is expected to come from the City of Dallas or elsewhere outside of the Sabine Basin.

4.1 **Aquifer Descriptions**: The general extent of Sabine Basin aquifers are illustrated in Figure 4.1, however, the figure lacks delineation of the aquifer recharge zones as required in the scope of work. Aquifer descriptions include only brief water quality references, which are inconsistent and lack meaningful detail. No figures or discussion was offered to illustrate aquifer layering, as required in the scope of work. References to static water levels were lacking valuation or geo-reference and not included in all aquifer descriptions. No maps or figures to illustrate static water levels were included.

Page 4-7, contains the following statements; "A few wells in the basin have been completed in other aquifers, such as the Trinity, Cypress Spring and Cain River. These other ground water sources provide approximately 470 acre-feet per year in the Sabine Basin." The terms Cypress aquifer and Cane River Formation/aquifer represent various water-bearing strata of the Wilcox and Claiborne Groups. With the exception of the Cane River Formation, the various water bearing strata of the Wilcox and Claiborne Groups were individually discussed in sub-section 4.1. If the terms Cypress Spring and Cain River were intended to refer to the Cypress and Cane River aquifers, the annual discharge of these wells should be reassigned appropriately. For clarification of formation and aquifer terminology, please refer to TWDB Report 27 *Ground-Water Resources of Harrison County* and TWDB Report 37 *Ground-Water Resources of Sabine and San Augustine Counties*. Please refer also to previous comments on aquifer layering.

4.2 **Aquifer Demands**: Selected groundwater demands are included in the discussion and Tables 4.1 and 4.2, however, only 1996 historic demands and year 2000 projected demands are offered in response to the scope of work requirements for historic and future groundwater demands. On page 4-6, attribution is made to TWDB as a source of projected demand data without further specification.

7.1 **Previously Proposed Reservoirs**: Figure 7.3 does not indicate the location of the water quality issues discussed on page 1-10. (Please refer to comments on Section 1.4)

8.1 **Development of Groundwater Supplies**: Lacks detail about the potential for groundwater development by particular communities or counties within the Sabine Basin. Statements on page 8-1 serve as an example, "The Carrizo-Wilcox aquifer is the most Important ground water resource in the Sabine River area and has the greatest potential for future development. Based on a TWDB evaluation, a significant increase of ground water could be attained with proper development." The discussion that follows these statements does not contain additional detail or explanation of what may constitute "proper development". Additionally, attribution is made to a TWDB evaluation without specification.

8.1.1 Ground Water Availability: Does not offer specific discussion on the actual methodology employed to determine the specific groundwater availability values included in Table 8.1. No estimate of aquifer storage gain or loss was included. An estimate of aquifer discharge including gains or losses to streams as specified in the scope of work was lacking

8.1.2 Costs: Does not specify estimated cost of either investigating feasibility of groundwater development or actual development of specific resources to meet identified needs. The discussion relies on terms such as: "relatively low costs" or "significantly higher cost" without an identifiable dollar value reference.

8.2 Aquifer Storage and Recovery: The conceptual applications of ASR technology for the Cities of Kilgore and Canton, lack justification relative to projected demand increases or the economy of ASR as opposed to other options. The list of potential sites considered for study in Smith, Wood, Rains and Van Zandt Counties with ranking of the sites as specified in the scope of work was not present in this section. The methodology for ranking of sites considered for study was not included. Aquifer parameters (transmissivity, storage and permeability) were not included as specified in the scope of work. Water demand projections for certain users, as specified in the scope of work, were not included. The two dimensional analytical modeling with regard to recharge and withdrawal specified in the scope of work was not performed for the Kilgore site. The methodology used for performing two-dimensional modeling of the recharge and withdrawal process for the Canton site was not referenced.

8.2.1 Preliminary Cost Estimates for ASR: The report lacks a complete summary of all costs specified in the scope of work *i.e.* estimated cost of ASR system operation. N on-quantified costs for ASR system operation and maintenance are referenced to conclude that application of ASR would be economically feasible. A conclusion of ASR economic feasibility should be supported by competitive economic justification of ASR against other potential supply/distribution options including all associated costs.

10.1.2 Watershed influences on Water Quality: The superfund site referenced in Table 10.2 is not discussed relative to water quality implications in the text and is not located on any map. Figure 10.8 should be further enlarged to allow greater clarity of detail sections to allow identification of industrial discharge locations.

10.2.2 __Existing Conditions__: Table 10.3 listing Endangered and Threatened Species Potentially Occurring in the Counties of Proposed Reservoir Development is cited without a date, for both state and federal species listings. Table 10.3 should include the most current available listing of species available.

10.2.4 __Recommendations for New Reservoir Development__: Table 10.5 on page 10-23 should be expanded in scope to allow greater clarity of the assessment of the relative risk by category (i.e. threatened/endangered species, archeological/cultural resources, bottomland hardwoods, etc.) associated with development of specific projects.

2. Construction projects to meet future basin water needs discussed in the report include reservoirs, major intra basin transmission pipelines, water supply wells, and aquifer storage and recovery (ASR) projects. All the projects discussed in the report appear to be feasible means of providing water supply and are eligible for financing through the Board's Texas Water Development Fund (state funds).

3. Information in this report would probably supply all the engineering information required to support an application to the Board for funding a recommended project through the Board's pre-design funding option. Additional maps or drawings may be needed to site some proposed projects. Legal and fiscal information as required by Board rules would also be required with an application, as would water conservation and emergency demand management plan that meets minimum Board requirements. At the time of an application for funding, estimated budgets should be updated and should include all elements (engineering, legal, fiscal, construction, project contingency, etc.) of the proposed project.

ATTACHMENT 2

The following items are Scope of Work deliverables. They were not included in the Draft Final Report and must be submitted for review prior to delivery of the Final Report in order to meet contractual requirements.

Task 2

1. GIS Map showing average annual evaporation in the Sabine Basin
2. GIS Map showing average annual runoff in the Sabine Basin
3. Table showing time histories of SRA reservoir contents
4. Table showing time histories of rainfall at 4 key rain gages
5. Table showing seasonal distribution of rainfall and runoff at key locations

Task 3

6. Delineation of aquifer recharge zones
7. Figures and discussion of aquifer layering and hydraulic connection
8. Estimates of aquifer discharge(pumpage and gains or losses to streams
9. Estimates of gains or loss of aquifer storage
10. Tabulation of historic and future groundwater demands

Task 4

11. Table showing the existing water rights in the Sabine Basin of Louisiana

Task 15

12. Description of the above items in the text
13. Aquifer paramenters (transmissivity, storage, permeability) for ASR evaluation-Task 15
14. Water demand projections for certain groundwater users for ASR evaluation-Task 15
15. Listing of potential recharge sites in Smith, Wood, Rains and Van Zandt Counties
16. Ranking of ASR sites selected for study
17. Two-dimensional analytical modeling for ASR recharge and withdrawal rates
18. ASR operating cost estimates

RESPONSES TO TWDB COMMENTS

To date, two sets of comments have been received from TWDB. One set was submitted by Richard Brown of TWDB in July 1999 as preliminary comments. The second set was submitted by Dr. Tommy Knowles on September 23, 1999. Beginning with Richard Brown's comments, our response to TWDB comments are in italics below.

Richard Brown Comments, July 1999

1. The funding from TWDB needs to be acknowledged in the report.

> *This has been corrected. The title page reflects that this study was performed in conjunction with TWDB. We have also stated in the introduction which tasks were funded by TWDB (Task 7 - Water Treatment Needs, Task 8 - Wastewater Treatment Needs, and Task 15 - Aquifer Storage and Recovery).*

2. Task 20: Mitigation Banking was added after the contract was approved, this seems to be a valuable task but we can not reimburse costs related to this task.

> *This task was added at SRA's cost. TWDB is funding only the three tasks listed above and has only been charged for the time and expenses associated with those three tasks.*

3. Section 1.3, 4th paragraph speaks to "...most of this water is being reserved for the future use*". Please clarify if the quantity of water is the existing water rights, or is there a different quantity being reserved.

> *The amount we show as being reserved for future use by an entity is the full amount of their existing water right or contract. Therefore, that water was not considered "available" for other entities.*

4. The assumption used here for manufacturing water demand projections is low oil price and no conservation. This is different than the consensus scenario used in 1997 State Water Plan and may not be consistent with the revisions to that scenario currently being requested by the Regional Water Planning Groups.

> *After looking at the Consensus numbers for manufacturing, they were deemed to be too low to be reasonable in this particular case, so the low oil price, no conservation scenario was used. In this Comprehensive Plan, the future development plan for the basin has been structured in a phased approach so that, if in fact, the manufacturing demand does not materialize, then large amounts of capital will not have been invested to provide for*

that demand. Chapter 13 of the report explains this in detail.

The water demand projections need to be coordinated through the Water Uses Section of TWDB (contact Butch Bloodworth) so they are consistent with any revisions being requested by the RWPGs.

The projections for this study were formulated at the beginning of this study, which preceded Senate Bill 1 and the Regional Water Planning Groups by more than a year. It is not feasible to require that this study be redone based on SB1 projections.

5. Section 3.4, last paragraph speaks to short term contracts. Senate Bill 1 may have made changes to the Texas Water Code which could impact this paragraph.

Senate Bill One does not change this.

6. Section 5.0, 2nd paragraph speaks to "Ground water supply was estimated from the year 2000 ground water projections*". Please clarify, are supply estimates per county constant for all future decades, and/or are these based on projected use in 2000 (from 1997 State Water Plan or some other use projection) or are these projected supply amounts (from 1997 State Water Plan or some other supply projection).

Groundwater supply estimates per county were held constant for all future decades.

7. Section 10.2.1 appears to be a useful summary of environmental regulations. However, in the Texas General Land Office portion is "Aquifer Recharge Rule" which states that "No permit is required to inject clean water into groundwater aquifers*". Actually such permitting authority resides with TNRCC and such an injection permit (Class V) is required. If surface water is the source, a new or amended water right permit would also be required from TNRCC.

This section has been changed to state that a TNRCC Class V injection permit is required.

Tommy Knowles Comments, September 1999

1. Background: Figure 1.1 does not identify the reservoirs pictured.

Figure 1.1 is intended to give an overall picture of the entire basin. Figure 1.1 has been changed to identify the three reservoirs referred to in this section (Lake Tawakoni, Lake

Fork, and Toledo Bend). Chapter 3, which discusses each reservoir in detail, contains figures that identify all of the reservoirs in the basin.

1.2 Sabine Watershed Hydrology: The 12 stream gages referenced in the text on page 1-5 are not located in Figure 1.2.

The 5 key stream gages selected as representative gages have been added to Figure 1.2.

The text should contain a justification of the selection of the 5 key gage locations currently shown in Figure 1.2

The text states that these five gages were selected "based on their location, period of record, and proximity to a rainfall monitoring station."

The maps describing the average annual evaporation and average annual runoff as required in the scope of work were not included in this section. The tables showing time histories of reservoir contents at SRA reservoirs, time histories of rainfall at 4 key rain gages, and seasonal distribution of rainfall and runoff at key locations as required in the scope of work were not included in this section. The text of this section was lacking description of the maps and tables noted as missing.

These maps have already been created and were included in the technical memorandum for Scope Task 2 and in the GIS package. It was decided that this level of detail was not needed in the final report. (Copies of all technical memoranda for this project will be provided to TWDB at the conclusion of the project.)

1.3 Water Rights: On page 1-7, the reference in the text to Iron Bridge Dam does not provide a location.

Reference has been added to describe the location of Iron Bridge Dam.

The Sabine Basin Annual Permitted Use total described in Table 1.1 does not distinguish between annual use permitted volumes committed inside and outside of the Sabine Basin. Of the volume permitted for annual use outside of the Sabine Basin, a distinction should be made in Table 1.1 between volumes permitted to the City of Dallas and other users.

The City of Dallas is the only entity outside of the Sabine Basin that holds water ***permits*** *in the Sabine Basin. Those permits are for portions of the Lake Fork and Lake Tawakoni yields. Other out-of-basin entities have* ***contracts*** *for Sabine Basin water. Those are detailed in Appendix E. Since Table 1.1 is dealing with* ***permits*** *rather than contracts, a column will be added to show Dallas' portions of water rights that are for use outside of the Sabine Basin, but will not show any* ***contracted*** *amount of water that are used out of the Basin.*

The text on pages 1-8 and 1-9 describes water from the Louisiana portion of the Sabine Basin as potentially available; the potentially available volumes should be tabulated in a format similar to Tables 1.1 and 3.3

The volume of water available from Louisiana has not been quantified, and it was beyond the scope of this project to quantify the amount available.

The point of Louisiana-Texas water sales described on page 1-9 should be located on a map.

The Logansport gage has been added to Figure 1.2. Text has been added to refer to this map for the location of Logansport, Louisiana, which is the point of the Texas-Louisiana sale.

1.4 Mineral Resources Evaluation: Figures 1.4, 1.5, and 1.6 lack the inclusion of county lines.

County lines have been added.

The first paragraph on page 1-10 references water quality issues associated with mining and energy generating facilities. Chapter 10 should offer greater detail on these issues.

It was determined that there was insufficient information available to make an accurate correlation between water quality and mining and energy generating facilities. Therefore, the text on page 1-10 has been taken out of the report.

2.2 Water Use: As noted on pages 2-2 and 2-3, the scenario for manufacturing water use projections differs from the one used in the Consensus-Based State Water Plan.

After looking at the Consensus numbers for manufacturing, they were deemed to be too low to be reasonable in this particular case, so the low oil price, no conservation scenario was used. The future development plan for the basin has been structured in a phased approach so that, if in fact, the manufacturing demand does not materialize, then large amounts of capital will not have been invested to provide for that demand. Chapter 13 of the report explains this in detail.

Note that any projections to be used for SB1 planning purposes must be approved by the appropriate Regional Water Planning Group(s). Additionally, any proposed changes to the state consensus projections will be review based on the criteria and data requirements described in "Guidelines and Data Requirements for Addressing Revisions of the Consensus-Based Population and Water Demand Projections."

The projections for this study were formulated at the beginning of this study, which preceded Senate Bill 1 and the Regional Water Planning Groups by more than a year. It *is not feasible to require that this study be redone based on SB1 projections.*

3.0 Existing Surface Water Supplies: Figure 3.1 and Table 3.1 do not indicated which reservoirs are used for water supply and which are used for recreation as referenced in the text on page 3-1.

A sentence was added clarifying that the four recreation lakes referenced in the text on page 3-1 are the Wood County Lakes. With this sentence, no change was necessary in Figure 3.1 or Table 3.1.

3.2.1 SRA Reservoirs and Canal System: Table 3.2 does not include the out of basin portion of allocations for lakes Fork and Tawakoni. It should be clarified whether the demand increase in the Upper Basin which is projected to exceed supply, described on page 1-8 and shown in Table 5.1, is expected to come from the City of Dallas or elsewhere outside of the Sabine Basin.

Table 3.2 shows the available supplies from each water sources, and does not deal with the ***allocation*** *of supply. Chapter 5 deals with the allocation of supplies to demands. Table 5.1 shows the total amount of water available in each county, then deducts the set amount of exports specified in the permits or contracts (not based on demand, but on permitted or contracted amounts). The demand increase in the Upper Basin, which is projected to exceed supply, is only for in-basin needs. No demands for out of basin entities were analyzed. In the case of Dallas, the specified amounts that are permitted to Dallas in the water rights were assumed to be exported out of basin to Dallas, regardless of what their future demands would be.*

4.1 Aquifer Descriptions: The general extent of Sabine Basin aquifers are illustrated in Figure 4.1, however, the figure lacks delineation of the aquifer recharge zones as required in the scope of work.

Figure 4.2 has been added showing the aquifer outcrops which are equivalent to the recharge zones.

Aquifer descriptions include only brief water quality references, which are inconsistent and lack meaningful detail. No figures or discussion was offered to illustrate aquifer layering, as required in the scope of work. References to static water levels were lacking valuation or geo-reference and not included in all aquifer descriptions. No maps or figures to illustrate static water levels were included.

The scope of work instructs the consultant to "review" the above topics and does not call for a detailed description of each. The topics for review were to provide information needed in the required water budget and availability analysis.

Page 4-7, contains the following statement; "A few wells in the basin have been completed in other aquifers, such as the Trinity, Cypress Spring and Cain River. These other ground water sources provide approximately 470 acre-feet per year in the Sabine Basin." The terms Cypress aquifer and Cane River Formation/aquifer represent various water-bearing strata of the Wilcox and Claiborne Groups. With the exception of the Cane River Formation, the various water-bearing strata of the Wilcox and Claiborne Groups were individually discussed in sub-section 4.1. If the terms Cypress Spring and Cain River were intended to refer to the Cypress and Can River aquifers, the annual discharge of these wells should be reassigned appropriately. For clarification of formation and aquifer terminology, please refer to TWDB Report 27 "Ground-Water Resources of Harrison County" and Report 37 "Ground-Water Resources of Sabine and San Augustine Counties." Please refer also to previous comments on aquifer layering.

This statement can be rewritten as follows:
A few wells in the basin have been completed in aquifers that are listed as "other" in Table 4.2. These specific aquifers were not identified due to their relative insignificance within the basin. A minor amount of groundwater is produced from the Trinity aquifer in Collin and Rockwall counties. In Harrison and Sabine counties, the aquifer terminology of Cypress Springs and Cain River have been used in older reports to depict aquifer units that are currently incorporated in aquifer units used in this report. Groundwater associated with the Cypress Springs and Cain River are likewise incorporated into the current aquifer usage. These "other" ground water sources provide approximately 470 acre-feet per year in the Sabine Basin.

4.2 Aquifer Demands: Selected groundwater demands are included in the discussion and Tables 4.1 and 4.2, however, only 1996 historical demands and year 2000 projected demands are offered in response to the scope of work requirements for historic and future groundwater demands.

This section is intended to characterize current groundwater demand. Future groundwater forecasts are combined with surface water demands and shown in Table 5.1.

On page 4-6, attribution is made to TWDB as a source of projected demand data without further specification.

The first line of the 4.2 Aquifer Demand section has been modified to include the underlined text below:
Approximately 48,000 acre-feet per year of ground water is projected by the TWDB in the development of the 1997 State Water Plan, to be used within the Sabine Basin by the year 2000.

7.1 Previously Proposed Reservoirs: Figure 7.3 does not indicate the location of the water quality issues discussed on page 1-10. (Please refer to comments on Section 1.4)

It was determined that there was insufficient information available to make an accurate correlation between water quality and mining and energy generating facilities. Therefore, the text on page 1-10 has been taken out of the report, and there is no need to identify any locations of water quality issues on Figure 7.3.

8.1 Development of Groundwater Supplies: Lacks detail about the potential for ground water development by particular communities or counties within the Sabine Basin. Statements on page 8-1 serve as an example, "The Carrizo-Wilcox aquifer is the most important ground water resource in the Sabine River area and has the greatest potential for future development. Based on a TWDB evaluation, a significant increase of ground water could be attained with proper development." The discussion that follows these statements does not contain additional detail or explanation of what may constitute "proper development".

The scope did not call for that level of detail and the budget for that task did not allow for that level of detail. The budget for the task ($28,500) is only 5% of the total project's original budget ($553,000).

Additionally, attribution is made to a TWDB evaluation without specification.

See answer to 4.2 above.

8.1.1 Ground Water Availability: Does not offer specific discussion on the actual methodology employed to determine the specific groundwater availability values included in Table 8.1. No estimate of aquifer storage gain or loss was included. An estimate of aquifer discharge including gains or losses to streams as specified in the scope of work was lacking.

The first paragraph of this section has been moved to Section 4.2.1 of the report and reads as follows:

> *Ground water availability can be estimated using several different methods, which have varying results. The TWDB developed a ground water model for a large area that included the upper portion of the Sabine Basin. To determine water availability to meet future needs, the model was run assuming all future demand was met by ground water. This resulted in large availability numbers for counties where large demands were projected (e.g., Harrison County was projected to have an annual ground water availability of 183,500 acre-feet per year). These high availability estimates include both effective recharge and the removal of ground water from storage. While the TWDB model does demonstrate that there is a sufficient amount of water contained in the Carrizo-Wilcox aquifer,*

the model was not run to simulate levels of pumpage that might be considered based on reasonable and practical economic assumptions.

Another method of estimating ground water availability assumes that the only water to be used is a quantity equivalent to the average annual effective recharge. This methodology is the most conservative since these availability estimates do not include the removal of water from storage in the aquifer. This approach allows for the assessment of long-term availability of the aquifer without incurring large water level declines.

For this Plan, the estimated ground water availability in the Sabine Basin is based on a modified water budget approach. The components of the budget consist of input to the aquifer system as recharge, water held in storage within the aquifer, and output or withdrawal from the aquifer as pumpage and spring flow. Annual effective recharge for the aquifers within the Sabine Basin were derived from estimates based on TWDB aquifer analyses and include consideration of input to the aquifer from both precipitation and seepage from streams. Water in storage is based on estimates of saturated thickness and storage coefficient of the aquifer medium. Total discharge from the aquifer includes pumpage and water that is naturally rejected from underground in the form of spring flow.

In quantifying availability, consideration was made concerning the historical use of each aquifer in each county. If water level records suggested a relatively static condition, then annual effective recharge was considered an appropriate availability estimate. However, if the aquifer in a particular county had been or is expected to be heavily used and recharge alone is insufficient to meet forecasted demands, then recharge along with a specified depletion of storage was assigned as availability. The availability estimates for the Gulf Coast, Sparta and Yegua aquifers are based solely on annual effective recharge, while estimates for the Carrizo-Wilcox, Queen City and Nacatoch aquifers include, for some counties, the depletion of a specified amount of water in storage.

Estimated ground water availability from the Carrizo-Wilcox aquifer in the Sabine Basin is based on the annual effective recharge throughout the aquifer extent, and also includes a three-percent per year depletion of storage in most counties. Nacatoch aquifer availability consists of effective recharge in outcrop counties and a combination of recharge and/or storage depletion in the downdip counties of Hopkins and Rains.

Water availability from the Queen City aquifer is limited to effective recharge in Harrison and Rusk counties where recharge is less relative to other counties. In the other counties, effective recharge estimates are significantly higher (Table 4.5) and do not realistically equate to availability. For these counties availability *is based on recoverability estimates for the portion of the aquifer with sufficient saturated thickness to support well yields of 200 gpm or more. Availability was estimated by establishing a conceptual well field over the designated area with wells spaced one mile apart and allowed to withdraw water at a rate of 12 hours per day for 365 days. This method allowed for a much more reasonable availability estimate in Gregg, Smith, Upshur and Wood counties. The total amount of water that is determined to be available from the Queen City aquifer in the Sabine Basin is about 32,000 acre-feet per year.*

A total of 138,492 acre-feet of ground water per year are estimated to be available in the Sabine Basin. Summaries of these estimates by county and aquifer are shown in Tables 4.4 and 4.5. Of the six primary aquifers in the basin, the Gulf Coast (53,003 acre-feet), the Carrizo-Wilcox (44,820 acre-feet) and the Queen City (32,012 acre-feet) contain 94 percent of the total annual available ground water.

Since there is ample surface water supply already developed in the lower basin, it is unlikely that future well fields in the Gulf Coast aquifer will be developed for regional supply. Ninety seven percent of the calculated availability from the Carrizo-Wilcox is located in the upper basin. The Queen City aquifer, located totally in the upper basin, has the greatest annual water recharge at 137,800 acre-feet per year. However, as previously discussed, much of the water is released from the aquifer to local streams and springs. Proper development of well fields could reduce the amount of lost recharge, but probably could never capture the recharge quantity indicated in Tables 4.4 and 4.5.

8.1.2 Costs: Does not specify estimated cost of either investigating feasibility of groundwater development or actual development of specific resources to meet identified needs. The discussion relies on terms such as: "relatively low costs" or "significantly higher cost" without an identifiable dollar value reference.

The scope did not call for any costs to be identified in specific dollar value. (See answer to comment 8.1 above.)

8.2 Aquifer Storage and Recovery: The conceptual applications of ASR technology for the Cities of Kilgore and Canton, lack justification relative to projected demand increases or the economy of ASR as opposed to other options. The list of potential sites considered for study in Smith, Wood, Rains, and Van Zandt Counties with ranking of the sites as specified in the scope of work was not present in this section. The methodology for ranking of sites considered for study was not included.

The following text will be inserted in this section.

Cities that utilize ground water and surface water within Rains, Smith, Van Zandt, and Wood counties were considered as potential candidates for artificial recharge. Discussions with the staff of the Sabine River Authority also provided information on cities that may be interested in artificial recharge as a water supply option. Kilgore in Smith County, Emory in Rains County, Canton and Grand Saline in Van Zandt County and Quitman in Wood County were considered as candidates. The City of Kilgore was considered a viable option for further study because of its well field in the Carrizo-Wilcox aquifer, the water-level decline(about 70 to 100 feet since 1952) that has occurred in the well field due to past pumping, and the availability of treated surface water from the City's system. The City of Canton in Van Zandt County also was considered a viable candidate because of the combined surface water and ground water supply and the increase in water demand that is occurring in the City due to growth and the commercial and reselling market served by the City's water supply system. Representatives of Canton and Kilgore also expressed an interest in the feasibility of artificial recharge to help provide additional water supply.

Quitman in Wood County has an adequate surface water supply and does not have the projected increase in demand as other cities. Grand Saline was not selected because treated surface water to the City would have to be provided via pipeline from another city in the area. Emory in Rains County is a town with 963 people and does not represent a large enough potential project to warrant further consideration.

The cities of Kilgore and Canton were selected also because they would represent a study of artificial recharge for a larger city of about 11,000 and the study of artificial recharge of a smaller city with a population of about 3,000. The aquifer conditions for the Kilgore well field in Smith County and for the water wells utilized by Canton indicate that it should be possible to store the water in the aquifer and have it retained there for utilization by the cities. There is very limited pumpage in proximity to Canton and the City of Kilgore well field.

Water usage by the City of Kilgore was 2,950 and 3,095 acre-feet per year (af/y) in 1996 and 1997, respectively. The municipal water demand for Kilgore is projected to be 2,794 af/y, 2,854 af/y, and 2,940 af/y by 2010, 2020, and 2030, respectively. In addition, Kilgore supplies approximately 700 af/y to wholesale municipal and industrial customers. Data for the City of Canton show that water usage was about 649 acre-feet in 1996 compared to 484 acre-feet in 1986. Municipal water demand is projected to be 681 af/y, 679 af/y, and 658 af/y by 2010, 2020, and 2030, respectively. In addition, Canton supplies approximately 100 af/y to wholesale municipal customers.

Aquifer parameters (transmissivity, storage and permeability) were not included as specified in the scope of work. Water demand projections for certain users, as specified in the scope of work, were not included.

Water demand projections for Kilgore and Canton have been added to the text.

The following text regarding aquifer parameters will be added to the report:

Aquifer Parameters - City of Kilgore

Values of transmissivity, permeability and storage coefficient of the aquifer at the City of Kilgore well field have been calculated based on available data. Production Wells No. 1 through No. 9 in the well field screen sands in the Carrizo Sand or in the Carrizo Sand and underlying Wilcox aquifer and at the time of the tests, the aquifers were under artesian conditions. Pumping tests in the well field provide a coefficient of transmissivity that ranges from about 19,000 to 38,000 gallons per day per foot (gpd/ft) with the range in transmissivity values caused by the differences in thickness and permeability of sands screened by the wells. In general, the permeability of sands in the Carrizo Sand is higher than the permeability of the sands in the Wilcox aquifer. The test results show this to be the case and the data indicate an average value of permeability of about 152 gallons per day per square foot (gpd/ft^2) for the sands. Interference drawdown tests indicate an average coefficient of storage of about 0.0002 which is in line with the coefficient of storage values for unconsolidated sand aquifers under artesian conditions.

The specific capacities of the City of Kilgore Wells Nos. 1 through 9 range from 6.4 to 37.4 gallons per minute per foot of drawdown (gpm/ft) and average 19.9 gpm/ft. The specific capacities indicate that the sands screened have good permeability and could be less susceptible to clogging during injection than wells with lower specific capacities.

Aquifer Parameters - City of Canton

Limited data are available on the transmissivity, permeability, and storage coefficient values for the Wilcox aquifer in the vicinity of Canton. Pumping tests have been performed on a number of wells in Rains and Van Zandt that screen the Wilcox aquifer with results provided in Texas Water Development Board Report 169 "Ground-Water Resources of Rains and Van Zandt Counties, Texas". The report gives values of permeability that range from 13.4 to 89.7 gpd/ft^2 and average 38.9 gpd/ft^2. Using an estimated value of permeability of 38.9 gpd/ft^2 and a screened interval for City of Canton Well No. 4 of 107 feet, results in an estimated value of transmissivity of 4,062 gpd/ft. The one-half hour specific capacity of Well No. 4 was measured at 3.3 gpm/ft in 1987. The value of specific capacity is consistent with the estimated transmissivity for the aquifers screened by the well. It is estimated that the coefficient of storage for the sands screened by City of Canton Well No. 4 is in the range of 0.00025 to 0.0004. A *pumping test has not been performed on the well with an accompanying observation well to obtain an coefficient of storage based on empirical data. A coefficient of storage of 0.00038 was calculated from an interference drawdown test of wells for the town of Grand Saline which is located about 11 miles from Canton and has wells that screen sands of the Wilcox aquifer.*

The two dimensional analytical modeling with regard to recharge and withdrawal specified in the scope was not performed for the Kilgore site. The methodology used for performing two-dimensional modeling of the recharge and withdrawal process for the Canton site was not referenced.

The following text regarding two-dimensional modeling will be added to the report:
Two-Dimensional Modeling of Recharge Effects for City of Kilgore

An aquifer model code was used to estimate the amount of water-level rise that would occur in the recharge wells as a result of artificial recharge. The results are based on 347 gpm (0.5 mgd) being injected through two wells for a period of five months followed by a non-injection period of one day. The two wells selected for the example are Wells 1 and 3 located about 1,700 feet apart in the well field. The aquifer was assumed to have a transmissivity of 18,000 gpd/ft and a storage coefficient of 0.0002. These values are in line with those obtained from pumping tests in the well field with the value of transmissivity being on the conservative side. Based on these assumptions, it was estimated that the water-level rise in the two wells would range from 20 to 30 feet at the end of five months of injection followed by one day of non-injection. During the injection period, the water-level rise in the wells could be in the range of 50 to 100 feet. With the static water level of the wells in the range of 250 to 320 feet, the well water levels during injection periods should remain 150 to 200 feet below land surface.

Two-Dimensional Modeling for the City of Canton Well No. 4

An aquifer model code was used to estimate the amount of water-level rise that could occur in Well No. 4 as the result of artificial recharge. The results are based on 120 gpm being injected through the well for a period of five months followed by a non-injection period of one day. The aquifer is assumed to have a transmissivity of 4,000 gpd/ft and a storage coefficient of 0.00025. These values are estimated are based on pumping test data from wells in Rains and van Zandt counties and on the estimate of transmissivity for Well No. 4. Based on theses assumptions, it is estimated that the water-level rise would range from 15 to 20 feet during five months of injection followed by one day with no injection. During the injection period, the water-level rise in the well could range from about 70 to 110 feet and with a static water level in the well of about 150 feet the wells water level during injection could remain 40 to 80 feet below land surface.

8.2.1 <u>Preliminary Cost Estimates for ASR</u>: The report lacks a complete summary of all costs specified in the scope of work *i.e.* estimated cost of SRA system operation. Non-quantified costs for ASR system operation and maintenance are referenced to conclude that application of ASR would be economically feasible. A conclusion of ASR economic feasibility should be supported by competitive economic justification of ASR against other potential supply/distribution options including all associated costs.

The current text has been replaced with the following:
<u>Preliminary Cost Estimate for the City of Kilgore</u>

Further studies and pilot testing of ASR are the next steps in assessing the feasibility of a recharge project. The chemical compatibility of the aquifer water and of the treated surface water should be studied and geochemical models used to help determine if chemical plugging of the well and aquifer may occur as the result of artificial recharge. The estimated cost is about $4,000 to $5,000 for collecting samples from the well and surface water supply, performing chemical analyses, and geochemical modeling. Pilot testing should be performed using probably Well No. 3 (34-48-202) to evaluate the aquifer response and well response to the injection of water.

At the ground storage facilities located in Kilgore, it is estimated that a small 500 gpm pump station would be required to pump surface water to the well field ground storage tank. It is estimated that the pump and motor, electrical equipment and piping modifications required at the ground storage tank in Kilgore could cost in the range of $40,000 to $50,000.

Piping and valving modifications and possibly a booster pump and motor and electrical controls would be required at the ground storage tank in the well field to route water back to Well No. 3. Minor piping modifications should be required at Well No. 3, along with installation of a filter or strainer, to route water down the well using the existing discharge piping and pump column assembly. It is estimated that the piping modifications, pump and motor and electrical costs in the well field could be about $40,000.

With the water delivery modifications completed at the ground storage facilities in Kilgore and in the well field and with the piping modifications performed at probably Well No. 3, pilot testing in the well field could begin. Pilot testing would help assess the rate at which the well will accept water and the response of the aquifer to the injection. The pilot testing would include injecting water and subsequently pumping it from the well and possibly repeating the sequence a number of times. It is estimated that the cost of pilot testing could be in the range of about $15,000. If the results of the pilot testing are satisfactory, Well No.

3 could be permanently equipped for ASR and additional booster pump and piping modifications could be completed to help automate the injection of water. Other wells in the well field also could be pilot tested as candidates for ASR. Considering all the above items, the total capital and pilot testing costs for ASR in Kilgore would range form $99,000 to $110,000.

Operating and maintenance costs are estimated as follows:

1. Electric power cost to pump water from Kilgore to well field for 175 feet of lift (500 gpm flow rate).	*6.6¢ per 1,000 gallons*
2. Labor cost at 4 hours per day at $20 per hour for 720,000 gallons of injection per day.	*11.1¢ per 1,000 gallons*
3. Treated surface water cost estimate from City of Kilgore	*$1.32 per 1,000 gallons*
4. Electric power cost for 375 feet of lift to pump water from well.	*14.2¢ per 1,000 gallons*
5. Well Maintenance/Cleaning ($15,000/two years with 5 months of injection per year at 500 gpm or 0.72 mgd.	*6.6¢ per 1,000 gallons*
Total O&M Cost	*$1.71 per 1,000 gallons*

If successful results are obtained during pilot testing and the artificial recharge system is enlarged to inject more than 500 gpm, then the booster pump facilities in Kilgore and at the well field would be expanded along with piping and monitoring modifications at additional wells. To increase the size of the system to handle about 1,050 gpm, it is estimated that it could cost an additional $150,000 to $200,000. The expenditure would be about evenly divided between facilities at the ground storage tanks in Kilgore and facilities modifications and additions in the well field. Utilization of an artificial recharge program would delay the construction of the next surface water treatment module of 3.5 million gallons per day. The estimated cost of that additional capacity is about $2.8 to $3.5 million.

The preliminary cost estimates are for a conceptual design of an ASR project. Pilot testing is required to help assess if ASR is a feasible water supply option. An economic comparison between a conceptual ASR project and other water supply options that may be considered by Kilgore is beyond the present scope of the study.

<u>Preliminary Cost Estimate for the City of Canton</u>

Further studies and pilot testing of ASR are needed to help assess the feasibility of a *recharge project. The chemical compatibility of the treated surface water and the aquifer water should be studied and geochemical models used to help determine if chemical plugging of the well and aquifer may occur as the result of artificial recharge. It is estimated that it could cost about $4,000 to $5,000 for collecting samples from the well and surface water supply, performing chemical analyses, and for geochemical modeling. Pilot testing should be performed using Well No. 4 (37-26-407) to evaluate the aquifer response and well response to the injection of water.*

Piping and pump modifications will be required at Well No. 4 to facilitate the injection of surface water. The well pump should be removed and small diameter injection tubes, probably no greater than 2 inches in diameter would be installed to extend below the static water level. The injection tubes would be connected to the well discharge piping and valves and a filter or strainer installed so that water could be routed from the distribution system to the injection tubes. Pump foundation and discharge head modifications may be required to perform the piping modifications. Safety equipment such as a high water-level cut off switch may be required to help insure that the water level does not rise too high in the well. It is estimated that the pump removal and reinstallation, injection tube installation, piping modifications, strainer, and electrical modification at Well No. 4 could cost about $30,000.

Following completion of the geochemical studies and the equipping and modifications at Well No. 4, pilot testing could begin. Pilot testing would help evaluate the rate at which the well will accept water and the response of the aquifer to the injection. Several cycles of injecting water and subsequently pumping it from the well could be required during the pilot testing phase. It is estimated that the cost of the pilot testing could range from about $10,000 to $15,000. If the pilot testing provides satisfactory results, Well No. 4 could be equipped on a permanent basis for ASR. Considering all the above items, the total capital and pilot testing costs for ASR in Kilgore would range form $44,000 to $55,000.

Operating and maintenance costs are estimated as follows:

1. Electric power cost for 270 feet of lift to pump water from well.	*10.2¢ per 1,000 gallons*
2. Labor cost at 2 hours per day at $20 per hour for 144,000 gallons of injection per day.	*27.7¢ per 1,000 gallons*
3. Treated surface water.	*$1.30 per 1,000 gallons*
4. Well Maintenance/Cleaning ($10,000/two years with 5 months of injection per year at 100 gpm or 0.144 mgd.	*22.6¢ per 1,000 gallons*
Total O&M Cost	*$1.91 per 1,000 gallons*

The study of the feasibility of artificial recharge would include, as mentioned previously, performing pilot studies, followed by artificial recharge using Well No. 4. Assuming artificial recharge using Well No. 4 is successful, the City could consider drilling additional wells at locations compatible with its distribution system to inject water into the Wilcox aquifer.

Utilization of artificial recharge to provide water to meet peak demands should help delay the expansion of the existing surface water treatment plant that is rated to provide 2 million gallons per day. Expansion of the plant, which could occur within the next 5 years, would be to a capacity of 4 million gallons per day. The estimated cost for expansion is about $1.6 to $2.0 million.

The preliminary cost estimates are for a conceptual design of an ASR project. Pilot testing, as stated previously, is required to evaluate the feasibility of the ASR option. An economic comparison between a conceptual ASR project and other water supply options that may be considered by Canton is beyond the present scope of the study.

10.1.2 Watershed Influences on Water Quality: The superfund site referenced in Table 10.2 is not discussed relative to water quality implications in the text and is not located on the map.

Table 10.2 has been removed. The associated paragraphs in this section were intended to describe the Subwatershed Approach as developed by the Sabine River Authority. More recent water quality conditions for each segment are presented in subsequent sections.

Figure 10.8 should be further enlarged to allow greater clarity of detail sections to allow identification of industrial discharge location.

This figure will be enlarged to an 11"x17".

10.2.2 Existing Conditions: Table 10.3 listing Endangered and Threatened Species Potentially Occurring in the Counties of Proposed Reservoir Development is cited without a date, for both state and federal species listings. Table 10.3 should include the most current available listing of species available.

Dates have been added to the appropriate citations in the reference section of the document.

10.2.4 Recommendations for New Reservoir Development: Table 10.5 on page 10-23 should be expanded in scope to allow greater clarity of the assessment of the relative risk by category (i.e., threatened/endangered species, archeological/cultural resources, bottomland hardwoods, etc) associated with development of specific projects.

It was determined that there is insufficient data available to quantify the risk by category between specific project sites. Table 10.5 presents a relative ranking of the overall risk for each project site and a list of the issues associated with that site. More detailed information about project sites with respect to each category is presented in sections 10.2.2 and 10.2.3. Further study would be necessary to produce quantifiable information which would be directly comparable between project sites.

Attachment 2 Responses:

The following items are Scope of Work deliverables. They were not included in the Draft Final Report and must be submitted for review prior to delivery of the Final Report in order to meet contractual requirements.

Task 2

1. GIS map showing average annual evaporation in the Sabine Basin.
   Included in Task 2 Technical Memorandum.

2. GIS map showing average annual runoff in the Sabine Basin.
   Included in Task 2 Technical Memorandum.

3. Table showing time histories of SRA reservoir contents
   Included in Task 2 Technical Memorandum.

4. Table showing time histories of rainfall at 4 key rain gages.
   Included in Task 2 Technical Memorandum.

5. Table showing seasonal distribution of rainfall and runoff at key locations.
   Included in Task 2 Technical Memorandum.

Task 3

6. Delineation of aquifer recharge zones.
   This has been added as Figure 4.2.

7. Figures and discussion of aquifer layering and hydraulic connection.
   See response to comment 4.1 above.

8. Estimates of aquifer discharge (pumpage and gains or losses to streams).
   See response to comment 8.1.1 above.

9. Estimates of gains or loss of aquifer storage.
   See response to comment 8.1.1 above.

10. Tabulation of historical and future groundwater demands.
    1996 historical demands were presented and future demands were held constant at year 2000 demands.

Task 4

11. Table showing the existing water rights in the Sabine Basin in Louisiana.

    Louisiana has no formal water rights allocation system therefore Louisiana water rights could not be listed in a table.

Table 15

12. Description of the above items in the text.

    Text describing all new tables and maps has been added.

13. Aquifer parameters (transmissivity, storage, permeability) for ASR evaluation-Task 15.

    See response to comment 8.2. An entire section has been added on this.

14. Water demand projections for certain groundwater users for ASR evaluation-Task 15.

    See response to comment 8.2. Projected demands for Kilgore and Canton have been added.

15. Listing of potential recharge sites in Smith, Wood, Rains and Van Zandt Counties.

    See response to comment 8.2. All potential sites have been listed.

16. Ranking of ASR sites selected for study.

    See response to comment 8.2.

17. Two-dimensional analytical modeling for ASR recharge and withdrawal rates.

    See response to comment 8.2. An entire section of text has been added on this.

18. ASR operating cost estimates.

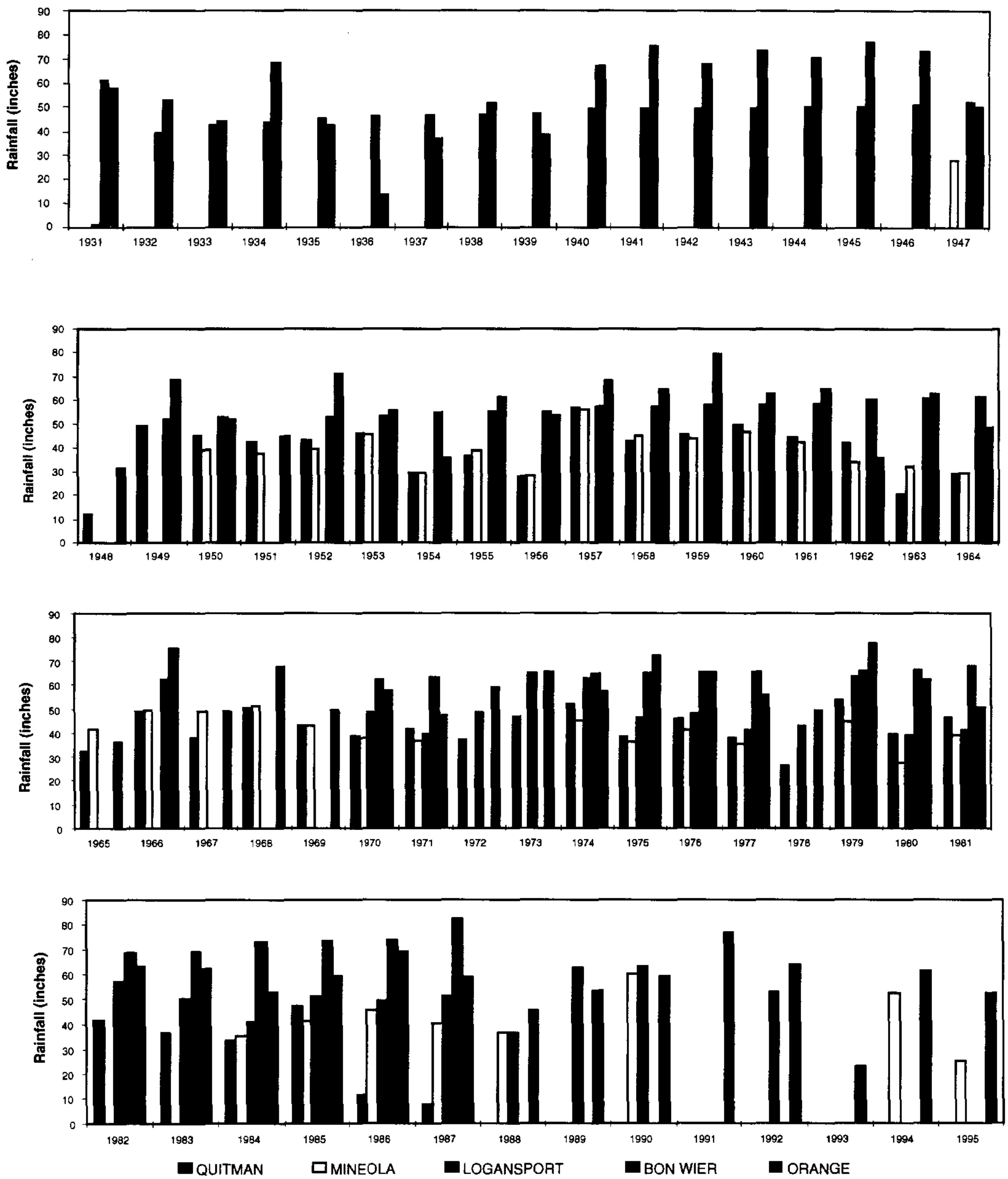
    See response to comment 8.2.1. Estimated operating and maintenance costs have been included.

Addendum

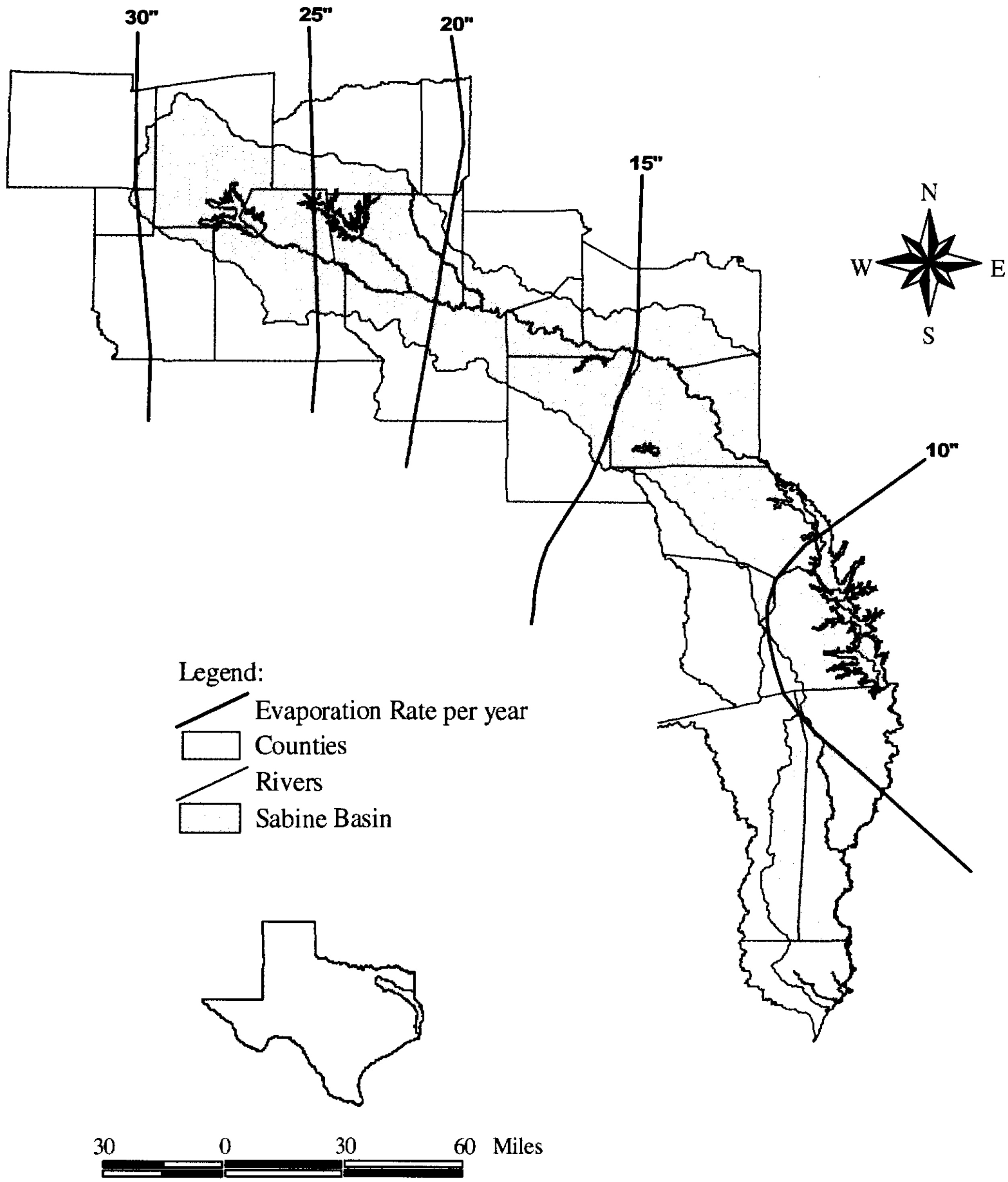
Figures and Tables requested by

Texas Water Development Board

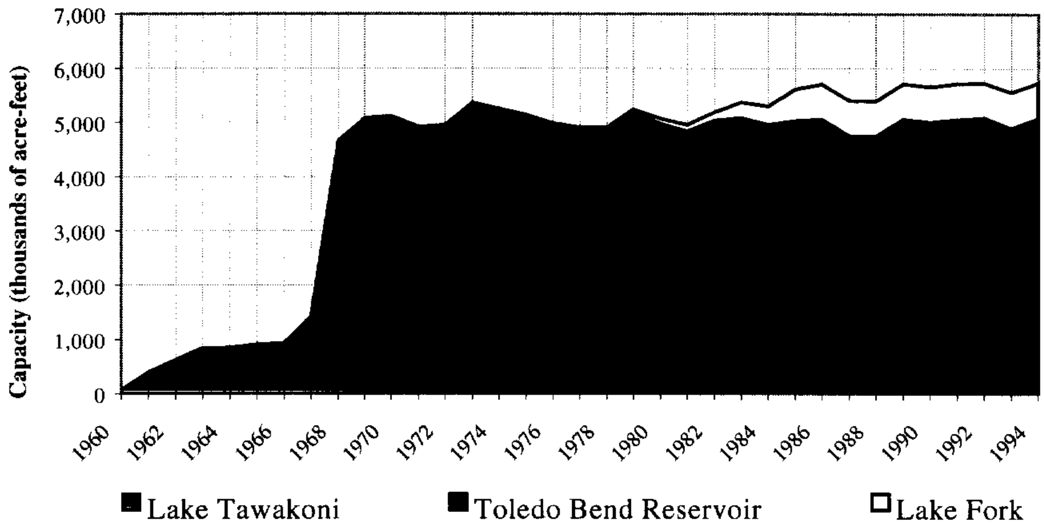
Average Annual Rainfall (1931-1995)



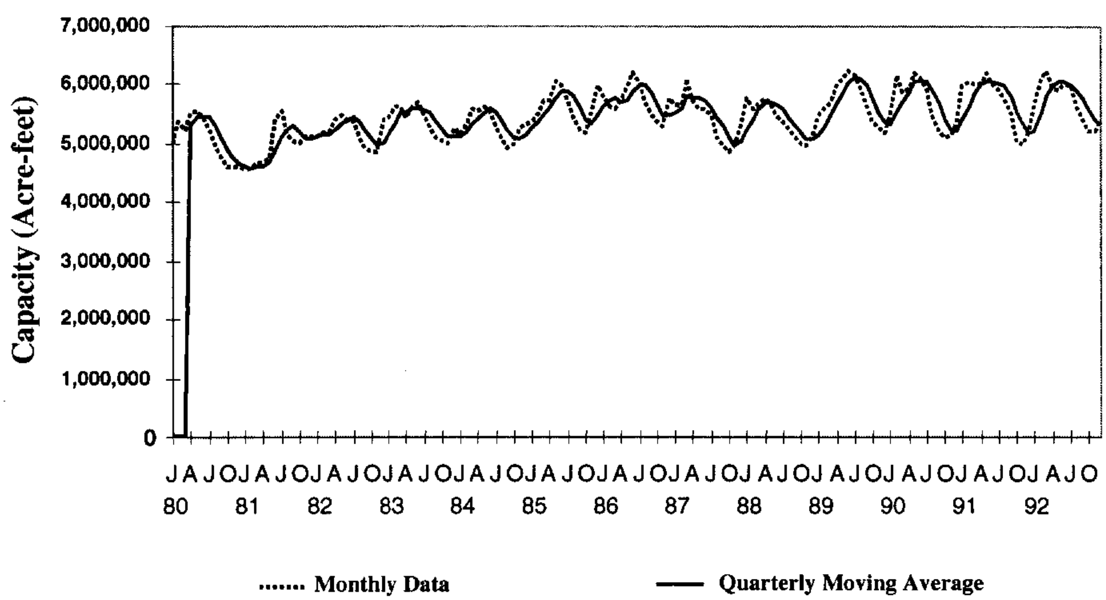
Evaporation Isoclines



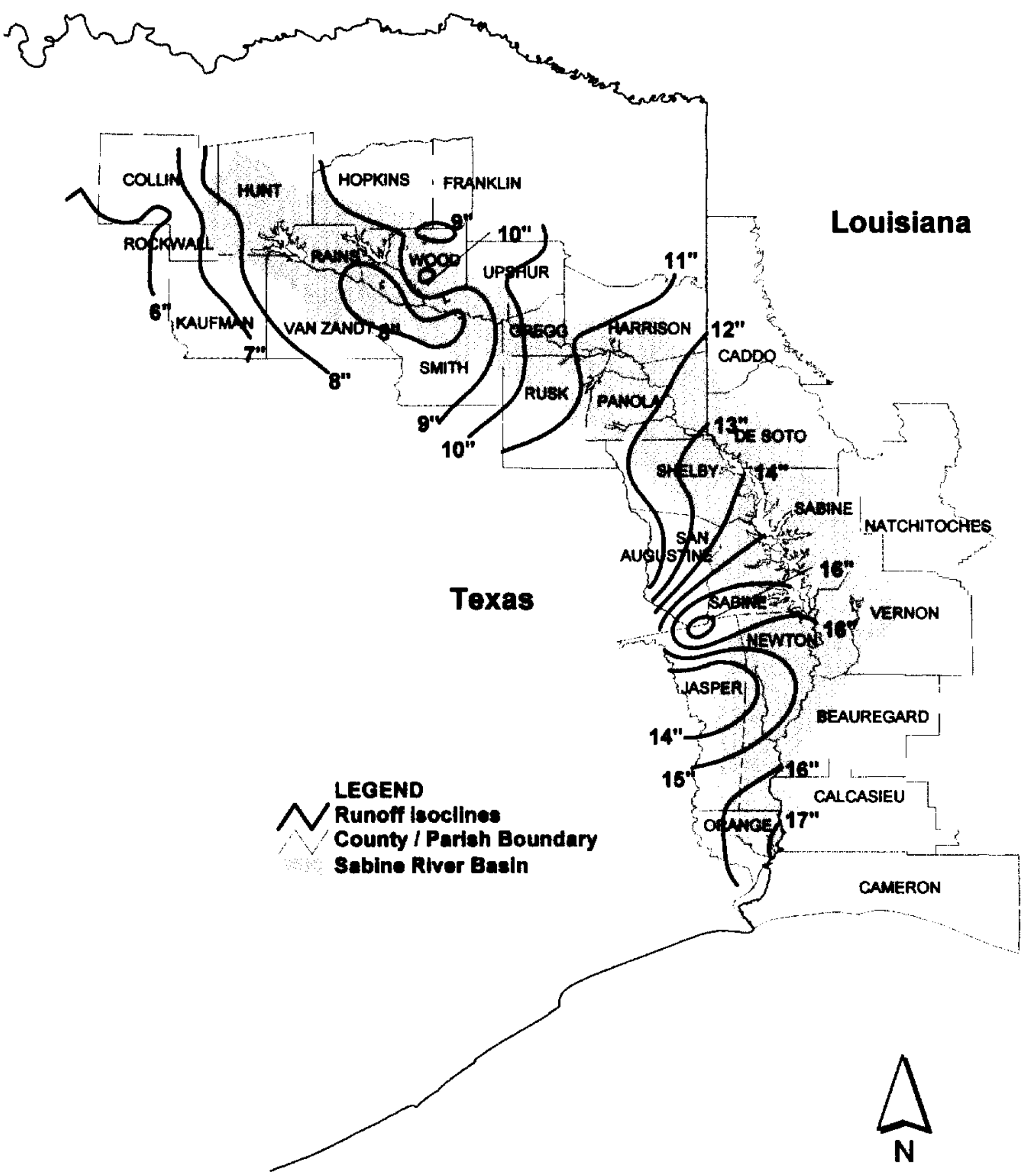
Storage Capacity over Time at 3 Largest Sabine Reservoirs



Average Stored Volume of 3 Largest Sabine Basin Reservoirs



Runoff Isoclines



HYDROSTRATIGRAPHIC UNITS IN THE SABINE RIVER BASIN AND THEIR WATER-BEARING PROPERTIES

Aquifer	Geologic Age	Water-Supply Availability (acre-ft / year)	Water-Bearing Properties
Gulf Coast Chicot Evangeline Jasper Catahoula	Tertiary	53,000	Yields moderate to large amounts of fresh to slightly saline water from four separate formation units. Excessive pumping near the coast may result in salt-water intrusion.
Yegua	Tertiary	1,000	Yields small to moderate quantities of fresh to slightly saline water in Southern Sabine County.
Sparta	Tertiary	7,400	Yields small to moderate quantities of fresh to slightly saline water primarily in the outcrop areas.
Queen City	Tertiary	32,000	Yields small to large quantities of fresh to slightly saline water primarily in the outcrop areas.
Carrizo - Wilcox	Tertiary	44,800	Most extensive aquifer in the Basin yielding moderate to large amounts of fresh to slightly saline water. Highest yields occur in the Carrizo portion of the aquifer.
Nacatoch	Cretaceous	234	Yields small to moderate amounts of fresh to slightly saline water only in the western extreme of the Basin.