EXECUTIVE SUMMARY

Senate Bill 1, passed by the 75^{th} Texas Legislature, requires that the Texas Natural Resource Conservation Commission (TNRCC) develop, or acquire, new reservoir/river basin simulation models in order to determine water availability in twenty-two river basins within Texas. In October of 2000, the TNRCC authorized Brown & Root Services to provide technical assistance for the water availability analysis for the Sabine River Basin in East Texas. R. J. Brandes Company and Crespo Consulting Services served as sub-consultants to Brown & Root Services on this project.

STUDY OBJECTIVES

The TNRCC, mandated by Senate Bill 1, is to conduct a water availability analysis to determine the:

- Projected amount of water available for all water rights during extended dry periods.
- Projected amount of water that would be available if cancellation procedures were instigated under the provisions of Subchapter E, Chapter 11, of the Texas Water Code.
- Potential impact of reusing municipal and industrial effluent on existing water rights, instream uses, and freshwater inflows to bays and estuaries.

As stated under Chapter 11.173 of the Texas Water Code, water rights cancellations can be performed:

a) Except as provided by Subsection (b) of this section, if all or part of the water authorized to be appropriated under a permit, certified filing, or certificate of adjudication has not been put to beneficial use at any time during the 10-year period immediately preceding the cancellation proceedings authorized by this subchapter, then the permit, certified filing, or certificate of adjudication is subject to cancellation in whole or in part, as provided by this subchapter, to the extent of the 10 years of nonuse.

b) A permit, certified filing, or certificate of adjudication or a portion of a permit, certified filing or certificate of adjudication is exempt from cancellation under Subsection (a) of this section:
   1) to the extent of the owner's participation in the Conservation Reserve Program authorized by the Food Security Act, Pub. L. No. 99-198, Secs. 1231-1236,99 Stat.1354, 1509-1514 (1985) or a similar governmental program; or
   2) if any portion of the water authorized to be used pursuant to a permit, certified filing, or certificate of adjudication has been used in accordance with a regional water plan approved pursuant to Section 16.053 of this code.

Nine different scenarios were analyzed in this study to simulate the effects of the above-described parameters. Scenarios one through eight were legislatively mandated, while scenario nine is basin specific. The eight mandated scenarios include: three reuse scenarios, four cancellation scenarios and one current conditions scenario (which includes term permits). The basin specific scenario represents a firm yield determination for all permitted reservoirs with capacities greater than 5,000 acre-feet per year (ac-ft/yr).

PROCEDURES

A Water Availability Modeling (WAM) team was established with representatives from the TNRCC, Texas Parks and Wildlife Department (TPWD), and the Texas Water Development Board (TWDB). This team prescribed general procedures to be followed in the development of a water availability analysis. These procedures include the development of naturalized streamflows from historical hydrological information, the utilization of the Water Rights Analysis Package (WRAP (VER 11/26/01)) program, and adhering to the Texas prior appropriation system, the Texas Water Code, and regulatory policies set by the TNRCC.

Naturalized streamflows are the flows that would have occurred in the absence of human activities such as reservoir development, diversions, and return flows. These naturalized flows are based on historical hydrologic records, as adjusted to remove the impact of human activities. The flows are used as input to the water availability analysis, which simulates the operation of existing water rights considering their location, characteristics, and priority under Texas Water Law. Naturalized streamflows were developed for selected USGS gage locations in the Sabine River Basin for each month over a 59-year historical period of record covering 1940 through 1998. The locations where naturalized streamflows were developed are called primary control points, and are distributed spatially throughout the river basin.

The WRAP (VER 11/26/01) model, developed by Dr. Ralph A. Wurbs at Texas A & M University, simulates a river basin using monthly time steps and historical hydrologic river basin characteristics, while adhering to Texas Water Law. The model performs a sequential monthly water volume accounting computation by determining if TNRCC permitted water diversions can be made at a particular location during a specified hydrologic period of analysis under given historic hydrologic conditions. The model is set up to allow water rights that have seniority the first right at diversion (“first in time, first in right”).

An additional consideration in developing the water availability model for the Sabine River Basin is the effect of the Sabine River Compact on water resources allocation between the States of Louisiana and Texas. The Sabine River Compact Administration (SRCA), is an interstate administrative agency consisting of two members from each state and one member representing the United States. The Compact was entered into by both states on January 26, 1953, under authority granted by an Act of the Congress of the United States approved November 1, 1951.

The principle objective of the SRCA is to provide for the equitable distribution of the waters of the Sabine River from the point where the river becomes the state line, south to the mouth of the river at Sabine Lake. Due to the limitations and conditions of the Compact, Texas is only entitled to use 50 percent of the streamflows of the Stateline reach. Therefore, before any water was diverted in the Stateline reach, the flows of the Stateline reach were divided, so that Texas water rights only had access to 50 percent of the total flows of the river in the Stateline reach. Review of Louisiana diversion records indicates that Louisiana diversions do not exceed the Louisiana portion of the water in the Stateline reach. The models developed in this study are considered to be consistent with the Sabine River Compact as well as the Texas Prior Appropriation Doctrine.

The specific steps taken to develop the Sabine River Basin Water Availability Model were to collect, analyze, and compile data needed for input into WRAP (VER 11/26/01). Data required for input into the model include control points, naturalized flows, evaporative losses, water rights information, reservoir area-capacity curves, return flow information, and water use demand patterns. There are a total of 183 water rights issued by TNRCC in the Sabine Basin of Texas totaling 1,886,424 ac-ft/yr. Once the data were obtained, nine scenarios were analyzed using WRAP (VER 11/26/01) to determine the effects of the water management strategies as outlined in the study objectives.

RESULTS

The detailed results from the water availability analysis, for the eight base scenarios for the Sabine River Basin are presented in Tables ES-1 through ES-3, at the end of this Executive Summary. These tables list all Texas water rights in the Sabine River Basin with authorized diversions and give a unique identification number for each water right. In many cases a water right has multiple entries which result from a water right having multiple diversion locations, use types, and/or priority dates, all of which are used in the WRAP (VER 11/26/01) model to simulate the written permit.

The water right identification number consists of 11 digits. The first digit represents the water right type (1 for Permit or 6 for Certificate of Adjudication), the second two digits represent the basin number, the next 5 digits represent the water right number, and the final 3 digits represent the water right feature (001-100 – diversion point, 101-200 downstream limit of a diversion segment, 201-300 – upstream limit of a diversion segment, 301-400 - on-channel reservoir, 401-500 – off-channel reservoir). Additionally, the table lists the authorized diversion amount, the simulated mean annual shortage, and the period and volumetric reliability for the 59-year period of record. Period reliability, expressed in percent, is defined as the ratio of number of months for which no shortages occurred to the total number of months in the simulation period. Volumetric reliability, expressed as a percent, represents the ratio of the mean annual diversion in a given model scenario to the corresponding authorized annual diversion amount. For Tables ES-2 and ES-3, an #N/A indicates a partial or total cancellation of that portion of the water right.

There are fifteen existing permitted reservoir projects within the Sabine River Basin with capacities over 5,000 acre-feet. Lake Anacoco and Lake Vernon are the only major reservoirs located entirely in Louisiana and are currently used only for recreation purposes.

Toledo Bend Reservoir is the largest reservoir in the basin with a conservation storage capacity of 4,477,000 acre-feet. The ownership and benefits are shared equally between the Sabine River Authority of Texas and Sabine River Authority, State of Louisiana. The reservoir is used for water supply, hydroelectric power generation, and recreation purposes. Lake Tawakoni and Lake Fork are the second and third largest reservoirs of the basin. These reservoirs are used primarily for municipal water supply. The water rights authorizing these reservoirs allow for the transfer of a portion of the supply out of the Sabine River Basin.

Table ES-4 at the end of this Executive Summary presents the firm yield determinations for the major water supply reservoirs in the Sabine River Basin. The firm yields determined in this study do not exceed the authorized amount as specified in the water right (refer to the TNRCC Resolved Technical Issues-Issue No. 10-August 12, 1999 for a description of the methodology recommended by the WAM Technical Committee).

CONCLUSIONS

The conclusions of this water availability study are as follows:

- The Sabine River Basin, located in southeastern Texas, drains an area of approximately 9,756 square miles. There are a total of 183 Texas water rights simulated with authorized annual diversions totaling 1,886,424 ac-ft/yr.

- Shortages occur frequently for a number of water rights; but the vast majority of these rights are located in the upper reaches of tributaries where streamflows are limited.

- Comparisons of the three reuse scenarios show that varying levels of wastewater reuse does impact water supply. The reliability of a water right generally decreases as the level of reuse increases. Reuse of wastewater decreases the amount of storage in a reservoir; but the magnitude of the decrease is much more pronounced for reservoirs in the upper basin.

- There are 57 water rights with authorized diversions totaling 5,450 ac-ft/yr, approximately 0.3 percent of the total authorized diversions in the basin, which were simulated as being canceled. Thus hypothetical cancellation of water rights has a negligible effect on the reliability of water supply for most rights in the basin. Limiting diversions in the maximum use scenarios reduces the diversion amount by approximately 1,240,800 ac-ft/yr and shows that water use in the basin is approximately 20 percent of the total authorized amount.

- The amount of unappropriated flows varies based on the location of the control point. In general, wastewater reuse has a greater effect on unappropriated flows for those locations in the upstream portions of the basin.

- The amount of regulated flows varies based on the location of the control point. In general, wastewater reuse has a greater effect on regulated flows for those locations in the upstream portions of the basin.

- Over a 59-year period of record, the average naturalized flow discharging into Sabine Lake from the Sabine River is approximately 6,857,000 ac-ft/yr, with a minimum annual inflow of 2,492,000 ac-ft/yr.

Table ES-4 Firm Yield Determination

Reservoir	Priority Date(s)	Authorized Capacity (ac-ft)	Authorized Diversion (ac-ft/yr)	Yield (ac-ft/yr)
Lake Tawakoni	09/12/1955 08/13/1985 05/21/1986	927,440	238,100	238,100
Lake Fork	06/26/1974 02/28/1983 08/13/1985	675,819	188,660	176,790
Lake Quitman [(a)]	12/19/1960	7,440	-	-
Lake Winnsboro [(a)]	12/19/1960 11/15/1965	8,100	-	-
Lake Holbrook [(a)]	12/19/1960	7,990	-	-
Lake Hawkins [(a)]	12/19/1960 11/15/1965	11,890	-	-
Lake Gladewater	05/17/1951	6,950	1,679	1,679
Lake Cherokee	10/05/1946	62,400	62,400	36,500
Brandy Branch Cooling Pond [(b)]	08/21/1978	29,513	11,000	-
Martin Lake	07/19/1971	56,500	25,000	25,000
Lake Murvaul	07/19/1956	44,650	22,400	22,400
Toledo Bend	03/05/1958 01/22/1986	4,477,000	750,000	750,000

(a) Reservoirs authorized for recreational use only. No yield determined.
(b) Reservoir requires interbasin transfers. No yield determined.
(c) To simulate subordination of Toledo Bend Reservoir to all water rights in the upper basin, the model priority date of Toledo Bend was set as 12/31/2000.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX

1.0 INTRODUCTION

1.1 Description of the Basin

The Sabine River Basin originates in northeast Texas near Dallas, and flows southeast towards Logansport, Louisiana, then south to Sabine Lake. The crescent-shaped basin is 48 miles across at its widest point and over 300 miles from its headwaters to Sabine Lake and the Gulf of Mexico. The Sabine River flows approximately 165 airline miles from the headwaters in Hunt County through Texas to become the Texas - Louisiana state line near Logansport, Louisiana. It serves as the state line between Texas and Louisiana for approximately 135 airline miles from Logansport to Sabine Lake. Figure 1 is a base map of the Basin.

All or part of twenty-one Texas counties and seven Louisiana parishes are in the Basin. The Texas counties are: Rockwall, Collin, Hunt, Kaufman, Hopkins, Rains, Van Zandt, Franklin, Wood, Smith, Upshur, Gregg, Rusk, Harrison, Panola, Shelby, San Augustine, Sabine, Newton, Jasper, and Orange. The Louisiana parishes are Caddo, De Soto, Sabine, Vernon, Beauregard, Calcasieu and Cameron. The total drainage area of the Basin is approximately 9,756 square miles with 7,396 square miles (76 percent) in Texas and 2,360 square miles (24 percent) in Louisiana.

The basin has different climatic characteristics north and south of the headwaters of Toledo Bend Reservoir. North of Toledo Bend, the Upper Basin is characterized by cool winters, hot summers and seasonal rainfall patterns. South of the reservoir, 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 upper north portion of the Upper Basin to 56 inches in the Lower Basin near the Gulf Coast. The historical streamflow patterns in the basin follow typical rainfall patterns, generally increasing from November to May, and decreasing from June to October. Average annual gross evaporation rates range from a low of 46 inches per year in the Lower Basin to a high of 57 inches per year in the upper north portion of the Upper Basin. The droughts of the 1950s and 1960s appear to be the most severe droughts of record that affected the Sabine Basin.

A gentle north to south slope characterizes the overall basin topography with elevations ranging from 700 feet above mean sea level at the headwaters of the basin to sea level in the coastal region. The Upper Basin is characterized by rolling to hilly topography with streams in shallow valleys. The Lower Basin is generally flat with a fairly uniform, mild slope.

Figure 1 Sabine River Basin Water Availability Modeling: Location of Primary Control Points

Three main types of soil dominate in the basin: East Texas Timberland, Blackland Prairie, and Coastal Prairie. The uppermost part of the basin has soils of the Blackland Prairie group, and is comprised of various clayey soils. The soils of the Blackland Prairie group generally are categorized into hydrologic soil group D, indicating slow infiltration rates and very high runoff potential. These soils are also susceptible to erosion due to their sloping nature and clay texture, resulting in higher sediment production rates. The East Texas Timberland series soils are primarily light-colored sandy loam and cover nearly 90 percent of the basin.

The soils in the East Texas Timberland group range from hydrologic soil group A to D, with the majority of the soils in the C and D groups, indicating a variety of infiltration rates, although predominately slow with high runoff potential. This type of soil is susceptible to heavy erosion when the natural vegetation is removed. The Coastal Prairie soils are located along the Gulf Coast, and are primarily dark gray to black clays. The soils in the Coastal Prairie group generally fall into hydrologic soil group D, again indicating slow infiltration rates and very high runoff potentials. The Coastal Region has the lowest erosion and sedimentation rates in the Sabine Basin due to its flat topography, poor drainage and grassy vegetation.

The vast majority of groundwater in the Sabine River Basin is contained in two major aquifers: the Carrizo-Wilcox aquifer and the Gulf Coast series of aquifers including the Catahoula, Jasper, Evangeline, and Chicot. Lower-yielding aquifers including the Nacatoch, Queen City, Sparta, and Yegua supply additional quantities of water. Most of the groundwater users are rural water supply corporations. Except in the lower basin, few cities and industries rely on groundwater due to limitations in quantity and quality.

1.2 Water Resources Regulation in the Sabine Basin

The Texas Natural Resource and Conservation Commission (TNRCC), the Sabine River Authority of Louisiana, and the Sabine River Compact Administration all have regulatory responsibilities relating to the allocation of waters of the Sabine Basin.

The Texas Natural Resources Conservation Commission is the regulatory agency in the State of Texas for air, water and waste and is responsible for implementing federal and state laws and regulations governing all aspects of permitting for the air, water and waste programs. The agency was created by the Texas Legislature effective September 1, 1993 as a comprehensive environmental protection agency by consolidation of the Texas Water Commission and the Texas Air Control Board.

The Sabine River Authority, State of Louisiana was created in 1950 for the purpose of conservation and reclamation of water within the Sabine watershed in Caddo, De Soto, Sabine, Vernon, Beauregard, Calcasieu, and Cameron Parishes in the State of Louisiana. It 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.

The Sabine River Compact Administration (SRCA), is an interstate administrative agency consisting of two members from each State and one member representing the United States. The Compact was entered into by both states on January 26, 1953, under authority granted by an Act of the Congress of the United States approved November 1, 1951. The principle objective of the SRCA is to provide for the equitable distribution of the waters of the Sabine River from the point where the river becomes the state line, south to the mouth of the river at Sabine Lake. As stated in Article VII, Section G of the Compact, the SRCA works in cooperation with the chief official administering water rights in each state and with appropriate Federal agencies to manage the conservation and utilization of the waters of the Sabine River. In the Compact, the point on the Sabine River where its waters in downstream flow first touch both Texas and Louisiana is named “Stateline”. The portion of the Sabine River between the Stateline and Sabine Lake is defined as the “Stateline reach”.

The major highlights 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 after January 1, 1953, neither State shall permit or authorize any additional uses which would have the effect of reducing the flow at the Stateline to less than 36 cubic feet per second (cfs).
- Any reservoir constructed in the watershed above the Stateline after January 1, 1953 will be liable for its pro rata share of the 36 cfs.
- Texas may either use the water stored in reservoirs above the Stateline or allow such stored water to flow downstream in the Stateline reach to a desired point of removal without loss of ownership subject to a reduction at the point of removal equal to any transmission losses.
- All free water in the Stateline reach will be divided equally between the two states.
- Water consumed for domestic and stock water purpose is excluded from the apportionment under the Compact.

1.3 Study Objectives

The objective of this study is to meet the requirements placed on the Texas Natural Resource Conservation Commission by Senate Bill 1. Senate Bill 1, passed by the 75th Texas Legislature, requires that the TNRCC develop or acquire new reservoir/river basin simulation models in order to determine water availability in twenty-two river basins within Texas. In October of 2000, the TNRCC authorized Brown and Root Services to estimate naturalized inflows and develop a water availability model for the Sabine River Basin in East Texas.

R. J. Brandes Company and Crespo Consulting Services served as sub-consultants to Brown and Root Services on this project.

In order to meet the study objectives for the Sabine River Basin Water Availability Study, two principal tasks had to be performed:

- Calculation of naturalized flows.
- Development of a water availability model using Texas A&M's Water Rights Analysis Package (WRAP (VER 11/26/01)).

As mandated by Senate Bill 1, the TNRCC is to determine, through the water availability analysis, the:

- Projected amount of water available for all water rights during extended dry periods.
- Projected amount of water that would be available if cancellation procedures were instigated under the provisions of Subchapter E, Chapter 11, of the Texas Water Code.
- Potential impact of reusing municipal and industrial effluent on existing water rights, instream uses, and freshwater inflows to bays and estuaries.

1.4 Study Approach

The Water Availability Modeling (WAM) Management team, with representatives from the TNRCC, Texas Parks and Wildlife Department (TPWD), and the Texas Water Development Board (TWDB), have prescribed general procedures to be followed in the development of a water availability model. These procedures include the development of naturalized streamflows from historical hydrological information and utilization of the Water Rights Analysis Package program, while adhering to the Sabine River Compact, Texas Water Law, and regulations set by the TNRCC. These procedures were followed in the development of naturalized flows and the water availability model for the Sabine River Basin.

Naturalized streamflows are those flows that would have occurred in the absence of human activities such as reservoir development, diversions, and return flows. These naturalized flows are based on historical hydrologic records, adjusted to remove the impact of human activities. They are used as input to the water availability model, which simulates the operation of existing water rights considering their location, characteristics, and priority under Texas water law.

The model selected by the TNRCC for use in this study was WRAP (VER 11/26/01). The WRAP (VER 11/26/01) program, developed by Dr. Ralph A. Wurbs at Texas A & M University, simulates a basin using monthly time steps and historical hydrologic river basin characteristics while adhering to the Texas prior appropriation system. The model performs a sequential monthly water volume accounting computation by determining if TNRCC permitted water diversions can be made at a particular location during a specified hydrologic period of analysis given historic hydrologic conditions. The model is set up to allow water rights that have seniority the first right at diversion, ("first in time, first in right").

This report serves to document the methodologies used in the development the Water Availability Model for the Sabine River Basin, and the results of the model simulation.

2.0 EXISTING WATER AVAILABILITY INFORMATION

Key data for water availability modeling include water rights, historical water use, historical return flows, historical streamflow, reservoir data, and evaporation rates. This section discusses available information on water rights, historical water use, historical return flows, treated wastewater effluent discharge, and previous water availability and planning studies. Existing hydrologic data on the Sabine River Basin is limited prior to 1940; therefore, this study will use hydrologic data from January 1940 through December 1998 as the period of record. This period of record was selected because sufficient data is available to make the modeling effort reliable and because it encompasses the droughts of 1951-1956, 1963-1964, 1965-1967, 1980, 1984, 1988, and 1996.

2.1 Water Rights

There are a total of 183 water rights, authorized by the State of Texas in the Sabine River Basin. Table 1 provides a summary of water rights by use type and illustrates that the total authorized diversions for these water rights is 1,886,424 acre-feet per year. Approximately 624,132 ac-ft/yr is authorized for municipal use, 1,158,299 ac-ft/yr for industrial purposes and 103,282 ac-ft/yr authorized for irrigation, with the remaining allocated to mining, recreation and other (fish and wildlife) uses. Information regarding water rights was obtained from: TNRCC master water rights database and hard copies of Texas water rights. While Louisiana diversions were taken into consideration during the streamflow naturalization process, they were not simulated in the WRAP (VER 11/26/01) model as explained later in this section. Appendix A is a copy of the current TNRCC master water rights database for the Sabine River Basin sorted by river order number and sequenced from downstream to upstream. Appendix B is the same database sorted by priority date from the most senior water right to the most junior water right. Current water rights documents (all certificates of adjudication and permits issued by the TNRCC through September 2000) were reviewed and compared to the TNRCC database. A memorandum with suggested corrections to the database was prepared (including identification of multiple diversion points) and is included in Appendix C.

Table 1 Summary of Sabine River Basin Water Rights by Subwatershed (ac-ft/yr)

USE TYPE	Municipal	Industrial*	Recreation	Mining	Irrigation	TOTAL
Upstream of Stateline	522,672	190,664	10	701	6,465	720,512
Downstream of Stateline	101,460	967,635	0	0	96,817	1,165,912
TOTAL	624,132	1,158,299	10	701	103,282	1,886,424

* Hydropower not included. Industrial, Downstream of Stateline does not include water right 05-4664, with an authorized diversion of 267,000 ac-ft/yr which is considered saline and simulated with no diversions.

Appendix D contains a memorandum identifying those saline water rights in the Sabine River Basin which were not simulated as outlined in the TNRCC Resolved Technical Issue No. 5.

The State of Louisiana has three categories of water rights: absolute ownership, state ownership and riparian. Absolute ownership is associated with groundwater rights where ownership is attached to the land. Surface water is State property except where riparian claims have been established before 1910. To simulate in WRAP (VER 11/26/01) the equitable distribution of water downstream of Stateline, as required by the Sabine River Compact, Louisiana water rights were excluded from the model, and instead 50 percent of the total streamflows downstream of Stateline was reserved for Louisiana. The only exception is the Sabine River Authority of Louisiana share of Toledo Bend Reservoir, which for the purpose of this study was set equal to 750,000 ac-ft/yr, the same as what is authorized for diversion by the Sabine River Authority of Texas. Simulating this “duplicate” water right results in the equitable distribution of water within Toledo Bend Reservoir as well as preserving the each State’s fair share of water downstream of Toledo Bend Reservoir.

2.2 Historical Water Use

Records obtained from the TNRCC and the SRA of Louisiana compiled historical water use by individual water rights owners in the basin. Surface water use records for water rights in the Sabine River Basin were obtained from the TNRCC in database format. The water use data obtained from the TNRCC is water use for each water right as reported to the TNRCC by all permittees. This data set included the use type and monthly use records. Water use records for diversions from the State of Louisiana were obtained from the SRA of Louisiana.

The permit files were reviewed to obtain water use data for water rights with large diversion amounts as well as to identify water rights with missing data. Water rights holders that had water use records with incomplete records were contacted to obtain additional information to fill in the missing data. If no data was available, water use data was estimated on a per capita basis for municipal water rights. Per capita water use estimations were determined by dividing the water use in a given year by the population of the community using the water in that same year. The per capita values were then multiplied by the population of the community during the period of missing data. Estimates for water use for industrial and irrigation water rights were based on historical use patterns of those water rights or rights with similar uses and diversion amounts. When a good estimate could not be formed, the historical use was estimated to be zero. This estimation provided a conservatively low estimate in the naturalized streamflow calculations. Appendix E provides a summary of water use by county in the Sabine River Basin. If any recorded data appeared suspect and had a significant impact on the estimated naturalized flows, responsible entities (reservoir owners/operators, USGS, and/or other sources) were contacted for additional information to assist in resolving the specific issue.

The basin's water use consisted of approximately 77% surface water and 23% groundwater in 1997. Surface water is supplied primarily by a number of water supply reservoirs as well as one large run-of-river water right in the lower basin. The vast majority of groundwater in the Sabine River Basin is contained in two major aquifers: the Carrizo Wilcox aquifer and the Gulf Coast series of aquifers including the Catahoula, Jasper, Evangeline, and Chicot. Lower-yielding aquifers including the Nacatoch, Queen City, Sparta, and Yegua supply additional quantities of water. Most of the groundwater users are rural water supply corporations. Except in the lower basin, few cities and industries rely on groundwater due to limitations in quantity and quality.

Currently manufacturing is the largest user of water in the basin (53%) followed by municipalities whose use composed nearly 25% of total water use. Table 2 shows future water demand and total water available as projected by the TWDB Regional Plans. Although the TWDB data suggests that there are shortages, the water available only includes existing contracts for water. The water held by major water suppliers which has not been contracted is not included, and once contracts are executed, many shortages can be reduced or eliminated.

Groundwater return flows were included in the model if the minimum discharge amount for the five-year period from 1994 to 1998 was in excess of 0.35 million gallons per day (mgd). Wastewater treatment plants which produce groundwater based return flows as all or part of the effluent are the cities of Bridge City, Carthage, Kilgore, Lindale, Mineola and Orange. The Louisiana-Pacific facility in Newton County and Equitable Bag Company and Bayer Corporation in Orange County are the major industries returning groundwater based effluent. Table 3 presents groundwater sources by county and aquifer source.

Table 2 Demand and Total Available Water (acre-feet per year)

County Name *	TWDB SB1 Planning Process Region	Regional Water Demand Projections						Total Water Available Under Existing Contracts					
		2000	2010	2020	2030	2040	2050	2000	2010	2020	2030	2040	2050
COLLIN	C	116	195	1,470	1,967	2,425	2,326	329	336	1,096	1,269	1,380	1,228
GREGG	D	39,596	42,386	45,540	49,378	53,589	58,362	68,108	55,872	56,729	57,192	43,228	28,971
HARRISON	D	122,395	146,999	153,833	160,083	173,644	188,943	214,688	213,440	214,114	214,353	214,929	210,436
HOPKINS	D	3,307	3,374	3,426	3,506	3,576	3,673	3,638	3,326	3,220	3,221	3,223	3,224
HUNT	D	12,887	13,635	14,171	15,050	15,818	16,630	35,282	10,114	5,108	4,760	3,960	3,961
JASPER	I	2,008	2,117	2,149	2,182	2,230	2,315	20,219	20,219	20,219	20,219	20,219	20,219
KAUFMAN	C	243	273	310	342	363	370	276	288	301	309	308	304
NEWTON	I	4,634	16,011	16,104	16,163	16,223	16,341	5,537	5,537	5,537	5,537	5,537	5,537
ORANGE	I	187,186	227,000	239,023	250,701	269,908	291,010	73,913	73,913	73,913	73,913	73,913	73,913
PANOLA	I	10,394	9,795	15,760	23,887	24,177	23,955	24,576	24,576	24,576	24,576	24,576	24,576
RAINS	D	2,096	2,235	2,359	2,509	2,662	2,833	3,616	3,616	2,576	1,471	1,471	1,471
ROCKWALL	C	1,153	1,611	2,143	4,356	5,364	6,411	1,550	1,520	1,642	2,802	2,916	3,161
RUSK	I	35,002	39,766	44,618	49,737	49,786	49,826	31,986	31,981	31,975	31,969	31,964	31,957
SABINE	I	53,522	69,691	81,294	96,994	98,575	99,736	3,309	3,309	3,309	1,467	1,467	1,467
SAN AUGUSTINE	I	207	211	218	227	236	248	214	214	214	214	214	214
SHELBY	I	7,327	8,271	9,327	10,587	12,024	13,765	11,397	11,250	11,250	11,250	11,250	11,250
SMITH	D, I	5,345	5,389	5,566	5,836	6,176	6,585	6,588	6,464	6,483	6,531	6,634	6,742
UPSHUR	D	2,252	2,354	2,351	2,428	2,519	2,570	2,883	3,149	3,149	3,149	3,149	3,149
VAN ZANDT	D	6,309	6,580	6,920	7,326	7,707	8,160	10,025	9,932	5,330	5,376	5,445	5,535
WOOD	D	9,864	33,191	33,267	33,489	32,867	29,565	16,647	39,675	39,486	39,299	33,924	22,534
TOTAL		505,843	631,084	679,849	736,748	779,869	823,624	534,779	518,730	510,226	508,876	489,707	459,849

Sources:
Region C Water Plan
North East Texas Regional Water Plan
East Texas Regional Water Plan
* Franklin County not included due to the small percentage of the County in the Sabine Basin

Table 3 Groundwater Sources and Supply in the Sabine River Basin

County Name	Aquifer Name	Year 2000 Groundwater Availability in the Sabine River Basin (Ac-Ft)	TWDB SB1 Planning Process Region
Collin	Undifferentiated	5	C
Collin	Trinity	125	C
Collin	Woodbine	94	C
Gregg	Carrizo-Wilcox	20,267	D
Gregg	Queen City	9,646	D
Harrison	Carrizo-Wilcox	112,071	D
Harrison	Queen City	2,756	D
Hopkins	Carrizo-Wilcox	4,033	D
Hopkins	Nacatoch	319	D
Hunt	Carrizo-Wilcox	5	D
Hunt	Nacatoch	197	D
Hunt	Trinity	433	D
Hunt	Woodbine	535	D
Jasper	Gulf Coast Aquifer	20,141	I
Kaufman	Undifferentiated	7	C
Kaufman	Undifferentiated	124	C
Newton	Gulf Coast Aquifer	28,765	I
Orange	Gulf Coast Aquifer	21,542	I
Panola	Carrizo-Wilcox	6,157	I
Rains	Carrizo-Wilcox	1,400	D
Rains	Nacatoch	2	D
Rockwall	Undifferentiated	188	C
Rockwall	Trinity	211	C
Rusk	Carrizo-Wilcox	5,752	I
Rusk	Queen City	2,756	I
Sabine	Carrizo-Wilcox	3,335	I
Sabine	Gulf Coast Aquifer	997	I
Sabine	Undifferentiated	534	I
Sabine	Sparta	6,512	I
San Augustine	Carrizo-Wilcox	26	I
San Augustine	Undifferentiated	2	I

2.3 Historical Return Flows and Treated Wastewater Effluent Discharge

Available records for return flows of treated Texas municipal and industrial wastewater effluent discharges were obtained from TNRCC for the time period 1978 through 1998. Prior to 1978, return flow records were generally not available. Return flows originating in Louisiana were obtained from the Louisiana Department of Environmental Quality (LDEQ) through the SRCA. The following techniques were used to estimate return flows where records were not available:

- For major return flows (more than 0.5 mgd), the entity was contacted to determine whether any records or estimates of flows existed for the time frame not covered by the TNRCC database.

- For cities without such records and with an estimated return flow over 0.5 mgd, return flows were estimated on the basis of water use or a per capita value.

- For industries without such records and with an estimated return flow over 0.5 mgd, return flows were estimated on the basis of water use.

- Return flows less than 0.5 mgd were not estimated.

- Agricultural return flows were neglected.

Facilities with major return flows (more than 0.5 mgd) were contacted to determine if any records or estimates of flow existed before 1978. Estimates of return flow were then calculated for all major return flow locations from the date in which the discharge began up through 1978.

Municipal return flows were calculated based on an assumed per capita value and corresponding water use data. Each return flow location was associated with one or more water rights, a groundwater source, an interbasin transfer, or a combination. The municipal return flows were calculated as a per capita value for the life of the treatment plants associated with each water right (assuming the water right had been granted before the treatment plant was operational). Industrial return flows were based on historical return flows and/or water use. Historical trends in return flow amounts and yearly distributions from 1978 through 1998 were used to estimate the return flow prior to 1978. Estimations prior to 1978 were calculated for the years that the water use for that industry was available. For example, if an industrial right was granted in 1958 then the return flow was only estimated from 1958 through 1978.

2.4 Previous Water Availability and Planning Studies

There are 65 major reports that provide information regarding the Sabine River Basin, 6 of which represent yield studies of the major reservoirs in the basin. A bibliography of these studies may be found in Appendix F.

According to these studies, the combined yields of those reservoirs studied in the Sabine River Basin ranged between 1.2 and 1.6 million acre-feet per year. The yields depend on assumed basin development, definition of yield, and reservoir operations. Additional assumptions which affect yields are the inclusion or exclusion of return flows and the allowed drawdown level of a reservoir during the critical period.

Other parameters that affected yield in previous studies included:

- Operational considerations such as minimum pool elevations.

- Simulated capacity, whether original or some future capacity.
- Treatment of upstream and downstream senior water rights, and/or instream flow requirements.
- Treatment of upstream junior water rights (requiring pass throughs or allowing diversions when reservoirs were not full.
- Inclusion of proposed reservoirs in the model.

2.5 Significant Considerations Affecting Water Availability in the Basin

Assumptions made in this study which may affect water availability include:

- A factor that can influence modeling results relates to the watershed parameters. During this study, the TNRCC has discovered problems in some river basin simulations with implementing the WRAP model-option that uses curve numbers (CN) in the distribution of naturalized flows to secondary control points. While this issue does not appear to have affected the Sabine River Basin WAM, the BRS team considers it prudent to distribute flows by drainage area only. We have included the CRWR-supplied average curve numbers in this report as well as in our input decks, as they may be used in the future if the curve number flow distribution problem can be resolved.
- Saline water rights located in the estuarine segments of the Sabine River are included as secondary control points but have no simulated diversions in the model since their diversions are not dependant on water quality and, as a result, should not affect water availability in the rest of the basin.
- Only currently permitted water rights as of September 2000 are modeled.
- Reservoirs less than 5,000 ac-ft are modeled using a regression relationship to relate reservoir storage to surface area.
- Channel losses are assumed to be negligible and are not included in the model.
- The model uses a monthly time step. Therefore, this type of analysis does not account for travel times between control points or flow requirements that depend on instantaneous flows such as instream flow requirements.
- In general, the amounts of appropriated water covered by existing rights are determined by the permitted diversion for each water right and are not based on firm yields, geographical location, or other practical limits. Thus, the remaining unappropriated water at any point in the basin is based on the assumption that all rights are taking their full paper values of diversions whenever that much water is available.
- Filling of downstream reservoirs with senior water rights take precedence over diversion by upstream junior water rights. The firm yield analysis for major reservoirs in this study did not allow for the demand to exceed the amount authorized

under the water right. Firm yields were determined only for those major reservoirs which experienced shortages under scenario three. The firm yield reported for those reservoirs which did not experience shortages in scenario three is the authorized amount as specified in the water right. The methodology for determining Firm Yields is outlined in the TNRCC Resolved Technical Issues - Issue No. 10 dated August 12, 1999.

- For water rights with off-channel storage, water rights are simulated in WRAP (VER 11/26/01) with a monthly streamflow depletion limit equal to the maximum pump rate and an annual streamflow depletion limit equal to the authorized diversion amount. The impact of the annual streamflow depletion limit is that reservoir storage is not refilled without limit, and evaporation can reduce the water right's reliability, even when unappropriated streamflows occur.

3.0 HYDROLOGIC DATA REFINEMENT

3.1 Naturalized Streamflow at Gaged Locations

Several USGS gage locations with extensive historical records served as primary control points. Naturalized streamflows were estimated at these control points by adjusting the gage records to account for the impacts of human activity.

3.1.1 Streamflow Naturalization Methodology

A primary task undertaken in this water availability study was to calculate naturalized streamflows.

Naturalized flow data is based on historical flows, adjusted to remove the effects of human activity. A general equation for naturalized flow is as follows:

Naturalized Flow = Historical Flow + Upstream Diversions – Upstream Return Flows + Changes in Upstream Reservoir Contents + Upstream Reservoir Evaporation

The elements of the equation are determined as follows:

- Historical Flow – Flow recorded at USGS streamflow gages or spills from a reservoir.
- Upstream Diversions – Upstream diversions as recorded in TNRCC records (or as estimated when records are missing).
- Upstream Return Flows – Upstream return flows as recorded in TNRCC records (or as estimated when records are not available).
- Changes in Upstream Reservoir Contents – Changes in contents for major upstream reservoirs are based on USGS records, records kept by others, or estimates of content changes if records were not available. Table 4 summarizes the sources of content data for each major reservoir. For reservoirs with no content data available for all or a portion of the period from 1940 to 1998, the content data was estimated using a simulation. The estimated reservoir contents were based on previous month end-of-period contents, estimated runoff, net evaporation, and historic water use and return flow records. Content changes for reservoirs with less than 5,000 acre-feet of conservation storage were neglected in the naturalization process.
- Upstream Reservoir Evaporation – Evaporation from upstream reservoirs is estimated by multiplying the net reservoir evaporation rate by the estimated reservoir surface area. Table 5 summarizes the method utilized for estimating the reservoir evaporation for each major reservoir based on TWDB Evaporation quadrangles. For these reservoirs, quadrangle coefficients were determined based on a ratio of the inverse of the distance squared from the reservoir centroids to the quadrangle centroids. Evaporation from reservoirs with less than 5,000 acre-feet of conservation storage is neglected in the streamflow naturalization.

Some reservoirs in the Sabine River Basin make releases for downstream use, transporting the water by the bed and banks of natural streams. In the computation of naturalized flows, these releases are treated as diversions at the point of use and not at the reservoirs.

Table 4 Sources of Reservoir Content Data

Reservoir	Period	Source of Content Data
Greenville City Lakes		N/A [(a)]
Lake Tawakoni	1960- Present	USGS
Lake Fork	1979 1979- Present	Simulated USGS
Lake Quitman	1962 – Present	Simulated
Lake Holbrook	1962 – Present	Simulated
Lake Hawkins	1962 – Present	Simulated
Lake Winnsboro	1962 – Present	Simulated
Lake Gladewater	1952 – Present	Simulated
Lake Cherokee	1948 – 1951 1951 – 1983 1983 – Present	Simulated USGS Simulated
Martin Lake	1973 – Present	USGS
Brandy Branch	1983 – Present	N/A [(b)]
Lake Murvaul	1957 – 1978 1978 – Present	USGS Simulated
Toledo Bend	1966 – Present	USGS
Lake Vernon	1963 – Present	Simulated
Lake Anacoco	1951 – Present	Simulated

(a) Off-channel reservoir complex with minimal drainage area, content change not applicable to naturalization process.

(b) Reservoir storage maintained with interbasin transfers, content change not applicable to naturalization process.

Table 5 Quadrangle Factors for the Estimation of Adjusted Net Reservoir Evaporation for Major Reservoirs in the Sabine River Basin

Reservoir	Evaporation Quadrangles and Quadrangle Factors *
Greenville City Lakes	0.438(411)+0.278(412)+0.155(511)+0.129(512)
Lake Tawakoni	0.182(411)+0.205(412)+0.277(511)+0.336(512)
Lake Fork	0.209(412)+0.791(512)
Lake Quitman	0.293(412)+0.707(512)
Lake Holbrook	1.000(512)
Lake Hawkins	1.000(512)
Lake Winnsboro	0.374(412)+0.626(512)
Lake Gladewater	0.456(512)+0.544(513)
Lake Cherokee	1.000(513)
Martin Lake	1.000(513)
Brandy Branch	1.000(513)
Lake Murvaul	0.556(513)+0.444(613)
Toledo Bend	1.000(614)
Lake Vernon	0.793(614)+0.207(714)
Lake Anacoco	0.646(614)+0.354(714)

* TWDB Quadrangles shown in parenthesis.

3.1.2 Streamflow Data Sources

Streamflow data in the Sabine River Basin were obtained from U.S. Geological Survey gage flows. The U.S. Geological Survey maintains a network of streamflow gages throughout the United States. USGS gage measurements are the most reliable source of historical streamflow data. Table 6 lists USGS streamflow gages in the Sabine River Basin. Figure 2 shows the length of record for each USGS streamflow gage in the basin.

3.1.3 Delivery Factors and Channel Loss Rates

In 1981 the USGS performed a Gain-Loss study in cooperation with the Sabine River Authority (SRA) for the Upper Sabine River Basin. The study was performed during the months of August and September and, while rainfall did occur during the study period, the overall period was considered to be representative of low flow conditions. The purpose of the study for the Upper Sabine River was to determine the efficiency of the Sabine River and Lake Fork Creek in conveying releases from Lake Tawakoni and Lake Fork, during dry conditions, to various downstream locations. The study concluded that

Table 6 USGS Streamflow Gages in the Sabine River Basin

Gage	USGS Number	Drainage Area (Square Miles)	Period of Record
Cowleech Fork Sabine River at Greenville, TX[a]	8017200	77.7	03/59 to present
South Fork Sabine River near Quinlan, TX[a]	8017300	78.7	03/59 to present
Lake Tawakoni near Wills Point, TX[a]	8017400	756	10/60 to present
Sabine River near Wills Point, TX[a]	8017410	756	10/70 to present
Sabine River near Emory, TX	8017500	888	52-73
Burnett Branch near Canton, TX	8017700	0.33	66-74
Sabine River near Golden, TX	8018000	1200	24-25
Grand Saline Creek near Grand Saline, TX	8018200	91.4	68-73
Sabine River near Mineola, TX[a]	8018500	1357	05/39 –09/59, 10/67 to present
Burke Creek near Yantis	8018730	33.1	79-89
Lake Fork Reservoir near Quitman, TX[a]	8018800	490	10/79 to present
Lake Fork Creek near Quitman, TX[a]	8019000	585	07/24-04/26, 03/39 to present
Sabine River near Hawkins, TX[a]	8019200	2259	10/97-10/99
Lake Winnsboro near Winnsboro, TX	8019300	27.1	62-86
Big Sandy Creek near Big Sandy, TX[a]	8019500	231	02/39 to present
Sabine River near Gladewater, TX[a]	8020000	2791	10/32 to present
Prairie Creek near Gladewater, TX	8020200	48.9	68-77
Sabine River above Longview, TX[a]	8020450	2943	08/83 to present
Sabine River Near Longview, TX	8020500	2947	04-07,24-33
Rabbit Creek at Kilgore, TX	8020700	75.8	67-77
Sabine River below Longview, TX[a]	8020900	3155	10/01/95 to present
Mill Cr near Henderson, TX	8020960	20.3	79-81
Mill Cr near Longview, TX	8020980	47.9	79-81
Tiawichi Cr near Longview, TX	8020990	62.7	78-81
Cherokee Bayou near Elderville, TX	8021000	120	40-49
Lake Cherokee near Longview, TX	8021500	158	04/51-12/75
Sabine River near Tatum, TX	8022000	3493	39-78
Sabine River near Beckville, TX[a]	8022040	3589	10/38 to present
Martin Lake near Tatum, TX [a]	8022060	130	04/74 to present
Martin Creek near Tatum, TX	8022070	148	04/74 to 96
Murvaul Lake near Gary, TX [a]	8022200	115	57-75
Murvaul Bayou near Gary, TX	8022300	134	58-83
Socagee Creek near Carthage, TX	8022400	82.6	62-73
Sabine River at Logansport, LA[b]	8022500	4842	07/03-02/68 (discharge) 03/68 to present (gage-height)
Bayou Castor near Funston, LA	8022765	91.5	82-86
Bayou Grand Cane near Stanley, LA[a]	8023080	72.5	80-present

Table 6 USGS Streamflow Gages in the Sabine River Basin (Continued)

Gage	USGS Number	Drainage Area (Square Miles)	Period of Record
Tenaha Creek near Shelbyville, TX	8023200	97.8	03/52-06/81
Bayou San Patricio near Benson, LA[a]	8023400	80.2	10/77-10/92, 10/94-present
Bayou San Patricio near Noble, LA	8023500	154	10/51-09/67
Bayou San Miguel near Zwolle, LA	8024000	111	10/48-09/67
Blackwell Cr. At Many, LA	8024060	3.16	10/59- 09/68
Hurricane Ck. Trib. @Loring Lk. near. Zwolle, LA	8024160	1.03	10/60- 09/66
Bayou La Nana near Zwolle, LA	8024200	130	55-67
Sabine River near Milam, TX	8024400	6508	24-25, 39-66
Palo Gaucho Bayou near Hemphill, TX	8024500	123	52-65
Mill Creek near Burkeville, TX	8025307	17.6	74-79
Toledo Bend Reservoir near Burkeville, TX[a]	8025350	7178	10/66 to present
Sabine River at Toledo Bend Reservoir near Burkeville, TX[a]	8025360	7178	10/71 to present
Bayou Toro near Toro, LA [a]	8025500	148	10/55-09/86, 10/88-present
Bayou Anacoco near Rosepine, LA [a] Sabine River near Bon Wier, TX[a]	8028000 8028500	365 8229	10/51-10/99 10/23 to present
Cypress Creek near Buna, TX	8030000	69.2	52-83
Sabine River near Ruliff, TX[a]	8030500	9329	10/24 to present
Cow Bayou near Mauriceville, TX	8031000	83.3	04/52-09/86

(a) Active Gages
(b) This gage is in Louisiana, but operated by USGS of Texas

Figure 2 Hydrological Records for USGS Gages in the Sabine River Basin

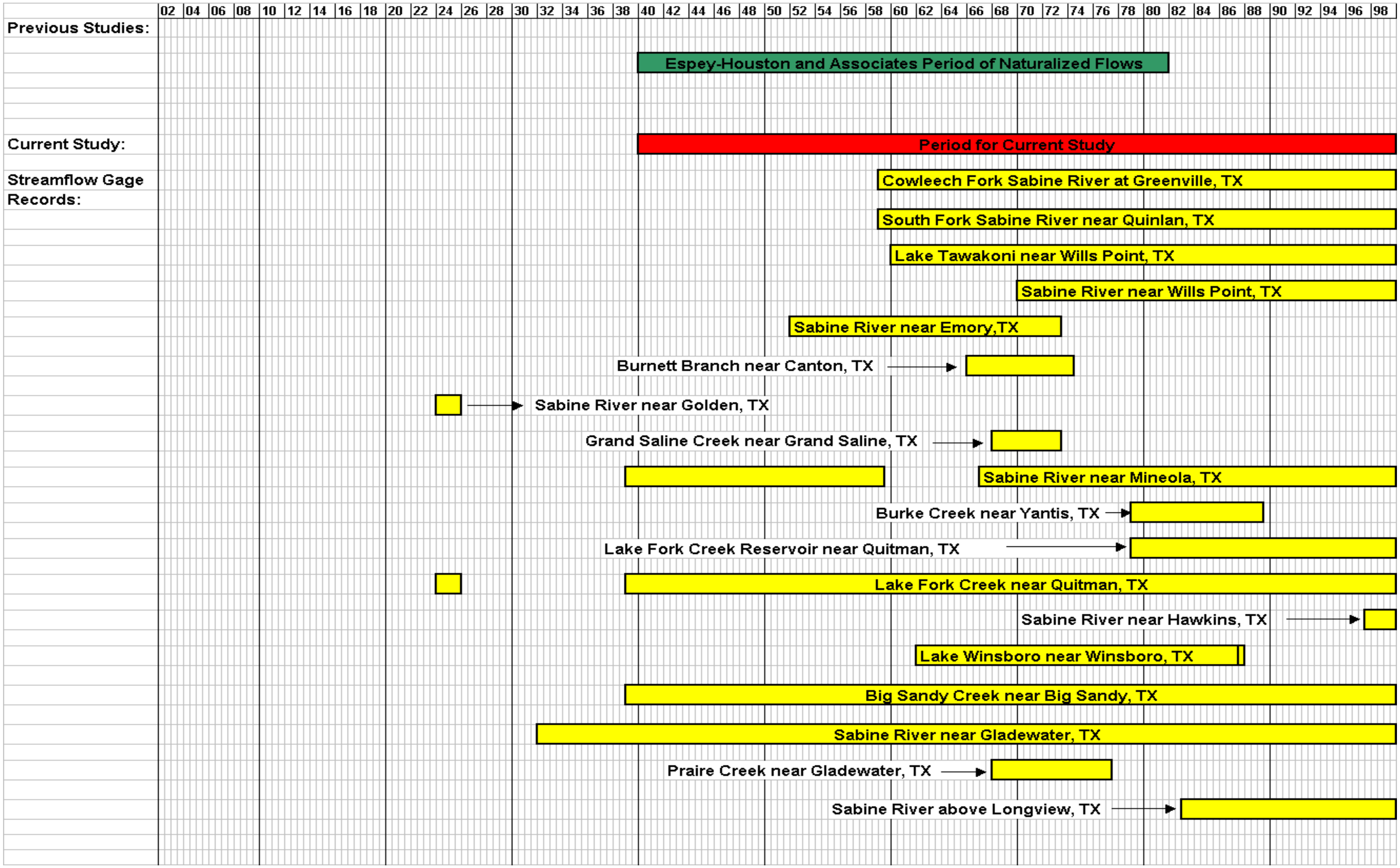


Figure 2 Hydrological Records for USGS Gages in the Sabine River Basin (Continued)

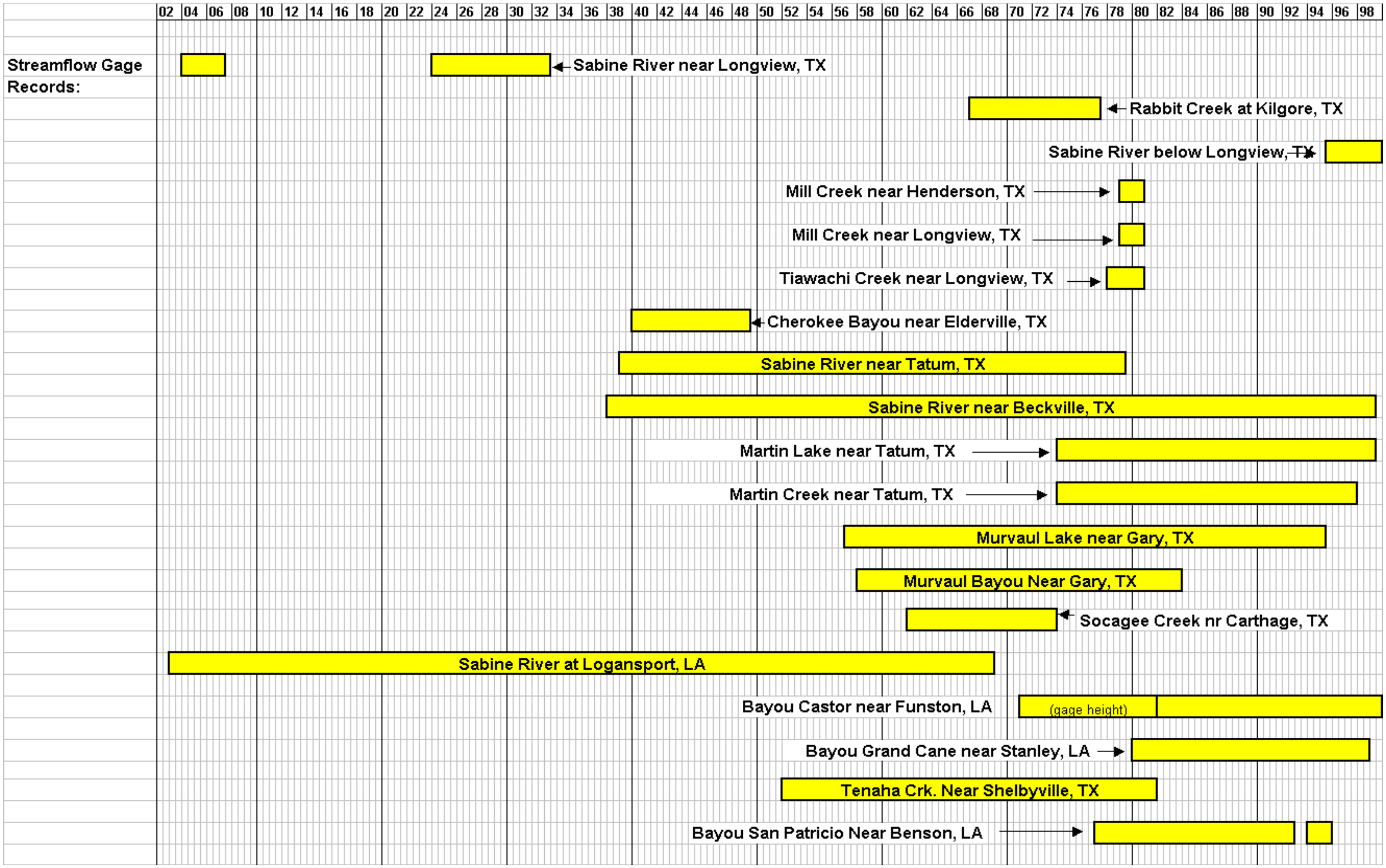
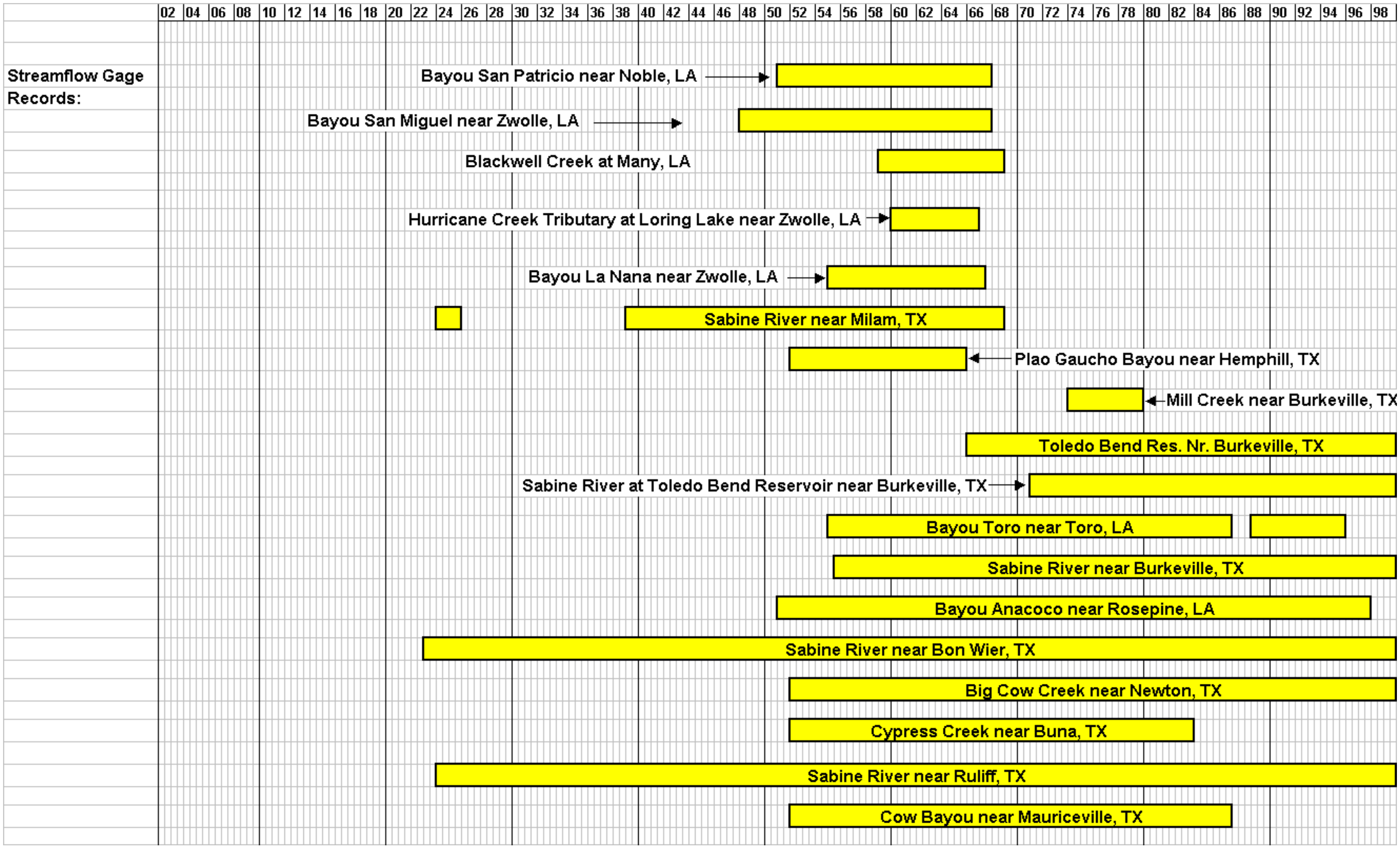


Figure 2 Hydrological Records for USGS Gages in the Sabine River Basin (Continued)



gains from bank seepage and small tributary flows compensate for losses due to evaporation, evapotranspiration and infiltration into the alluvial aquifers.

A general review of the geologic maps within the Sabine River Basin indicate that the Texas Coastal Uplands aquifer system underlies the upper Sabine River and the Coastal Lowlands aquifer system underlies the lower Sabine River region. Sediments of the Texas Coastal Uplands aquifer dip towards the coast beneath the Coastal Lowlands aquifer system. Both aquifer systems are predominately characterized by sand, silt and clay sediments. The Texas Coastal Uplands system contains outcrops for the Carrizo-Wilcox, the most productive aquifer in the upper basin. Likewise, the Gulf Coast aquifer is the predominant system in the lower portion of the Sabine Basin. While there may be some localized channel losses due to recharge at outcrop zones of both aquifers, and/or the alluvial aquifer along the Sabine River, it is unlikely that significant losses occur in the Sabine Basin.

This assumption was tested during the investigation of negative incremental flows, to determine if the existence of negative incremental flows represent long-term average losses, or can be explained by problems with gage data, and/or historical adjustment data (i.e. diversions, reservoir content change, return flows, etc). Negative incremental flows appeared to be due to errors in the historical adjustments, or gage flows, rather than channel losses. There is no evidence of consistent channel losses in the Sabine River Basin; therefore, channel losses were not derived, nor included in this study. During the course of the streamflow naturalization process, negative incremental flows were obtained for some primary control points, as discussed in section 3.1.4.

Another issue affecting the conveyance of streamflows in the Lower Sabine River relates to the divergence of flow from the main stem of the Sabine River into Indian Bayou and Old River. In 1966 the USGS performed a low flow study of a segment of the Sabine River in the lower basin. One of the objectives of the study was to assess the distribution of flow in the main stem and anabranches of the Sabine River between the U.S.G.S. Ruliff gage (#8030500) and Interstate Highway 10. Downstream of the Ruliff gage, Cutoff Bayou forms the Old River anabranch of the Sabine River diverting a portion of the main stem flows to Louisiana. A little further downstream on the main stem another anabranch, Indian Bayou diverts main stem flows to Texas. Indian Bayou rejoins the Sabine River at Swift Lake, just downstream of the Sabine River Authority of Texas Diversion Canal. Old River rejoins the Sabine River main stem upstream of the City of Orange, Texas. While there are water rights on both anabranches, there currently are no water rights on the main stem segment between where they diverge from and rejoin the Sabine River. The study concluded that the flow division between Indian Bayou and Old River is fairly equivalent during low flow conditions. Two control points, CUTOFF and CONFLU, have been added to the model developed in this study to identify the extents of the anabranches, in order to assist the TNRCC and others in the assessment of unappropriated water reported by WRAP within this reach.

3.1.4 Completion of Streamflow Records

Most of the streamflow gages which are used as primary control points in the Sabine River Basin do not have a complete flow record for 1940 through 1998. The periods of record for the primary control points are shown in Figure 3. For the most part, missing data was filled in using statistical relationships with other control points. Table 7 lists the period of missing data for each gage and the potential sources for filling of missing flows. The statistical relationship between control points was established by analysis of monthly flows for the period of overlapping records. In many cases, more than one source was considered to fill in missing data. Scatter plots and double mass curves were used to analyze each potential source. The method and source with the best "fit" during the period of overlapping records (based on R^2 values and graphical comparison) was used. Table 8 summarizes the period of missing flow data for each control point and the statistical relationship used to fill in the missing data. Appendix G gives a complete list of the options considered to fill in missing data and the results of the analyses.

There are no records of historical streamflow at the mouth of the Sabine River at Sabine Lake. Naturalized flows for this location were estimated on the basis of naturalized flows at the Sabine River at Ruliff and Cow Bayou near Mauriceville gages.

There were two specific issues that arose during the naturalization process that resulted in a manual change to data of record. Both issues are considered to be errors in published data.

The first instance concerns the electronically reported content data published by the USGS for Toledo Bend Reservoir for September 1973. The USGS reported an End Of Month (EOM) storage of 4,581,000 ac-ft for Toledo Bend Reservoir, while a document published by the Texas Department of Water Resources reports for the same month an EOM storage of 4,039,000 ac-ft. The value reported in the TDWR report is consistent with reservoir elevation records which were obtained from the Sabine River Authority of Texas. The difference between the two values is 542,000 ac-ft. For the remaining months which were reported in the TDWR document, the values were identical to the electronic data. For this study, the EOM storage as reported by the TDWR was used for September 1973.

The second case of error in recorded data involved electronic data reported by the USGS EOM storage for Lake Tawakoni for July 1990 and August 1990. For July 1990, the reservoir had an EOM storage increase of 92,900 ac-ft. In August 1990, the EOM storage was reported to have decreased by 143,600 ac-ft. A review of daily content data published in the USGS Water Data Report TX-90-1 showed a content increase on July 6, 1990 of 118,100 ac-ft, and a decrease of 119,700 ac-ft on August 6, 1990. Daily reservoir elevation records were obtained from the Sabine River Authority (SRA) of Texas and were compared to USGS data. The records did not agree, with SRA data showing only slight elevation changes on the dates in question, and as a result reservoir elevation data obtained from the SRA was used to estimate EOM storage for July 1990.

Figure 3 Hydrology Records for Primary Control Points in the Sabine River Basin

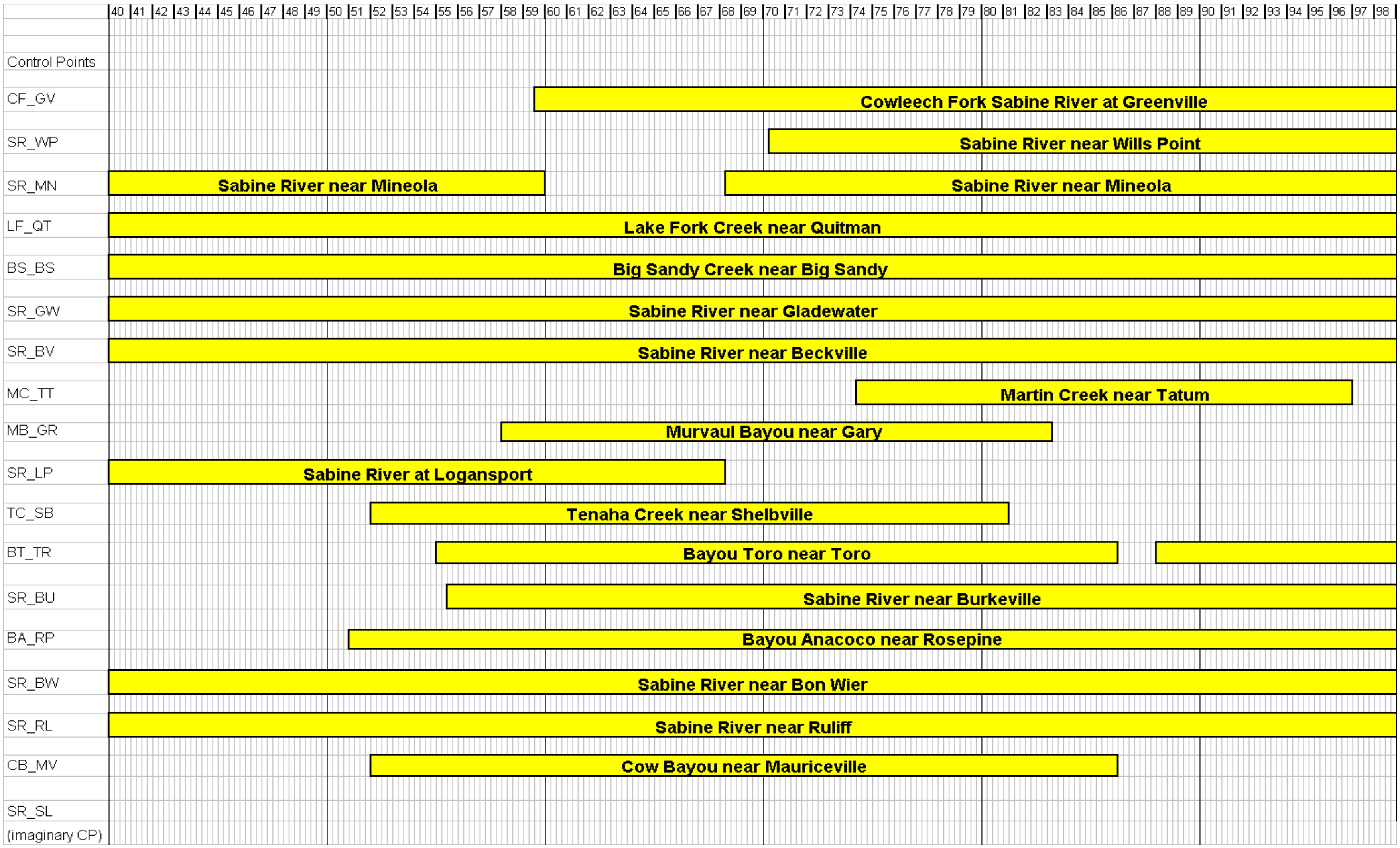


Table 7 Estimation of Missing Naturalized Flow Data

ID	Control Point	Missing Data	Possible Source(s) to Fill in Data	Period of Overlap	Possible Period to Fill
CF_GV	Cowleech Fork at Greenville, TX	01/40-01/59	Sabine River near Mineola	10/67-present	01/40-01/59
SR_WP	Sabine River near Wills Point, TX	01/40-09/70	Sabine River near Mineola or	10/70-present	01/40-09/59, 10/67-10/70
			Cowleech Fork near Greenville or	10/70-present	02-59-09/70
			Sabine River near Gladewater – Lake Fork Creek near Quitman - Big Sandy Creek near Big Sandy	10/70-present	01/40-09/70
SR_MN	Sabine River near Mineola, TX	10/59-09/67	Sabine River near Gladewater - Lake Fork near Quitman – Big Sandy Creek near Big Sandy	05/39-09/59, 10/67-present	10/59-09/67
LF_QT	Lake Fork Creek near Quitman, TX	None			
BS_BS	Big Sandy Creek near Big Sandy, TX	None			
SR_GW	Sabine River near Gladewater, TX	None			
SR_BE	Sabine River near Beckville, TX	None			
MC_TT	Martin Creek near Tatum, TX	01/40-03/74, 10/96-12/98	Sabine River near Burkeville - Sabine River near Beckville or	04/74-09/96	09/55-03/74, 10/96-12/98
			Sabine River near Burkeville - Sabine River near Beckville- Murvaul Bayou near Gary or	04/74-12/83	04/58-03/74
			Sabine River near Burkeville - Sabine River near Beckville- Murvaul Bayou near Gary - Tenaha Creek near Shelbyville or	04/74-06/81	04/58-03/74
			Murvaul Bayou near Gary or	04/74-12/83	04/58-03/74, 10/96-12/98
			Sabine River near Beckville - Sabine River near Gladewater	04/74-09/96	01/40-03/74, 10/96-12/98
MB_GR	Murvaul Bayou near Gary, TX	01/40-03/58, 1/84-12/98	Martin Creek near Tatum or	04/74-12/83	1/84-09/96
			Sabine River at Logansport - Sabine River near Beckville or	04/-02/68	01/40-03/58
			Sabine River near Burkeville- Sabine River near Beckville	04/58-12/83	1/84-12/98

Table 7 Estimation of Missing Naturalized Flow Data (continued)

ID	Control Point	Missing Data	Possible Source(s) to Fill in Data	Period of Overlap	Possible Period to Fill
SR_LP	Sabine River at Logansport, LA	03/68-12/98	Sabine River near Beckville or	10/38-02/68	03/68-12/98
			Sabine River near Beckville+ Murvaul Bayou near Gary	04/58-02/68	03/68-12/83
TC_SV	Tenaha Creek near Shelbyville, TX	01/40-02/52, 07/81-12/98	Sabine River near Burkeville- Sabine River near Beckville- Murvaul Bayou near Gary – Martin Creek near Tatum or	04/74-06/81	07/81-12/83
			Martin Creek near Tatum or	04/74-06/81	07/81-09/-96
			Sabine River near Bon Wier- Sabine River near Logansport or	03/52-02/68	01/40-02/52
			Sabine River near Burkeville- Sabine River near Beckville	09/55-06/81	07/81-12/98
BT_TR	Bayou Toro near Toro, LA	01/40-09/55, 11/86-09/88, 11/97-12/98	Sabine River near Bon Wier- Sabine River at Logansport or	10/55-02/68	01/40-09/55
			Bayou Anacoco near Rosepine or	10/55-10/86, 10/88-10/97	10/51-09/55, 11/86-09/88
			Sabine River near Bon Wier- Sabine River near Burkeville	10/55-10/86, 10/88-10/97	11/86-09/88, 11/97-12/98
SR_BU	Sabine River near Burkeville, TX	01/40-08/55	Sabine River near Bon Wier or	09/55-present	01/40-08/55
			Sabine River near Bon Wier- Sabine River at Logansport	09/55-02/68	01/40-08/55
BA_RP	Bayou Anacoco near Rosepine,LA	01/40-09/51	Sabine River near Bon Wier- Sabine River near Logansport	09/55-10/97	11/97-12/98
SR_BW	Sabine River near Bon Wier, TX	none			
SR_RL	Sabine River near Ruliff, TX	none			
CB_MV	Cow Bayou near Mauriceville, TX	01/40-03/52 10/86-12/98	Sabine River near Ruliff- Sabine River near Bon Wier	04/52-09/86	01/40-03/52, 10/ 86-12/98
SR_SL	Sabine River at Sabine Lake, TX	01/40-12/98	Sabine River near Ruliff + Cow Bayou near Mauriceville or	04/52-09/86	04/52-09/86
			Sabine River near Ruliff	01/40-12/98	01/40-12/98

Table 8 Summary of Equations Used to Complete Naturalized Flow Data

Control Point (Subbasin)	Fill Period	Fill Sources	Fill Equation
CF_GV	01/40-02/59	SR_MN	y=0.0573x
SR_WP	01/40-09/59, 10/67-09/70	SR_MN	y=0.5787x
	10/59-9/67	SR_GW	y=0.2756x
SR_MN	10/59-09/67	SR_GW	y=0.5000x
LF_QT	None		
BS_BS	None		
SR_GW	None		
SR_BE	None		
MC_TT	04/58-03/74	MB_GR	y=1.1045x
	01/40-03/58, 10/96-12/96	EF_ACU (Neches)	y=0.9675x
	01/97-12/98	BS_BS	y-0.6407x
MB_GR	01/40-03/58, 10/96-12/96	EF_ACU (Neches)	y=0.8778x
	12/83-09/96	MC_TT	y=0.8028x
	01/97-12/98	BS_BS	y=0.5505x
SR_LP	05/68-12/98	SR_BE	y=1.2978x
TC_SV	01/40-02/52, 04/81-12/96	AY_SA (Neches)	y=0.9320x
	01/97-12/98	BA_RP	y=0.1811x
BT_TR	01/40-09/51	AY_SA (Neches)	y=1.4991x
	10/51-09/55, 10/86-09/88	BA_RP	y=0.3208x
SR_BU	01/40-08/55	SR_BW	y=0.8828x
BA_RP	01/40-09/51	SR_BW - SR_LP	y=0.1544x
SR_BW	None		
SR_RL	None		
CB_MV	01/40-03/52, 10/86-12/96	PI_SL (Neches)	y=0.2479x
	01/97-12/98	BA_RP	y=0.2179x
SR_SL	01/40-03/52, 10/86-12/98	SR_RL	y=1.0458x
	04/52-09/86	SR_RL(a) + CB_MV (b)	y=1.0000a + 5.1261b

A cursory review of other reservoir-content data reported by the USGS, as compared to reservoir operator records indicated that while the records did not match exactly, they appear reasonable. It should be noted that for large reservoirs such as Toledo Bend, Lake Fork and Lake Tawakoni, a slight error in recording reservoir elevation can represent a loss or gain of a significant amount of storage volume. The problem this creates in regards to the streamflow naturalization process is the possibility of creating negative flows or negative incremental flows, among other things. Engineering judgement was used for those months in which negative flows or negative incremental flows were calculated and by all accounts appear to result from errors in historical adjustments.

USGS periodically rates the hydrologic records for gaging stations to qualify reported gage data. The ratings for the primary control points in the Sabine River Basin are generally classified as "Good", with an occasional "Fair" rating for selected daily discharge estimates.

Prior to October 1978, the USGS gage Sabine River near Beckville (USGS #08022040 – Drainage area 3,589 mi.^{2}) was published as "near Tatum" (USGS #08022000 – Drainage area 3,493 mi.^{2}). Naturalized flows estimated at the Beckville gage prior to October 1978 were adjusted to reflect the effects of the approximate three percent increase in drainage area.

The computation of naturalized streamflows described above resulted in negative flows for some months. Since negative flows are physically impossible, they were set to zero, and flows for surrounding months were decreased to maintain proper totals. On the other hand negative incremental flows between control points are physically possible. Negative intervening flows can be due to a variety of causes including:

- Timing Issues (i.e. USGS gage records documenting storm runoff at the end of a given month at an upstream gage and documenting the same storm runoff at the beginning of the next month at a downstream gage).
- Channel losses.
- Lack of accuracy in USGS gage records.
- Lack of accuracy in historical adjustments.

Although negative intervening flows are physically possible, they are unlikely to represent real losses in the Sabine River Basin. It is believed that they represent data problems or timing problems.

3.1.5 Comparison with Other Naturalized Streamflows

In 1985, Espey-Huston & Associates (EHA) and Tudor Engineering Company prepared a study for the Sabine River Authority of Texas in which reservoir inflows (1940-1980) were developed for the purpose of determining reservoir yields. The study developed estimates of monthly naturalized streamflow at selected gages, and computed, using drainage area ratios, reservoir inflow data for the uncontrolled areas upstream of reservoirs to account for the effects of any upstream reservoirs and water demands not associated with the uncontrolled watershed. The study published only reservoir inflows for the uncontrolled (incremental) drainage areas of all reservoirs with capacities greater than 5,000 ac-ft with the exception of Brady Branch Cooling Pond. The EHA study does not provide documentation which would allow for the assessment of the data collection and fill relationships used in the development of reservoir inflows.

In 1991 Brown & Root Inc. prepared a study for the Toledo Bend Project Joint Operation in which reservoir inflows (1940-1989) were developed for Toledo Bend Reservoir for the purpose of determining reservoir yield. The Toledo Bend Natural Inflows represented the incremental naturalized inflows to Toledo Bend Reservoir assuming no spills from either Lake Tawakoni or Lake Fork. The gaged records were adjusted to remove the impact of diversions associated with water rights upstream of Toledo Bend but downstream of Lake Tawakoni and Lake Fork. The net inflows represent approximately 60 percent of the drainage area of the Sabine River Basin.

Appendix H contains double mass curves providing a comparison of naturalized streamflow estimates developed in this study with those estimates developed in the Espey – Huston / Tudor Engineering study and the Brown & Root Inc. study. The set of naturalized flows developed for this study, based on the above analysis procedures, are provided in Appendix I. As shown, a complete monthly flow record is provided throughout the 59-year period of record for each control point.

3.1.6 Statistical Assessment of Trends in Streamflow

Trends in streamflow were analyzed by comparing double mass curves of historical to naturalized flows at selected control points (See Figure 4, Figure 5, and Figure 6). Complete tables for each of these control points are in Appendix J. The minimum, median and maximum flows for control points SRGW, SRLP and SRRL are displayed graphically in Figure 7, Figure 8 and Figure 9 respectively.

The graph for control point SRRL demonstrates the cumulative effects of development for most of the basin. The minimum flow patterns are quite different, which are likely due to regulation by Toledo Bend Reservoir. Summer releases cause the historical flows to be generally greater than the naturalized flows and reservoir refilling during winter months cause the historical winter flows to be less than the naturalized flows. A comparison of maximum flows show virtually no change between historical and naturalized conditions.

In general, historical minimum and median flows are somewhat lower than naturalized flows throughout the year indicating the effects of regulation, while maximum flows show minimal differences between historical and natural conditions.

Changes over time were analyzed by creating double mass curves comparing historical to naturalized flows at all primary control points that are also USGS gages. This technique graphically compares the cumulative sums of the historical and naturalized flows. These double mass curves show the cumulative impact of human activity for the time period of the gage record. A slope of 1.0 would imply that man has had no appreciable impact on the cumulative flows from a watershed. A slope greater than 1.0 is evidence of the consumptive impacts of human activity in the form of diversions and evaporative losses. Breaks in the slope of the curves indicate changes in the relationship of the historical to naturalized flows. A perfect relationship between the two sets of data should result in a relationship of 1 to 1 (or a slope of 1.0) on a double mass plot. However, given the inaccuracies related to hydrologic data and historical adjustments, a 5% deviation from the ideal is considered reasonable. A complete set of these curves for all primary control points may be found in Appendix J.

The Sabine River near Ruliff gage is the most downstream gage in the basin and has gage flow records for the entire study period. Based upon the slope of 1.03, the cumulative impact of human activity in the basin from 1940 to 1998 can be stated as relatively low, contributing to consumptive losses of approximately three percent. This consumption is representative of the average from 1940 to 1998 and includes a significant number of years prior to the impoundment of large water supply reservoirs, and thus is not representative of current conditions.

By far the greatest slope is for the Sabine River at Wills Point, with a value of 1.40. For this gage, the period of record is from October 1970 to December 1998. Lake Tawakoni was impounded in the 1960s, and thus the impact of Lake Tawakoni diversions and evaporative losses are included in every year of the gage records.

The double mass curve for Sabine River near Burkeville is for the period from September 1955 to December 1998 with a slope of 1.095. This gage is downstream of the largest water supply reservoir in the Sabine River Basin. While the gage records do pre-date the impoundment of Lake Tawakoni, Lake Fork and Toledo Bend Reservoir, the impact of these diversions and evaporative losses associated with these reservoirs can be seen more readily at Burkeville than at the downstream Ruliff gage.

Figure 4 Sabine River at Gladewater Statistical Comparison of Annual Historical and Naturalized Flows

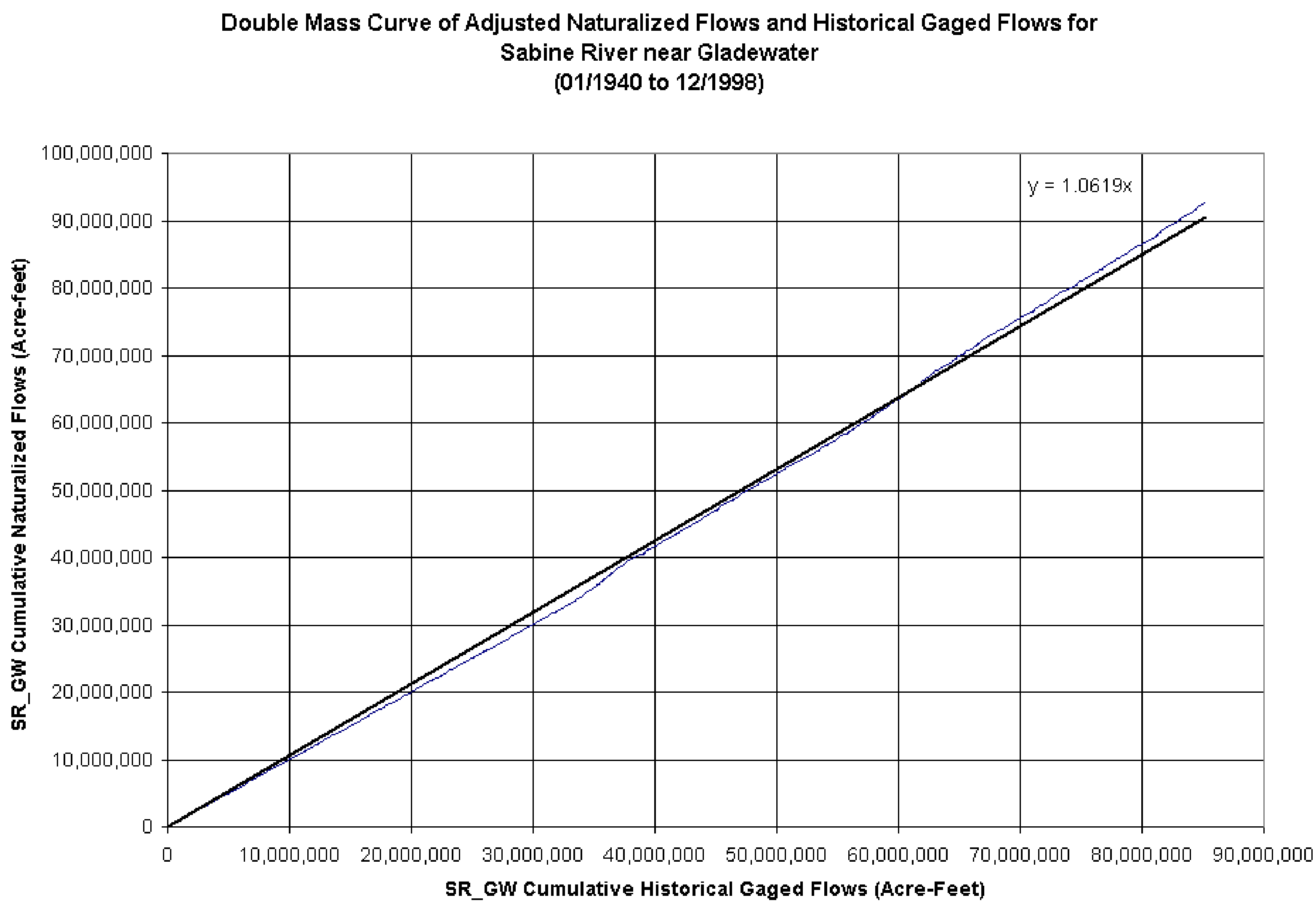


Figure 5 **Sabine River at Logansport Statistical Comparison of Annual Historical and Naturalized Flows**

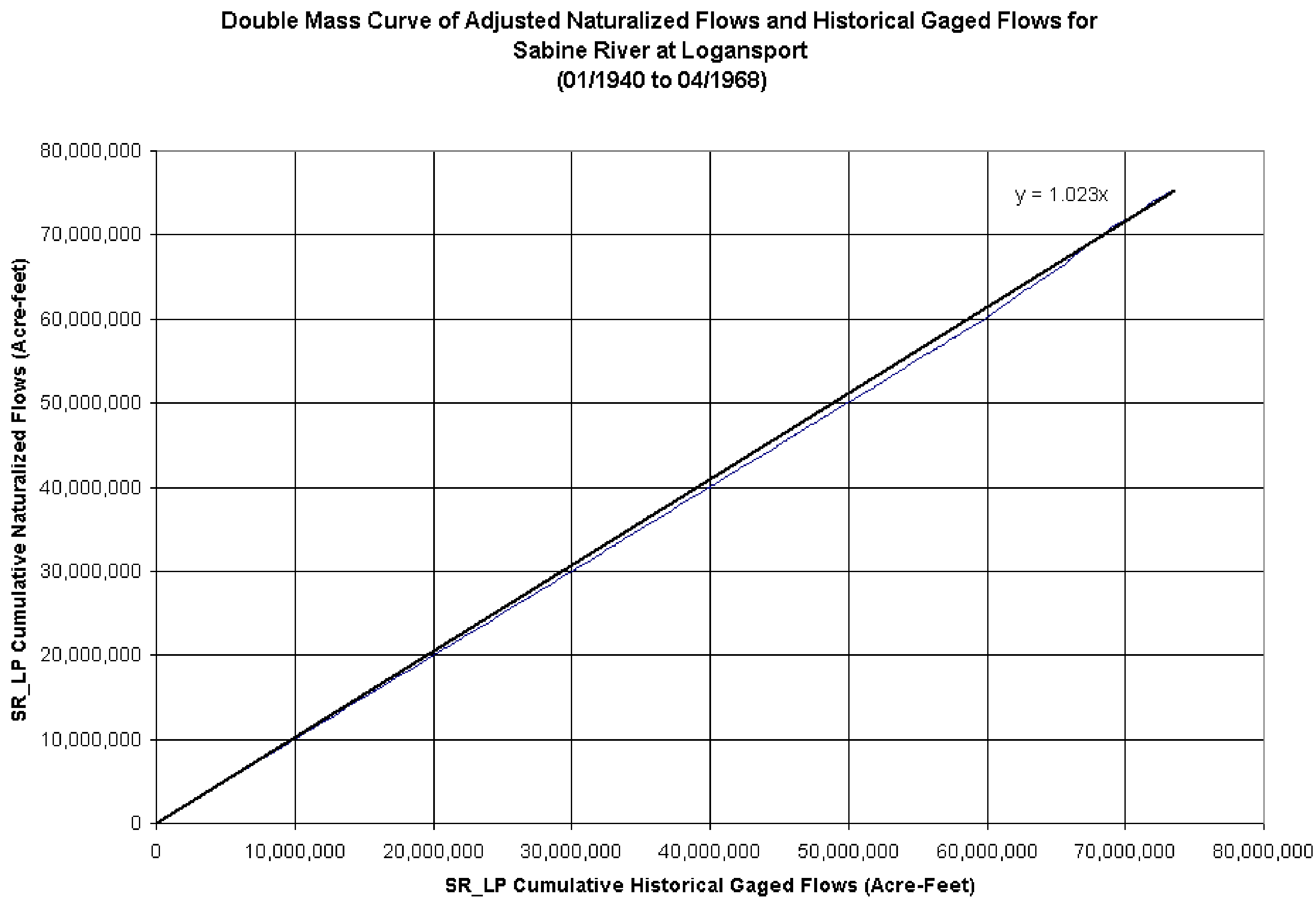


Figure 6 Sabine River at Ruliff Statistical Comparison of Annual Historical and Naturalized Flows

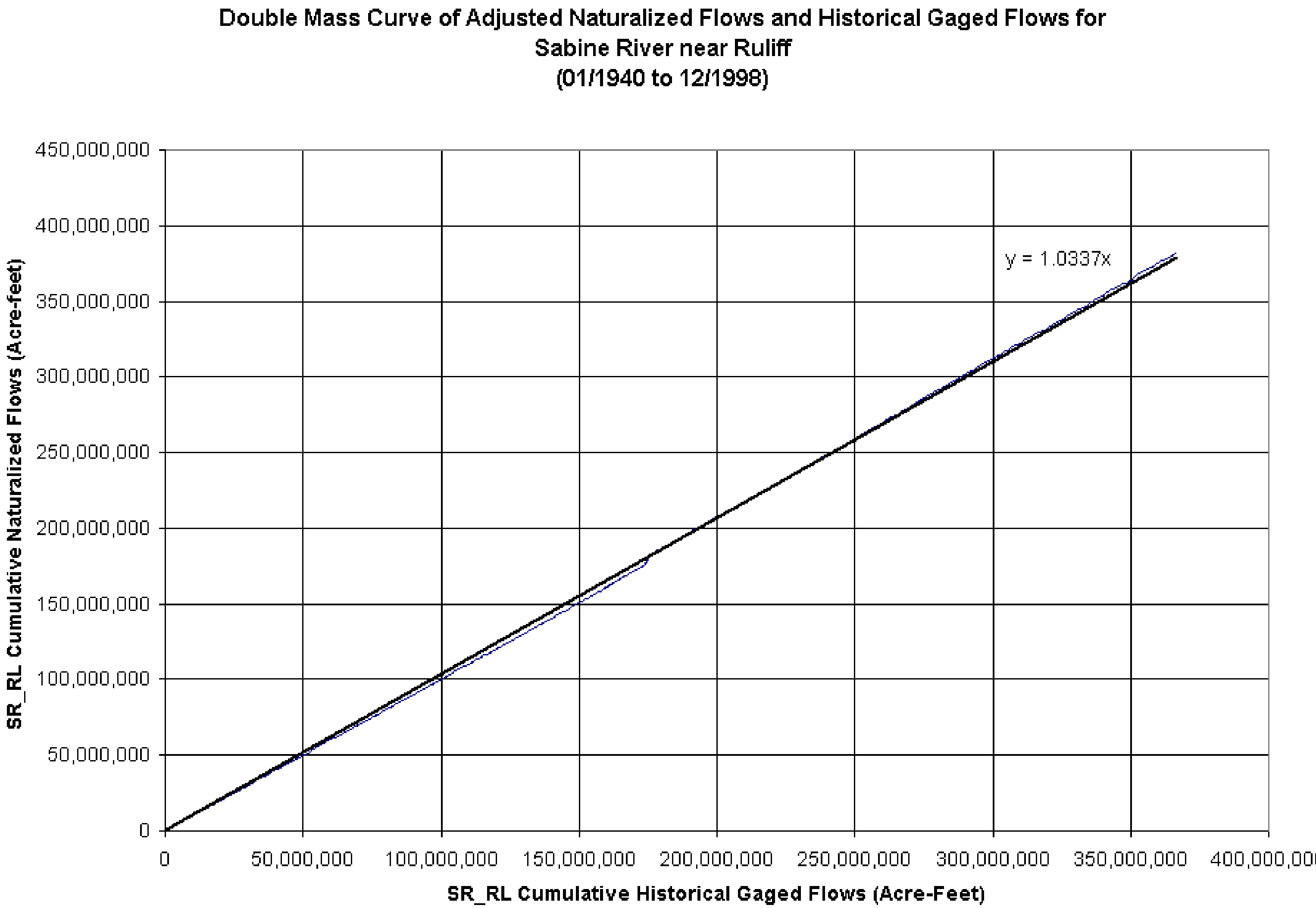
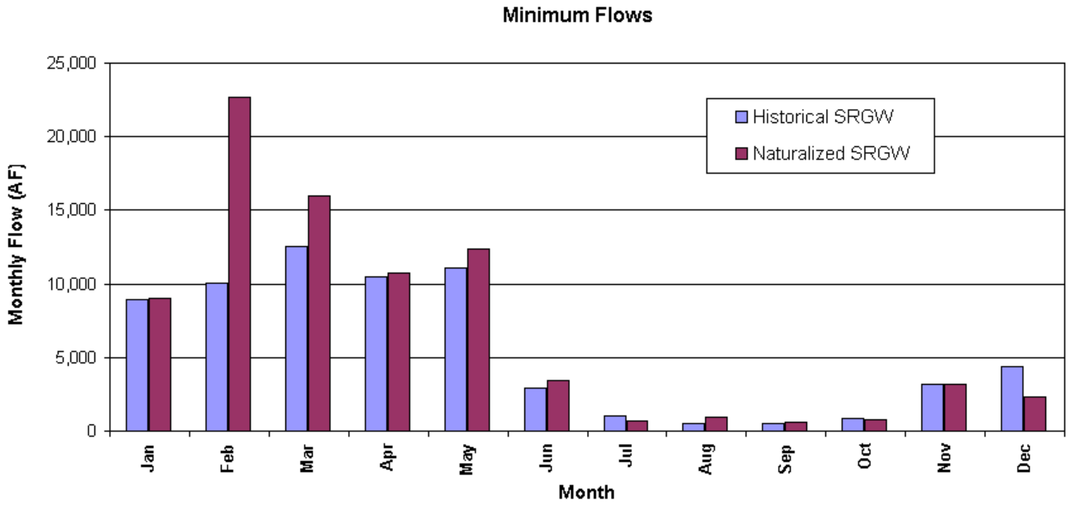
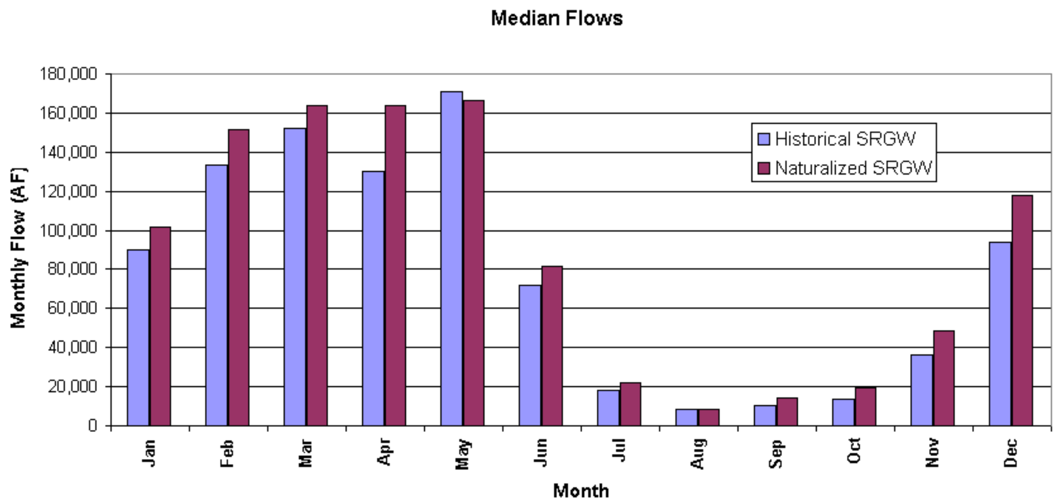


Figure 7 Minimum, Median, and Maximum Flows at SRGW





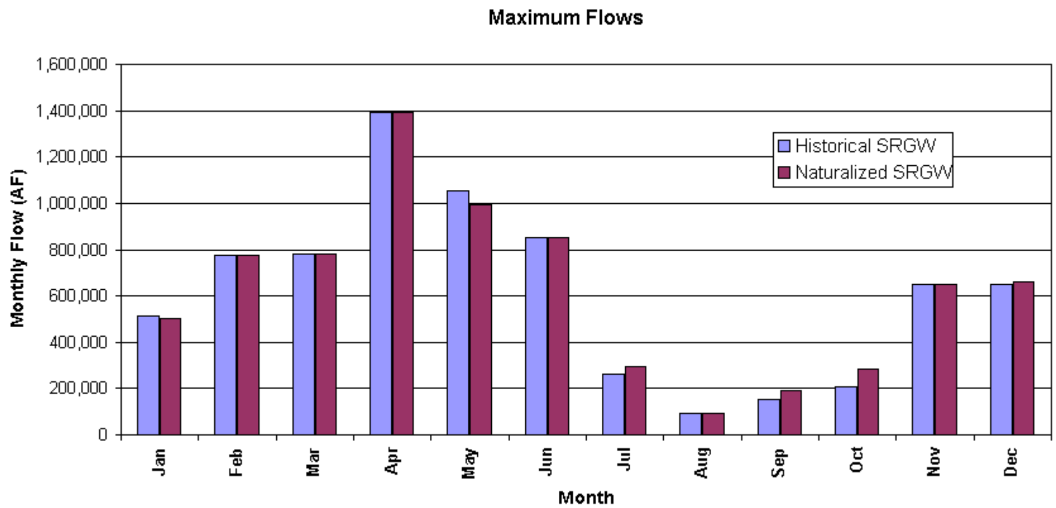
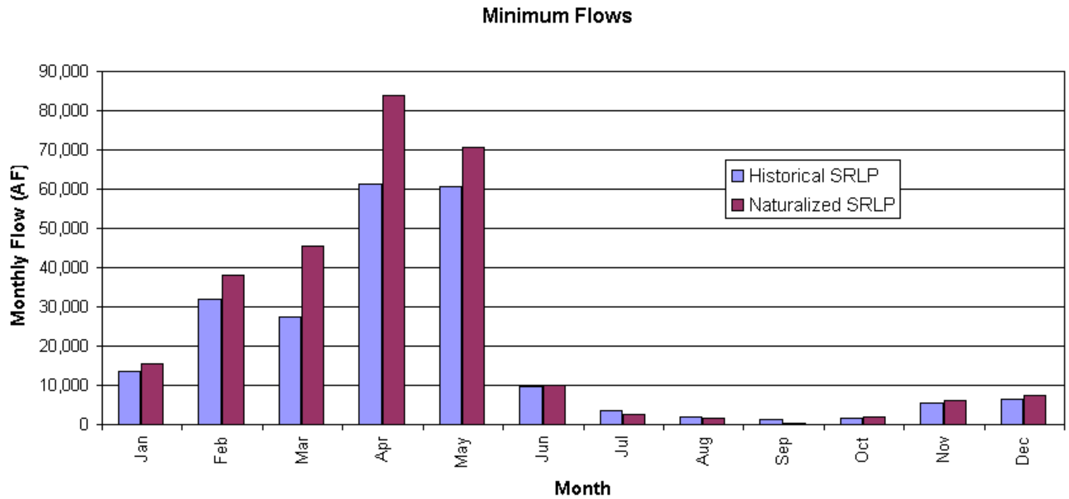
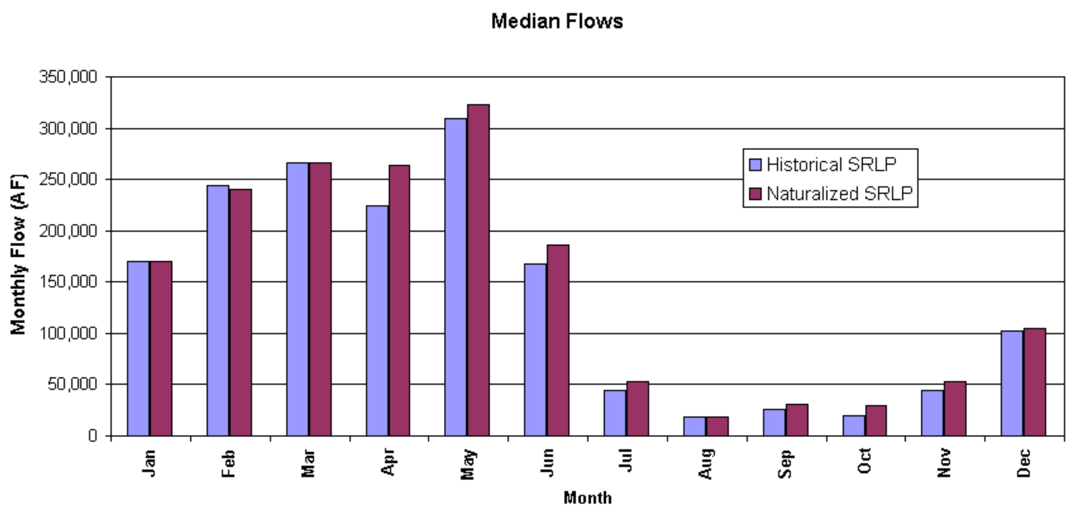


Figure 8 Minimum, Median, and Maximum Flows at SRLP





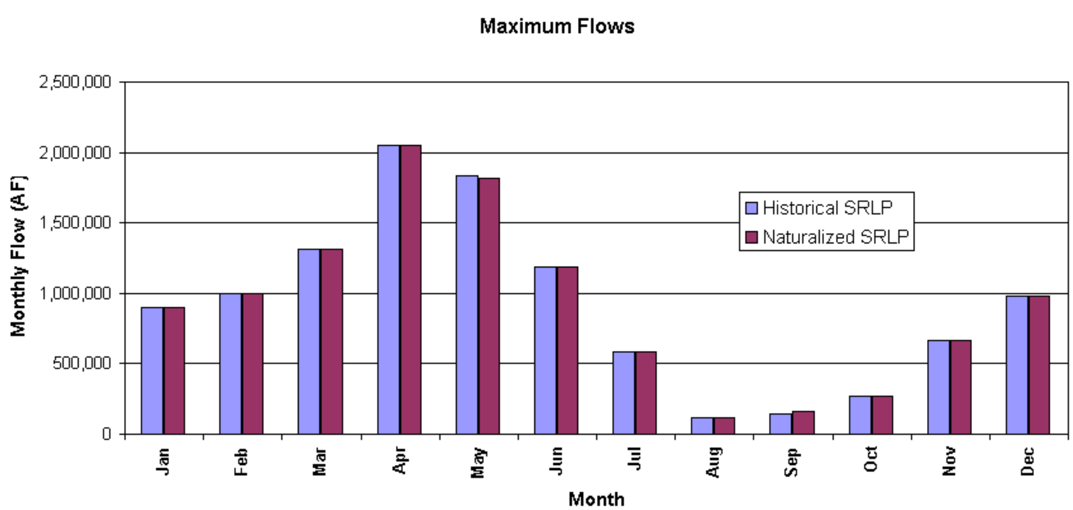
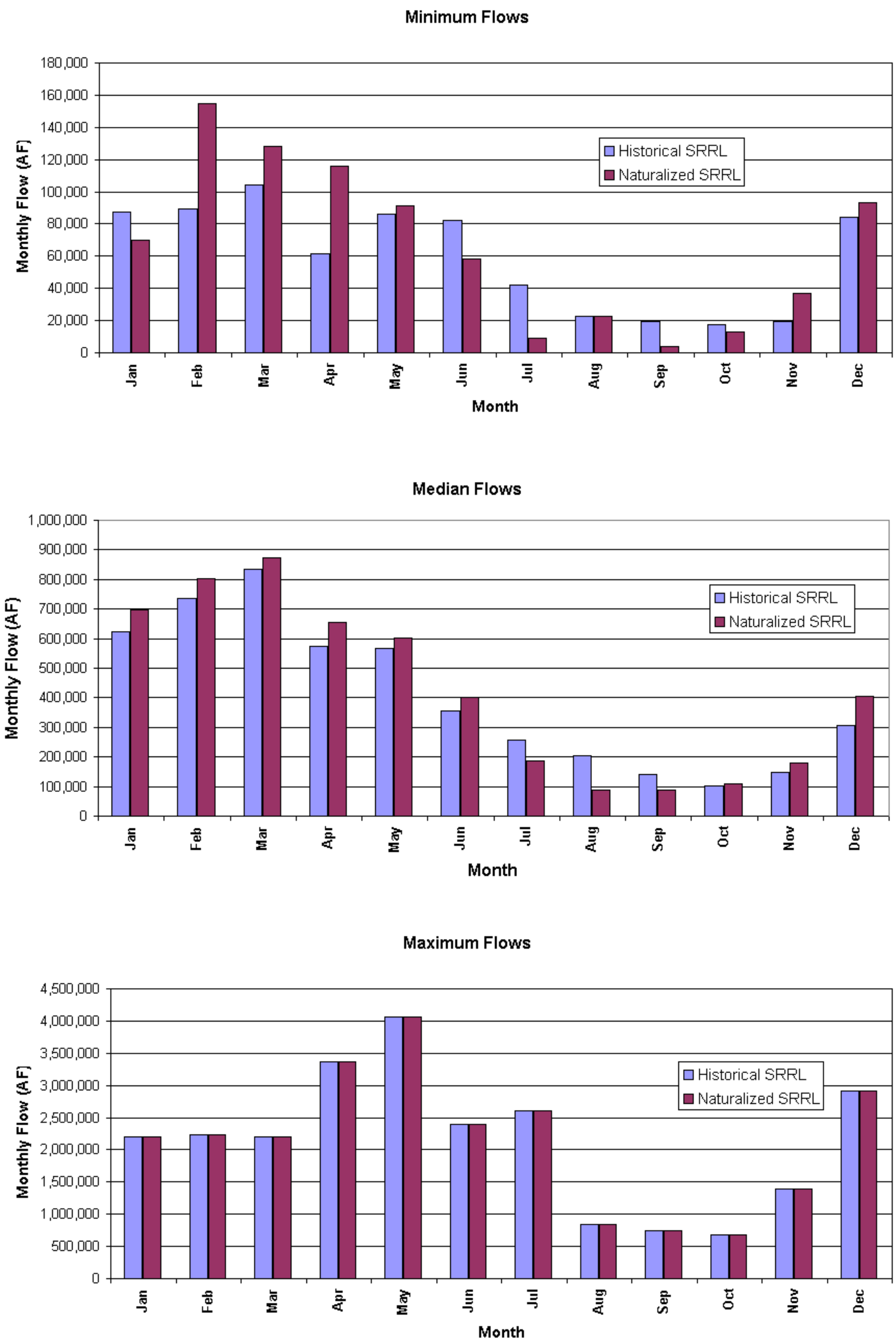


Figure 9 Minimum, Median, and Maximum Flows at SRRL



3.2 Naturalized Streamflow at Ungaged Locations

Naturalized streamflows were derived at ungaged locations in the Sabine River Basin utilizing data from gaged sites, watershed parameters at ungaged sites, and the program WRAP (VER 11/26/01). Ungaged sites, or secondary control points, include any ungaged location within the basin where water availability calculations need to be performed including diversion locations for water rights, the extents of classified stream segments, and return flow or groundwater inflow locations. The map attached in Appendix K provides the locations of all primary (gaged) and secondary (ungaged) control points.

The program WRAP (VER 11/26/01), developed by Dr. Ralph A. Wurbs at Texas A & M University, can compute naturalized flows at ungaged sites by utilizing the U. S. Natural Resources Conservation Service (NRCS) curve number (CN) method. However, as mentioned earlier in section 2.5 and discussed in Section 5.4, naturalized flows were computed at ungaged sites in this study by drainage area only. Specifically, naturalized flows or inflows and evaporation data at gaged sites are input into the program along with curve numbers, mean annual precipitation, and total drainage areas of gaged and ungaged points. Watershed parameters were obtained from the University of Texas Center for Research in Water Resources (CRWR). The specific methods used in this program are described in the WRAP User Manual. Secondary control points located at off-channel reservoirs were assumed to have no drainage areas so inflows at these points were set to zero. Table 9 provides the watershed parameters at all control points.

The NRCS CN method was developed in the 1950's by the Soil Conservation Service as a means of evaluating the effects of agricultural activities on runoff volumes. It has since been used to incorporate the effects of soil type and land cover, and mean precipitation to determine flow at ungaged sites. These parameters allow for localized effects in the computation of flows instead of determining flows at a point based solely on the ratio of the ungaged and gaged sites drainage areas. The NRCS CN method reduces to the drainage area method if the CN and precipitation at the ungaged and gaged sites are the same. The drainage area method distributes flow from a gaged to an ungaged location utilizing the following equation:

$$Q_{ungaged} = Q_{gaged}\left(\frac{A_{ungaged}}{A_{gaged}}\right)$$

The NRCS Curve Number relationship is as follows:

$$Q = \left[\frac{(P - 0.2S)^2}{(P + 0.8S)}\right]$$

$$if\ \ P \geq 0.2S$$

$$Q = 0 \longrightarrow if\ \ P \leq 0.2S$$

$$where\ \ S = \left(\frac{1000}{CN}\right) - 10$$

In this equation S represents the potential maximum retention, an upper limit on the amount of water that can be removed through surface storage, infiltration, or other hydrologic methods by the watershed. The value for S is derived from the curve number. The CN is a dimensionless parameter ranging in value from 0 to 100 that represents the ability of the watershed to absorb water. A CN of zero represents a watershed that is capable of absorbing all rainfall regardless of amount while a CN of 100 represents an impervious watershed that is incapable of absorbing any rainfall.

The program WRAP (VER 11/26/01) utilizes the following algorithm to calculate flows at ungaged sites:

1. The runoff at the gage (Q) is computed by dividing streamflow at the gage by the drainage area of the gage and multiplying the product by a conversion factor to change the units of runoff from acre-feet per month to inches per month.

2. The precipitation depth (P) at the gage is calculated through an iterative solution of the above equation given the runoff computed in step 1 and the value of S.

3. The precipitation depth at the ungaged site is computed by adjusting the precipitation depth at the gaged site by the ratio of the mean precipitation depth (M) at the ungaged and gaged sites.

$$P_{ungaged} = P_{gaged}\left(\frac{M_{ungaged}}{M_{gaged}}\right)$$

4. The runoff at the ungaged site is then computed by inputting the values for P and S at the ungaged site in the NRCS CN method equation. The computed value for the runoff is then converted to streamflow at the ungaged site by multiplying it by the drainage area of the ungaged site. Finally, a conversion factor is used to change the units of streamflow from inches per month to acre-feet per month.

Table 9 Control Points and Corresponding Watershed Parameters

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
5	WQS5	9792.18	67.44	48.77
6	WQS6	9354.57	67.70	48.38
7	WQS7	9354.88	67.70	48.38
8	WQS8	209.24	62.10	53.50
9	WQS9	4.84	54.82	54.46
10	WQS10	4269.34	68.28	43.51
11	WQS11	2792.50	68.12	41.96
12	WQS12	4212.72	68.26	43.46
13	WQS13	0.32	90.57	41.34
14	WQS14	2792.45	68.12	41.96
15	WQS15	0.37	65.01	39.76
16	WQS16	7.83	69.87	42.20
17	WQS17	9510.09	67.60	48.53
18	WQS18	17.04	65.85	57.64
21	WQS21	60.07	76.12	46.05
22	WQS22	116.19	76.38	46.53
31	WQS31	8.95	71.21	45.99
32	WQS32	158.50	69.73	45.89
35	WQS35	178.36	60.37	56.71
36	WQS36	9783.00	67.44	48.76
37	WQS37	102.18	69.65	42.87
38	WQS38	33.11	71.87	43.20
39	WQS39	8928.28	68.18	47.99
40	WQS40	0.03	30.14	54.33
41	WQS41	238.51	66.60	42.73
42	WQS42	0.27	75.38	43.31
43	WQS43	2073.64	69.64	41.63
44	WQS44	480.92	70.10	43.10
300	WW300	0.99	72.41	57.87
424	WW424	1.15	74.36	57.71
452	WW452	3208.30	68.00	42.41
474	WW474	9510.14	67.60	48.53
610	WW610	0.32	71.24	47.58
624	WW624	24.77	69.43	57.71
625	WW625	23.96	69.15	57.71
674	WQS674	9785.26	67.44	48.77
775	WW775	259.44	62.18	56.83
789	WW789	9355.02	67.70	48.38
1158	WW1158	38.32	74.49	46.16
1214	WW1214	26.12	57.67	55.86
1465	WW1465	0.01	90.00	49.61
1783	WW1783	4.50	60.87	46.85
1788	WW1788	0.02	62.05	46.85
1828	WW1828	30.24	64.15	46.66
3297	WW3297	246.11	61.77	56.80
3315	WW3315	0.26	89.06	49.61
3327	WW3327	13.07	78.54	47.63
3473	WW3473	21.60	77.89	45.59
3515	WW3515	24.83	69.43	57.71
3602	WW3602	7.20	78.09	42.70
3627	WW3627	1.19	56.76	41.01
3688	WW3688	20.80	65.39	41.90
3716	WW3716	0.27	67.53	41.73
3739	WW3739	15.75	65.35	45.02
3789	WW3789	8.91	78.73	40.23
3938	WW3938	5.58	65.50	47.69
3945	WW3945	38.32	74.49	46.16
3980	WW3980	9452.62	67.62	48.48
4218	WW4218	22.09	68.46	45.61
99996	CONFLU	9404.16	67.64	48.43
99997	CUTOFF	9347.18	67.71	48.37
99998	STLINE	4831.30	68.88	44.04
99999	SRSL	9796.95	67.44	48.78
8017200	CFGV	81.15	70.41	41.02
8017300	17300	77.91	70.45	39.99
8017410	SRWP	765.89	72.17	40.68
8018500	SRMN	1366.03	69.68	41.06
8019000	LFQT	577.86	70.25	42.90
8019200	19200	2258.36	69.17	41.67
8019500	BSBS	230.44	66.92	42.71
8020000	SRGW	2792.50	68.12	41.96
8020450	20450	2944.06	67.93	42.11
8020900	20900	3159.46	67.99	42.35
8022040	SRBE	3590.56	67.74	42.83
8022070	MCTT	147.90	71.65	46.27
8022300	MBGR	131.51	76.63	46.65
8022500	SRLP	4857.79	68.91	44.07
8023200	TCSV	97.85	71.48	49.68
8025360	25360	7199.44	70.35	46.29
8025500	BTTR	147.71	62.06	53.42
8026000	SRBU	7512.63	69.96	46.60
8028000	BARP	364.07	63.58	55.01
8028500	SRBW	8272.11	69.12	47.41
8029500	29500	128.77	50.31	54.03
8030500	SRRL	9299.63	67.79	48.33
8031000	CBMV	89.14	60.43	55.99

Table 9 Control Points and Corresponding Watershed Parameters (continued)

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
10503899001	E3899P	237.93	66.68	42.73
10503931301	E3931P	0.05	70.00	42.91
10503942001	E3942P	0.72	55.00	43.24
10503969001	E3969P	230.01	66.95	42.71
10503969501	E3969Z	230.44	66.92	42.71
10504202101	E4202P	603.68	70.19	42.85
10504202201	E4202Q	602.57	70.18	42.85
10504226001	E4226P	0.26	66.64	48.25
10504226301	E4226P	0.26	66.64	48.25
10504238001	E4238P	192.57	71.54	46.42
10504248001	E4248P	0.10	78.00	43.70
10504248002	E4248Q	1.19	64.66	43.46
10504248301	E4248P	0.10	78.00	43.70
10504293301	E4293P	1.45	67.38	41.34
10505046301	E5046P	4.80	70.50	42.32
10505082001	E5082P	0.13	55.00	46.85
10505082002	E5082Q	3.91	61.31	46.85
10505082301	E5082P	0.13	55.00	46.85
10505082302	E5082Q	3.91	61.31	46.85
10505090001	E5090P	2944.14	67.93	42.11
10505090501	E5090Z	38.32	74.49	46.16
10505124001	E5124P	0.63	60.02	46.85
10505124002	E5124Q	0.28	55.00	46.85
10505124003	E5124R	0.07	58.56	46.83
10505124301	E5124P	0.63	60.02	46.85
10505124302	E5124Q	0.28	55.00	46.85
10505124303	E5124R	0.07	58.56	46.83
10505158001	E5158P	0.10	64.00	46.85
10505158002	E5158Q	0.15	68.40	46.82
10505158003	E5158R	1.18	59.92	46.77
10505158004	E5158S	1.03	59.78	46.82
10505158005	E5158T	0.38	66.63	46.85
10505158006	E5158U	0.50	69.42	46.79
10505158007	E5158V	0.06	65.11	46.46
10505158301	E5158Q	0.15	68.40	46.82
10505158302	E5158R	1.18	59.92	46.77
10505158303	E5158S	1.03	59.78	46.82
10505158304	E5158T	0.38	66.63	46.85
10505158305	E5158U	0.50	69.42	46.79
10505158306	E5158V	0.06	65.11	46.46
10505158307	E5158P	0.10	64.00	46.85
10505158501	E5158Z	4.31	63.34	46.75
10505158502	E5158Q	0.15	68.40	46.82
10505158503	E5158S	1.03	59.78	46.82
10505158504	E5158S	1.03	59.78	46.82
10505158505	E5158S	1.03	59.78	46.82
10505158506	E5158Y	5.33	61.27	46.83
10505177001	E5177P	3.95	62.44	46.54
10505177301	E5177P	3.95	62.44	46.54
10505207301	E5207P	0.56	70.00	53.15
10505217301	E5217P	0.96	68.77	43.66
10505219001	E5219P	5.92	58.49	46.85
10505219002	E5219Q	0.10	55.00	46.85
10505219301	E5219P	5.92	58.49	46.85
10505219501	E5219Z	4.31	59.00	46.85
10505219502	E5219P	5.92	58.49	46.85
10505229301	E5229P	0.58	45.26	40.94
10505246001	E5246P	1.14	58.68	46.46
10505246301	E5246P	1.14	58.68	46.46
10505287301	E5287P	2.43	38.92	42.96
10505380001	E5380P	1.36	76.00	45.68
10505380501	E5380Z	1.36	76.00	45.68
10505382001	E5382P	0.31	59.94	46.46
10505382301	E5382P	0.31	59.94	46.46
10505419301	E5419P	5.26	58.94	43.30
10505419302	E5419Q	151.06	68.48	42.60
10505439001	E5439P	2.76	61.08	46.46
10505439301	E5439P	2.76	61.08	46.46
10505441001	E5441P	5.03	66.87	45.65
10505441002	E5441Q	3.24	62.55	45.67
10505441301	E5441P	5.03	66.87	45.65
10505441302	E5441Q	3.24	62.55	45.67
10505454001	E5454P	0.04	56.83	46.85
10505454301	E5454P	0.04	56.83	46.85
10505468301	E5468P	0.86	59.63	46.85
10505491001	E5491P	0.12	83.08	45.99
10505491501	E5491Z	0.14	83.19	46.00
10505492301	E5492P	2.12	75.20	46.69
10505504301	E5504P	0.02	71.23	46.85
10505519001	E5519P	1.02	63.71	45.46
10505519301	E5519P	1.02	63.71	45.46
10505526301	E5526P	0.42	59.31	46.63
10505578001	E5578P	0.48	65.80	45.28
10505578301	E5578P	0.48	65.80	45.28
10505607001	E5607P	4.43	60.91	46.85
10505607501	E5607Z	0.02	61.76	46.85

Table 9 Control Points and Corresponding Watershed Parameters (continued)

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
10505643301	E5643P	0.71	70.00	46.85
60504590502	E4590Y	4.02	60.55	46.85
60504622301	E4622A	6.23	61.69	45.30
60504623001	E4623A	0.16	81.02	46.06
60504624001	E4624A	2944.14	67.93	42.11
60504624301	E4624A	2944.14	67.93	42.11
60504625301	E4625A	0.30	63.42	44.49
60504625302	E4625B	0.75	74.93	44.49
60504626001	E4626A	0.40	67.79	44.49
60504626002	E4626B	0.23	74.84	44.49
60504626301	E4626A	0.40	67.79	44.49
60504626302	E4626B	0.23	74.84	44.49
60504627001	E4627A	0.59	72.73	44.49
60504627301	E4627A	0.59	72.73	44.49
60504628001	E4628A	0.49	84.24	45.90
60504628301	E4628A	0.49	84.24	45.90
60504629001	E4629A	0.83	62.21	46.30
60504629002	E4629B	0.93	61.44	46.31
60504629301	E4629A	0.83	62.21	46.30
60504629501	E4629Z	0.85	62.07	46.30
60504630001	E4630A	0.05	62.29	46.46
60504630301	E4630A	0.05	62.29	46.46
60504631001	E4631A	3160.73	67.99	42.35
60504631002	E4631B	45.93	69.10	46.58
60504631003	E4631C	10.38	70.36	46.52
60504631004	E4631D	2.24	70.58	46.74
60504631005	E4631E	28.98	68.02	46.56
60504631301	E4631C	10.38	70.36	46.52
60504631302	E4631D	2.24	70.58	46.74
60504631303	E4631E	28.98	68.02	46.56
60504632001	E4632A	0.32	56.71	46.46
60504632301	E4632A	0.32	56.71	46.46
60504633001	E4633A	0.57	76.11	46.46
60504634001	E4634A	0.01	78.00	46.46
60504635001	E4635A	0.42	67.76	46.46
60504635301	E4635A	0.42	67.76	46.46
60504636301	E4636A	1.17	74.35	45.28
60504637001	E4637A	0.36	79.84	45.28
60504637301	E4637A	0.36	79.84	45.28
60504638001	E4638A	13.89	73.43	45.29
60504638002	E4638B	12.98	73.44	45.29
60504638003	E4638C	12.93	73.46	45.29
60504639001	E4639A	37.35	73.98	45.43
60504640001	E4640A	0.56	71.80	46.06

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
60504640301	E4640A	0.56	71.80	46.06
60504641001	E4641A	0.25	62.41	46.06
60504641301	E4641A	0.25	62.41	46.06
60504642001	E4642A	158.53	69.73	45.89
60504642002	E4642A	158.53	69.73	45.89
60504642003	E4642A	158.53	69.73	45.89
60504642301	E4642A	158.53	69.73	45.89
60504643301	E4643A	1.35	59.34	46.75
60504644301	E4644A	0.20	55.11	46.46
60504644302	E4644B	0.64	59.99	46.46
60504644303	E4644C	0.73	60.38	46.46
60504645301	E4645A	0.64	59.99	46.46
60504646001	E4646A	0.22	63.59	46.46
60504646301	E4646A	0.22	63.59	46.46
60504647001	E4647A	4.02	60.55	46.85
60504647301	E4647A	4.02	60.55	46.85
60504647501	E4647A	4.02	60.55	46.85
60504648001	E4648A	0.23	61.10	45.67
60504648002	E4648A	0.23	61.10	45.67
60504648003	E4648A	0.23	61.10	45.67
60504648301	E4648A	0.23	61.10	45.67
60504648302	E4648B	0.12	56.42	45.67
60504649001	E4649A	130.18	72.26	46.21
60504649301	E4649A	130.18	72.26	46.21
60504649501	E4649A	130.18	72.26	46.21
60504650301	E4650A	1.28	81.41	47.41
60504651301	E4651A	0.00	70.00	47.64
60504652001	E4652A	1.88	43.39	47.63
60504652301	E4652A	1.88	43.39	47.63
60504653001	E4653A	48.99	75.77	46.03
60504653002	E4653B	48.97	75.77	46.03
60504653003	E4653C	1.68	75.70	46.46
60504653004	E4653D	1.55	74.99	46.46
60504654001	E4654A	115.78	76.34	46.52
60504654001	E4654A	115.78	76.34	46.52
60504654301	E4654A	115.78	76.34	46.52
60504654301	E4654A	115.78	76.34	46.52
60504655001	E4655A	0.08	70.06	47.64
60504655301	E4655A	0.08	70.06	47.64
60504656001	E4656A	4799.77	68.86	44.01
60504657001	E4657A	16.16	65.54	49.81
60504657301	E4657A	16.16	65.54	49.81
60504658001	E4658A	7199.44	70.35	46.29
60504658002	E4658B	7199.44	70.35	46.29

Table 9 Control Points and Corresponding Watershed Parameters (continued)

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
60504658003	E4658C	7199.44	70.35	46.29
60504658004	E4658D	7199.44	70.35	46.29
60504658005	E4658E	7199.44	70.35	46.29
60504658006	E4658F	7199.44	70.35	46.29
60504658007	E4658G	7199.44	70.35	46.29
60504658008	E4658H	7199.44	70.35	46.29
60504658301	E4658A	7199.44	70.35	46.29
60504658302	E4658B	7199.44	70.35	46.29
60504659001	E4659A	30.49	32.21	54.53
60504659002	E4659B	30.43	32.14	54.53
60504660001	E4660A	1.06	58.71	55.91
60504660301	E4660A	1.06	58.71	55.91
60504661301	E4661A	2.42	32.77	56.30
60504662001	E4662A	9347.98	67.71	48.37
60504663001	E4663A	12.43	61.61	57.38
60504664001	E4664A	30.81	69.87	57.73
60504665001	E4665A	38.82	69.00	41.31
60504665301	E4665A	38.82	69.00	41.31
60504665302	E4665B	3.53	70.06	40.64
60504665501	E4665B	3.53	70.06	40.64
60504666301	E4666A	0.04	67.66	39.76
60504667001	E4667A	92.31	71.16	40.92
60504668301	E4668A	13.34	70.30	40.36
60504669001	E4669A	480.86	70.09	43.10
60504669002	E4669B	2949.06	67.93	42.12
60504669301	E4669A	480.86	70.09	43.10
60504669302	E4669B	2949.06	67.93	42.12
60504670001	E4670A	765.85	72.18	40.68
60504670301	E4670A	765.85	72.18	40.68
60504671001	E4671A	1.83	70.33	42.40
60504671301	E4671A	1.83	70.33	42.40
60504672301	E4672A	0.40	73.00	42.13
60504673001	E4673A	2.93	71.19	42.13
60504673301	E4673A	2.93	71.19	42.13
60504674301	E4674A	0.68	34.19	42.09
60504675001	E4675A	10.87	60.73	42.31
60504675002	E4675B	9.83	59.25	42.33
60504675301	E4675B	9.83	59.25	42.33
60504676001	E4676A	4.28	68.32	41.38
60504676301	E4676A	4.28	68.32	41.38
60504677301	E4677A	1.36	67.07	41.71
60504678001	E4678A	1.60	70.07	41.85
60504678301	E4678A	1.60	70.07	41.85

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
60504679001	E4679A	1.77	71.26	41.73
60504679301	E4679A	1.77	71.26	41.73
60504680301	E4680A	1.28	70.47	42.12
60504681001	E4681A	10.27	65.51	41.61
60504681301	E4681A	10.27	65.51	41.61
60504682001	E4682A	1136.76	70.82	41.03
60504682301	E4682A	1136.76	70.82	41.03
60504683301	E4683A	1.64	61.17	41.34
60504684001	E4684A	0.38	69.94	42.05
60504684002	E4684B	1.12	69.36	42.03
60504684301	E4684A	0.38	69.94	42.05
60504684302	E4684B	1.12	69.36	42.03
60504685301	E4685A	0.55	40.47	41.76
60504686301	E4686A	0.41	66.53	41.34
60504687301	E4687A	0.74	64.73	41.62
60504687302	E4687B	0.55	66.32	41.70
60504687303	E4687C	0.07	63.77	40.94
60504688001	E4688A	1.43	69.12	41.73
60504688301	E4688A	1.43	69.12	41.73
60504689001	E4689A	0.83	73.20	41.73
60504689301	E4689A	0.83	73.20	41.73
60504690301	E4690A	12.83	62.79	41.26
60504691301	E4691A	0.81	53.78	40.94
60504692301	E4692A	0.63	62.92	41.19
60504693001	E4693A	2.44	70.28	41.34
60504693301	E4693A	2.44	70.28	41.34
60504694301	E4694A	3.61	69.41	41.12
60504695301	E4695A	1.18	66.08	40.61
60504696301	E4696A	0.23	48.37	40.94
60504697301	E4697A	3.20	47.17	41.09
60504698001	E4698A	1388.48	69.62	41.07
60504698002	E4698B	1392.02	69.61	41.07
60504698003	E4698C	40.33	69.01	41.46
60504698004	E4698D	40.54	69.02	41.46
60504698005	E4698E	45.83	68.29	41.49
60504698006	E4698F	46.15	68.33	41.50
60504698007	E4698G	46.27	68.35	41.50
60504699001	E4699A	1.15	69.78	43.31
60504699301	E4699A	1.15	69.78	43.31
60504700001	E4700A	1.96	55.42	42.52
60504700301	E4700A	1.96	55.42	42.52
60504701001	E4701A	221.64	68.61	43.13
60504702001	E4702A	1.70	69.23	43.98

Table 9 Control Points and Corresponding Watershed Parameters (continued)

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
60504702301	E4702A	1.70	69.23	43.98
60504703001	E4703A	0.04	66.31	45.28
60504703301	E4703A	0.04	66.31	45.28
60504704001	E4704A	0.07	70.00	42.37
60504704002	E4704B	0.07	70.00	42.13
60504704301	E4704A	0.07	70.00	42.37
60504704302	E4704B	0.07	70.00	42.13
60504705301	E4705A	1.41	69.24	44.09
60504707301	E4707A	2.19	62.90	41.73
60504708301	E4708A	28.44	73.64	42.19
60504709301	E4709A	0.05	70.00	41.73
60504709302	E4709B	0.01	70.00	41.73
60504709303	E4709C	0.02	63.89	41.73
60504709304	E4709D	0.08	70.45	41.73
60504709305	E4709E	0.27	72.04	41.73
60504709306	E4709F	0.18	73.06	41.73
60504709307	E4709G	0.03	70.00	41.73
60504709308	E4709H	0.02	70.33	41.73
60504709309	E4709I	0.03	70.00	41.73
60504710001	E4710A	578.69	70.25	42.90
60504710002	E4710B	578.59	70.25	42.90
60504710003	E4710C	578.52	70.25	42.90
60504711301	E4711A	0.71	57.22	42.33
60504712301	E4712A	4.53	64.57	42.25
60504713301	E4713A	2.72	78.82	41.79
60504713302	E4713B	0.26	79.27	41.73
60504713303	E4713C	0.19	78.98	41.73
60504713304	E4713D	0.57	79.55	41.73
60504713305	E4713E	0.14	80.82	41.73
60504713306	E4713F	0.11	78.00	41.73
60504713307	E4713G	0.09	78.00	41.73
60504714001	E4714A	1.27	58.30	41.04
60504714301	E4714A	1.27	58.30	41.04
60504714501	E4714A	1.27	58.30	41.04
60504715301	E4715A	1.39	42.39	41.08
60504716001	E4716A	0.38	54.56	41.34
60504716301	E4716A	0.38	54.56	41.34
60504717301	E4717A	1.29	74.05	42.52
60504718001	E4718A	0.01	55.00	42.64
60504718002	E4718B	0.23	69.96	42.82
60504718003	E4718C	0.01	80.63	42.52
60504718004	E4718D	0.76	72.88	42.52
60504718005	E4718E	0.03	55.00	42.59
60504718301	E4718A	0.01	55.00	42.64
60504718302	E4718B	0.23	69.96	42.82
60504718303	E4718C	0.01	80.63	42.52
60504718304	E4718D	0.76	72.88	42.52
60504718305	E4718E	0.03	55.00	42.59
60504719301	E4719A	0.71	70.72	42.13
60504720301	E4720A	3.39	47.46	41.99
60504721301	E4721A	0.51	72.77	42.34
60504722001	E4722A	0.34	55.39	42.52
60504722301	E4722A	0.34	55.39	42.52
60504723301	E4723A	0.08	67.00	41.34
60504723302	E4723B	0.20	62.14	41.34
60504723303	E4723C	0.08	66.91	41.34
60504723304	E4723D	0.03	44.05	41.34
60504723305	E4723E	0.05	59.95	41.34
60504724001	E4724A	3.49	60.71	41.72
60504724301	E4724A	3.49	60.71	41.72
60504724302	E4724B	4.63	64.34	41.69
60504725301	E4725A	0.12	41.22	41.73
60504726301	E4726A	1.73	50.43	41.73
60504727001	E4727A	0.18	78.16	41.73
60504727002	E4727B	3.66	57.10	41.73
60504727301	E4727A	0.18	78.16	41.73
60504727302	E4727B	3.66	57.10	41.73
60504728001	E4728A	3.57	56.83	41.73
60504728002	E4728B	0.13	66.00	41.73
60504729301	E4729A	1.04	67.15	41.73
60504730301	E4730A	5.26	35.24	42.91
60504731301	E4731A	1.20	66.63	42.56
60504732001	E4732A	0.53	63.99	44.49
60504732301	E4732A	0.53	63.99	44.49
60504733301	E4733A	0.68	69.20	42.52
60504734301	E4734A	9.65	61.71	42.56
60504734302	E4734B	8.27	62.55	42.57
60504735301	E4735A	2.16	63.21	42.52
60504736301	E4736A	22.51	62.38	42.49
60504737001	E4737A	3.79	66.10	42.43
60504737301	E4737A	3.79	66.10	42.43
60504738001	E4738A	3.88	66.25	42.42
60504738301	E4738A	3.88	66.25	42.42
60504739001	E4739A	0.96	70.47	42.25
60504739301	E4739A	0.96	70.47	42.25
60504740001	E4740A	0.13	59.05	43.06

Table 9 Control Points and Corresponding Watershed Parameters (continued)

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
60504740301	E4740A	0.13	59.05	43.06
60504741301	E4741A	1.48	35.74	42.96
60504742001	E4742A	3.16	40.93	42.95
60504742301	E4742A	3.16	40.93	42.95
60504743001	E4743A	1.58	62.20	42.93
60504744301	E4744A	1.28	62.53	43.70
60504745001	E4745A	23.40	58.62	43.73
60504746001	E4746A	0.12	63.43	43.31
60504746301	E4746A	0.12	63.43	43.31
60504747001	E4747A	0.20	65.82	43.31
60504747301	E4747A	0.20	65.82	43.31
60504748001	E4748A	0.31	69.80	42.68
60504748002	E4748B	119.47	61.12	43.45
60504748003	E4748C	0.55	72.80	42.74
60504748004	E4748D	0.55	72.80	42.74
60504748301	E4748A	0.55	72.80	42.74
60504749301	E4749A	27.72	77.11	42.74
60504750001	E4750A	0.25	78.08	42.13
60504750301	E4750A	0.25	78.08	42.13
60504751301	E4751A	0.55	55.00	42.91
60504751302	E4751B	2.27	56.60	42.91
60504752001	E4752A	8.83	65.62	42.50
60504752002	E4752B	8.61	65.89	42.50
60504753301	E4753A	5.51	57.34	43.05
60504753302	E4753B	1.80	56.89	42.92
60504754001	E4754A	6.93	57.21	43.02
60504754301	E4754A	6.93	57.21	43.02

CRWR ID	WAM ID	Area (sq. mile)	Average Curve Number	Average Precipitation (inches)
60504755001	E4755A	9.16	62.70	43.29
60504755301	E4755A	9.16	62.70	43.29
60504756301	E4756A	6.05	59.15	42.83
60504757301	E4757A	6.83	58.68	42.84
60504758001	E4758A	235.31	66.74	42.72
60504758002	E4758B	235.62	66.74	42.72
60504758003	E4758C	0.93	57.10	43.56
60504758301	E4758C	0.93	57.10	43.56
60504759001	E4759A	2944.14	67.93	42.11
60504759002	E4759B	237.40	66.72	42.73
60504759301	E4759B	237.40	66.72	42.73
60504759501	E4714A	237.42	66.72	42.73
60504760301	E4760A	3.70	59.07	43.99
60504761001	E4761A	0.05	78.00	44.09
60504761301	E4761A	0.05	78.00	44.09
60504762001	E4762A	44.30	64.43	44.33
60504762301	E4762A	44.30	64.43	44.33
60504763001	E4763A	47.90	64.19	44.36
60504763301	E4763A	47.90	64.19	44.36
60504764301	E4764A	2.77	68.65	43.82
60504765301	E4765A	4.52	66.91	43.92
60504769001	E4769A	0.24	67.58	42.52
60504769301	E4769A	0.24	67.58	42.52
60504770301	E4770A	3.39	57.20	42.09
60504771001	E4771A	29.47	63.31	42.45
60504771301	E4771A	29.47	63.31	42.45

In this study, the following datasets were used to develop a geospatial database for the Sabine Basin, from which delineated drainage areas, curve numbers, and mean annual precipitation values were calculated for the incremental watersheds draining to each water right diversion location:

- Digital Elevation Models (DEMs), developed by the USGS
- National Hydrography Dataset (NHD) stream coverage files, developed by the USGS
- Stream gage locations, provided by the USGS
- Parameter-elevation Regressions on Independent Slopes Model (PRISM) for mean annual precipitation, developed by the U.S. Department of Agriculture
- Water right diversion locations, developed by the TNRCC
- 1:250,000 scale grid coverage of curve numbers, obtained from the CRWR

These watershed parameters (CN, mean precipitation, and drainage areas at gaged and ungaged sites) were derived by the CRWR using a geographic information system (GIS) grid-based methodology.

3.2.1 Distribution of Naturalized Flows Considering Channel Losses

No specific channel losses were discovered in the Sabine River Basin. Refer to the discussion in section 3.1.3.

3.2.2 Impacts on Instream Flows and Sabine Lake Inflows

The impacts on instream flows were monitored by comparing unappropriated and regulated flows for scenarios one, three and eight at all control points in the watershed. In addition, comparisons of unappropriated and regulated flows for all scenarios were made for Sabine River at Stateline (STLINE) and at the terminus point of the basin, Sabine River at Sabine Lake (SRSL). The Results are presented in section 5.2, with the specific discussion on Sabine Lake Inflows in section 5.2.5.

3.3 Adjusted Net Reservoir Evaporation

Adjusted Net Evaporation data are utilized in water availability modeling in two ways:

1. Computation of naturalized streamflows to remove the effects of reservoirs on flow
2. Water availability computations at primary and secondary control points located at reservoirs.

Adjusted Net Evaporation for reservoirs, explained in section 3.3.2, was derived from gross reservoir evaporation and precipitation data obtained from the TWDB.

3.3.1 Evaporation Data Sources

The TWDB has developed historical evaporation rates for the State of Texas since the 1960s. Their most recent data set is for gross evaporation rates from 1954 through 1998 using an improved methodology not used in previous evaporation data sets. Evaporation data for the period from 1940 through 1953 are not available using the new method, so previously developed data was used. Precipitation data was also obtained from the TWDB. Runoff data was obtained from USGS gages and reservoir mass balance calculations.

3.3.2 Procedures for Estimation of Adjusted Net Reservoir Evaporation

Adjusted Net Reservoir Evaporation is the rate at which water is lost to evaporation from the surface of a reservoir. It represents the net impact of evaporation and of rainfall directly on the reservoir surface. The equation for adjusted net reservoir evaporation used in this study is:

$$ANE = GE - R + xR$$

where ANE is the adjusted net reservoir evaporation rate, GE is the gross reservoir evaporation rate, R is the rate of precipitation, and xR is the fraction of rainfall that would have resulted in runoff in the absence of a reservoir.

3.3.3 Comparison of Evaporation Data Sets

Annual values of Adjusted Net Reservoir Evaporation for each of the fifteen major reservoirs were used as input to the 59-year period WRAP (VER 11/26/01) model of the Sabine River Basin. These fifteen sets were combined in two groups for comparative purposes: an upper watershed group consisting of Lake Tawakoni, Lake Fork, Greenville City Lakes, Lake Gladewater, Lake Cherokee, Martin Lake, Lake Quitman, Lake Hawkins, Lake Winnsboro, Lake Holbrook, Brandy Branch Cooling Pond and Lake Murvaul; and a lower watershed group consisting of Toledo Bend, Lake Vernon and Lake Anacoco. The average annual adjusted net evaporation rates for the two groups are plotted on the graph in Figure 10 for the entire 1940 through 1998 analysis period. As expected, the general trend exhibited by this data is for the adjusted net evaporation to increase in the northerly direction toward the upper portion of the Sabine River Basin.

3.4 Reservoir Elevation-Area-Capacity Relationships

Area-capacity relationships in this study were derived from two primary sources: original area-capacities were used for reservoirs with capacities over 5,000 acre-feet; and a standard area-capacity relationship was developed for reservoirs with capacities less than 5,000 acre-feet. Table 10 is a list of major reservoirs in the Sabine River Basin (over 5,000 acre-feet of conservation storage).

Figure 10 Annual Adjusted Net Evaporation for the Upper and Lower Sabine Basin

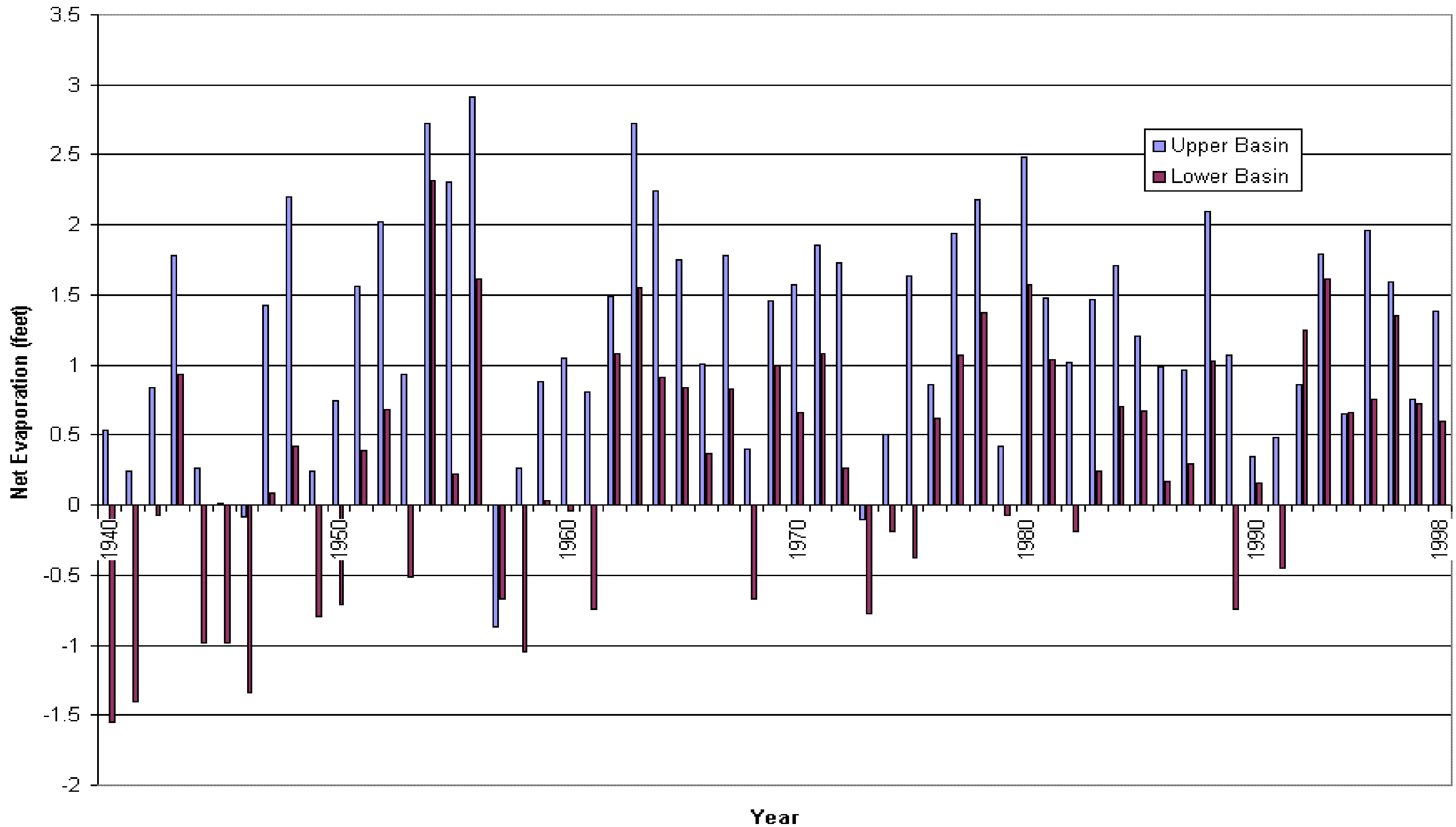


Table 10 Major Reservoirs in the Sabine River Basin

Reservoir	Drainage Area (Square Miles)	Stream	Date of Impoundment	Original Conservation Storage	Original Area-Capacity Source
Lake Tawakoni	756	Sabine River	Oct 1960	936,200	TWDB Mainframe 1984, TWDBR R-126
Lake Fork	493	Lake Fork Creek	July 1979	675,800	TWDB Mainframe 1984
Toledo Bend	7,178	Sabine River	Oct 1966	4,477,000	TWDB R-126, Pt.1, 1974, Forrest and Cotton
Greenville City Lakes*	NA	Cowleech Fork Sabine River	1888-1957		City of Greenville Public Works (no area-capacity data is available, only lake levels)
Quitman Holbrook Hawkins Winnsboro	31 15 30 27	Dry Creek Keys Creek Little Sandy Big Sandy	May 1962 Sept 1962 Aug 1962 June 1962	7440 7990 11,890 8,100	TWDB R-126 Engineering: Wisenbaker, Fix & Ass., Freese & Nichols
Lake Gladewater	35	Glade Creek	Sept 1952	6950	TWDB Mainframe
Lake Cherokee	158	Cherokee Bayou	Oct 1948	46,700	TWDB R-126, Pt.1, 1974, Powell and Powell
Martin Lake	130	Martin Creek	April 1974	77,500	TWDB R-126, Pt.1, Engineering: Forrest & Cotton, Inc.
Lake Murvaul	115	Murvaul Bayou	Dec 1957	45,840	TWDB R-126, Pt.1, 1974 Engineering: Forrest & Cotton
Brandy Branch	4	Brandy Branch	1982	29,513	
Lake Vernon	112	Anacoco Bayou	1963	57,000	
Anacoco Lake	209	Anacoco Bayou	1951	24,000	

* Off-channel reservoir complex with minimal drainage area.

The elevation-area-capacity relationship for a reservoir is necessary to describe the storage capabilities of the reservoir along with the evaporative potential. The relationship, which is also referred to as the area-capacity curve, is typically developed during the reservoir design phase from the topography of the area to be inundated by the reservoir. The original capacity at the normal pool of the reservoir is typically the authorized capacity of the water right holder's permit. Once impoundment of the reservoir begins, the reservoir accumulates sediment as a result of inflows from the unregulated watershed. The sediment which is deposited within the reservoir reduces the capacity and area of the reservoir at various storage stages because it is not evenly deposited across the cross-section of the reservoir, thereby reducing the yield and changing the evaporative characteristics of a reservoir. The following sections describe procedures used to estimate area-capacities relationships for reservoirs in the Sabine River Basin for use in the WRAP (VER 11/26/01) model.

3.4.1 Large Reservoirs

Original area-capacity conditions are used in all modeling scenarios (except the Current Conditions-scenario eight) as per TNRCC Resolved Technical Issues -Issue No. 6 dated January 1, 1999. Use of the original area and capacity results in conservatively low estimates of water remaining available for appropriation.

The original area-capacity curves were obtained from various sources for all the major reservoirs. These area-capacity curves were collected from design reports, studies and other documents, as listed in Table 10. The original area-capacity curves were used as the authorized area-capacity relationship for all reservoirs except for Lake Cherokee and Brandy Branch Cooling Pond. The as-constructed capacity of Lake Cherokee was 46,700 acre-feet while the permitted impoundment is 62,400 acre-feet. The original area capacity curve was extended from 46,700 acre-feet to the permitted amount of 62,400 acre-feet using regression. Similarly, the area-capacity curve for Brandy Branch was also extended from 29,000 acre-feet to the permitted capacity of 29,513 acre-feet. The original curves were reviewed for consistency with other available information. All the area-capacity data from the original information were plotted and inspected. Up to twelve representative points, the maximum allowable number of area-capacity curve points in the WRAP (VER 11/26/01) model were selected for each reservoir.

Scenario eight (Current Conditions) requires the use of year 2000 area-capacity relationships. The general methodology used for developing the year 2000 area-capacity relationship for each of the large reservoirs involved the following steps:

- Obtain the most recent available area-capacity information,
- Estimate annual sediment delivery for sub-basins in terms of acre-feet of sediment per square mile per year,
- Estimate total sediment delivery to the impoundment's since the last area-capacity survey,

- Distribute the sediment throughout the impoundment using the average end-area method,
- Prepare the year 2000 curves,
- Select the twelve representative points for input to WRAP.

Recent data for Lake Fork, Lake Tawakoni, Lake Gladewater, Lake Cherokee, Martin Lake, and Lake Murvaul were obtained from the volumetric surveys performed by the Texas Water Development Board between 1996 and 2001. These new curves were used as the starting point for the year 2000 area-capacity calculations. Greenville City Lakes are a series of off-channel reservoirs that are used to impound waters from the Cowleech Fork Sabine River. These lakes have no area-capacity information and therefore the year 2000 capacity could not be determined.

Estimates of historical sediment delivery to the different reservoirs were obtained from Report 268 entitled "Erosion and Sedimentation by Water in Texas" (1982) prepared by the Texas Department of Water Resources. This report provides an estimated sediment delivery rate in acre-feet per square mile based upon location of "yield points" within the Sabine Basin. In many cases, the yield points are reservoirs or other significant hydrologic features. In cases where recent volumetric survey information was available, a new sediment rate was calculated based upon the capacity lost in the resurvey. These new calculated sediment delivery rates are often higher than those found in Report 268.

The actual volume of sediment reaching the reservoir is a function of both the sediment delivery rate and the total uncontrolled drainage area upstream of the reservoir. As reservoirs are built within the watershed, the effective sediment contributing area is reduced to the reservoirs downstream. For reservoirs downstream of other reservoirs, the average sediment delivery rate and incremental drainage areas were determined for each time period between construction of upstream reservoirs. For all reservoirs, the total sediment volume was then estimated for each time period and accumulated to determine the total change in sediment contributing to reservoir drainage over time. For example, Toledo Bend Reservoir was built in 1966 when eight upstream reservoirs existed effectively reducing the total drainage area contributing sediment by 1,009 square miles. This reduction in drainage area contributing sediment therefore reduces the total expected sediment load for Toledo Bend.

Table 11 presents the re-survey information and sedimentation rates for the major reservoirs in the Sabine River Basin.

Table 11 Major Reservoirs in the Sabine River Basin Re-Survey and Sedimentation Information

Reservoir	Date of Impoundment	Conservation Storage Original (acre-feet)	Date of Resurvey	Conservation Storage Re-Surveyed (acre-feet)	Total Drainage Area (sq. mi.)	Sedimentation Rate (ac-ft/sq. mi./yr)
Lake Tawakoni	Oct 1960	936,200	April 1997	888,137	756	1.72
Lake Fork	July 1979	675,800	March 2001	636,133	493	3.70
Toledo Bend	Oct 1966	4,477,000			5384	0.12
Greenville City Lakes*	1888 -1957	Na				Na
Quitman Holbrook Hawkins Winnsboro	May 1962 Sept 1962 Aug 1962 June 1962	7440 7990 11,890 8,100			31 15 30 27	0.18 0.13 0.20 0.23
Lake Gladewater	Sept 1952	6950	March 2000	4738	35	1.32
Lake Cherokee	Oct 1948	46,700	Octr 1996	41,506	158	0.67
Martin Lake	April 1974	77,500	May 1999	75,116	130	0.73
Lake Murvaul	Dec 1957	45,840	Nov 1998	38,284	115	1.60
Brandy Branch	1982	29,513			4	0.20
Lake Vernon	1963	57,000			112	Na
Anacoco Lake	1951	24,000			209	Na

* Multiple off-channel reservoirs

3.4.2 Small Reservoirs

A single area-capacity relationship has been used in the water availability analyses for the small reservoirs with less than 5,000 acre-feet of storage capacity. The original permitted capacity for these reservoirs is utilized with the area-capacity relationship to estimate the area for any simulated volume. All permitted impoundment's have been included in the WRAP (VER 11/26/01) model regardless of size, and all exempt impoundment's documented in water rights have been modeled.

Area-capacity curves for these reservoirs have been developed using several sources. The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), was involved in the design and construction of many of these impoundment's. The elevation-area-capacity curves and tabular data of these relationships were obtained from the NRCS office in Temple, Texas. The TNRCC Phase I Dam Safety files also have been examined, and in most cases, the tabular elevation-area-capacity data was obtained. These original area-capacities were utilized for reservoirs with capacities less than 5,000 acre-feet. The original curves were reviewed for consistency with other available information from adjacent basins.

For small reservoirs, standardized area-capacity curves have been generated using the equation:

$$Area = a(Capacity)^b + c$$

This form of equation is known as a power function and is the function utilized by WRAP (VER 11/26/01). To obtain the coefficient a, b, and c, regression analyses of available area-capacity data for existing small reservoirs have been performed. All available area-capacity curves for the small reservoirs in the Sabine River Basin were plotted, and power function regression analyses were performed to obtain the best-fit equation. The best-fit equation resulted in the following coefficients. The R^2 for the best-fit lines are also shown below.

Reservoirs < 5000 acre-feet a= 1.0098; b=0.6889; c=0; $R^2 = 0.9606$

The graph for the equation shown above and the original data points are shown in Figure 11.

3.5 Aquifer Recharge

Aquifer recharge was not analyzed as part of this study (See section 3.1.3).

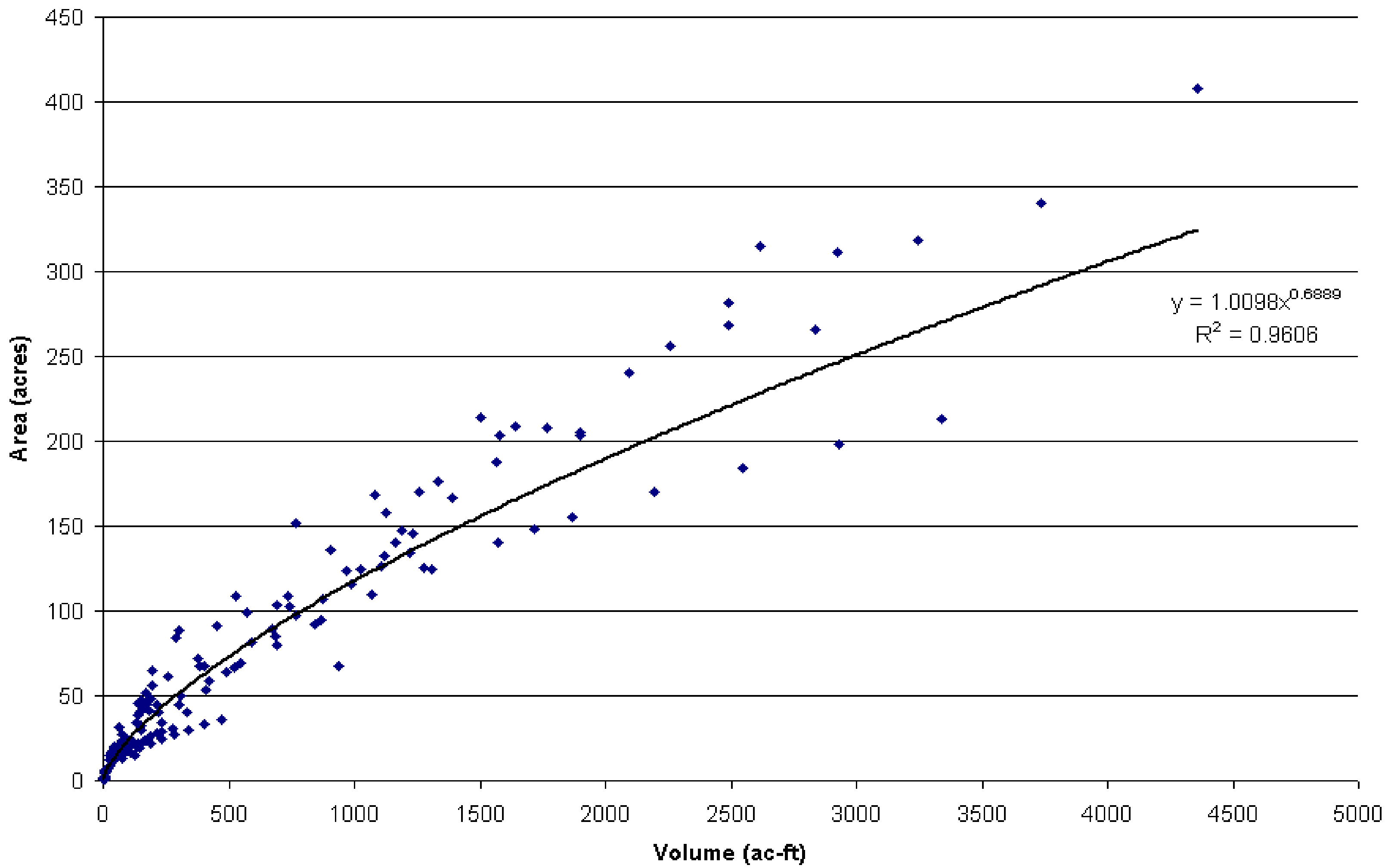
3.5.1 Historical Recharge

Not applicable.

3.5.2 Enhanced Recharge

Not applicable.

Figure 11 Sabine River Basin Standard Area-Capacity Curve for Reservoirs with Less Than 5,000 acre-feet of Storage



4.0 WATER AVAILABILITY MODEL OF THE BASIN

Water availability modeling of the Sabine River Basin was performed using the WRAP (VER 11/26/01) program along with input data specific to the Sabine River Basin including water rights, Sabine River Compact requirements, reservoir information, and naturalized streamflows. The WRAP program was originally developed at the Texas A&M University in March 1986. Since 1986 the program has undergone numerous upgrades, including WRAP (VER 11/26/01) which was used for this project. The WRAP program was recommended by a group of engineering firms which evaluated a number of models and subsequently selected by the WAM Management Team as the best model available to model the Texas prior appropriation system as well as to meet the requirements set forth by Senate Bill 1. The WRAP program and the specific parameters utilized in running the program will be discussed in the following sections.

4.1 Description of WRAP Model

The WRAP program was designed to simulate management and use of the streamflow and reservoir storage resources of one or more river basins under the prior appropriation system. The WRAP program is capable of evaluating river basins that have numerous diversions and use types (including hydropower), systems with multiple-reservoirs, complex allocation systems, and reservoirs with multiple users.

WRAP simulates a river basin by performing water accounting computations at each water right and control point based on the prior appropriation system in monthly time steps. This water accounting system tracks the effects of reservoir storage, instream flow, diversions and return flows on streamflow data. Simulations using the model are typically based on the following assumptions:

1. Basin hydrology is represented by an assumed repetition of historical period of record naturalized streamflows and reservoir evaporation rates.
2. The full amounts of all permitted water rights requirements are met as long as water is available from streamflow and/or specified reservoir storage.

The WRAP program provides flexibility to incorporate a wide range of approaches based on the parameters used to accurately model the water rights of a river basin. The characteristics of specific water rights are incorporated as assumptions in the input data especially in the WR record, WS record, SO record and the OR record. These four input records set up how a water right will be simulated (from run of river, reservoir storage, or both), how the water rights will be divided (into use types and priority), how a hydropower right will operate, and how multiple-reservoir operations will be defined.

WRAP handles hydroelectric energy in a fairly simplistic manner. Input requirements are Firm Annual Energy Target, monthly distribution, tailwater elevation, turbine efficiency and reservoir storage versus elevation. For a given month the energy target is met if there is sufficient streamflows and/or reservoir storage. However, shortages will occur if there is insufficient streamflows and/or reservoir storage.

The energy produced on a monthly basis is a function of discharge through the turbines and the head over the turbines. Hence the hydropower releases are variable depending primarily on the current end-of-period storage for the reservoir. Options allow for generating electricity with releases for other uses such as municipal, industrial and irrigation.

Some water rights have special conditions which subordinate the right to upstream junior water rights. In almost all cases subordination conditions within the water right cannot be simulated in WRAP (VER 11/26/01). The impact the subordination condition for Toledo Bend Reservoir (05-4658) will be discussed in section 5.2.

4.1.1 Base WRAP Model

The WRAP model works by performing a water accounting simulation utilizing a series of loops. Specifically, the WRAP simulation is composed of the following loops:

1. **Loop 1:** The input data including water rights, storage-area tables, basin configuration, use types, return flow factors, and gains and losses in the basin are read into the program and water rights are then ranked in priority order.
2. **Loop 2:** The hydrology records, inflow and evaporation, are read and adjustments for negative incremental flows and December return flows (made to January flows) are performed in an annual loop.
3. **Loop 3:** A monthly loop is performed in which net-evaporation-precipitation adjustments are made, spills are computed based on constant or monthly varying storage capacities, flow adjustments for constant inflow/outflows are computed, a water right loop is performed, and then control point and reservoir records are developed. The water rights loop is run for each water right in priority order and is composed of determining the amount of water available for each water right, checking unappropriated and regulated flows, making diversions, reservoir releases, and return flows, adjusting available streamflows at all control points, and creating output records for each water right.

4.1.2 Basin Specific WRAP Model

No changes were made to the WRAP (VER 11/26/01) program for modeling the Sabine River Basin.

4.2 Development of WRAP Water Rights Input File

The water rights (WR, WS, SO and OR), input records and river basin control point schematic were created by reviewing: hard copies of Water Rights, revised TNRCC master water rights list, and geo-referenced data from the TNRCC (obtained from the CRWR).

The basic steps included in creating the water right input cards include:

- Locating all water right diversion locations.
- Characterizing the written permit by aggregating the water rights into diversions, use type and priority dates.
- Determining if the water right diversion was backed by storage.
- Compiling and computing return flows for all industrial and municipal water right diversions including interbasin transfers.
- Computing monthly use factors.
- Identifying hydropower water rights.
- Creating a Control Point Schematic.

The task methodology is described in the following sections.

4.2.1 Control Points

Control points are used in the WRAP (VER 11/26/01) program as a means of spatially referencing the position of all inflows and outflows in a river basin. The actual formulation of the basin schematic used for the WRAP (VER 11/26/01) program is done in the CP record. The river layout is reproduced in the CP record by listing each control point and the next downstream control point. In the Sabine River Basin Water Availability Model, control points were segregated into two distinct types:

- Primary control points – points where naturalized streamflows were developed, including USGS streamflow gage locations, and the mouth of the Sabine River at Sabine Lake.
- Secondary control points – points located at water right diversions or impoundment's, water import locations, groundwater return flow sites, return flow sites, stream segment boundaries, and streamflow gage locations that are not primary control points.

The control points with calculated flows (Primary) are discernable from control points with estimated flows at ungaged sites (Secondary). Also, the two types of control points were labeled in different manners in the model. Primary control points were labeled using a four-letter acronym that represents the name of the USGS gage (Ex: SRGW – Sabine River near Gladewater). Secondary control points were labeled distinctly for water rights, wastewater return flows, water quality segment boundaries and non-primary streamflow gages using an alphanumeric code of up to six digits.

For water rights, the six-digit code is in the form: EXXXXY, and is defined below:

- E represents the Sabine River Basin (Basin 05)

- XXXX represents the water right identification number
- Y (optional) represents the unique diversion, reservoir or return flow point number for a water right

For wastewater return flows, the points are labeled as WWxxxx, with xxxx being up to a four-digit number.

For water quality boundaries, the points are labeled as WQSxxx, with xxx being up to a three-digit number.

For non-primary USGS streamflow gages, the points are labeled using the USGS streamflow gage number, with the first two digits (80) omitted. For the basin schematic shown in Appendix K, the full seven-digit USGS number is shown.

4.2.2 Monthly Demand Distribution Factors

Seasonal use patterns were determined by type of use for significant water rights within the Sabine River Basin. The historical water use data for this project was the source of information for this analysis. The most recent ten years of data was utilized to determine the seasonal use patterns when available. Data that had been estimated or were unrepresentative of proximate years were discarded. The years of estimated or unrepresentative data are highlighted in the working files. The seasonal patterns were evaluated by upper and lower basin with the SR_LP (Logansport) control point dividing the basin. Often the data for the lower basin was limited. For example, only one significant water right was found to determine the seasonal use pattern for irrigation. Also, there were no significant mining or recreation permits in the lower basin. Therefore the same seasonal use coefficients were used for both the upper and lower basins.

4.2.3 Water Rights

Water rights are defined in the WRAP model with parameters for permitted diversions, priority, reservoir storage, and diversion location. This is accomplished in the WR records of WRAP, which formulates the manner in which a particular water right is configured. In the WR records, a permitted diversion is segmented into several water rights based on the language of the Permit or Certificate of Adjudication (CA). For example, a water right with more than one diversion point, or having multiple uses will have more than one WR record to represent the permit in the model. Appendix L shows the WR, WS, SO and OR records used in the WRAP (VER 11/26/01) model.

Water rights are identified using an eleven digit alphanumeric code in the form of TBBXXXXXFFF, as defined below:

- T represents the Water Right Type (1 for Permit, 6 for Certificate of Adjudication)
- BB represents the Basin Number
- XXXXX represents the Permit or Certificate of Adjudication Number
- FFF represents the water right feature, where

  001 – 100 is for diversion points
  101 – 200 is for downstream boundaries of diversion areas
  201 – 300 is for upstream boundaries of diversion areas
  301 – 400 is for on-channel reservoirs
  401 – 500 is for off-channel reservoirs

Water rights in the Sabine River Basin are listed in Table 12. This table gives each water right location, permitted diversion amount, use type, priority date, and how each water right permit was segregated into multiple parts. The specific locations of the water rights can be geo-referenced on the map of the Sabine River Basin attached as Appendix K.

4.2.3.1 Priority Dates

Priority dates were derived directly from hard copies of water rights obtained from the TNRCC. While most water rights have only one priority date, some have multiple priority dates. Multiple priority dates may be found on water rights with multiple diversions, with multiple reservoir impoundment's, or in amended water rights.

Some water rights were characterized by multiple entries based on priority dates for storage, use types, as well as diversion locations. The priority date for each water right is included in Table 12. The format of the priority dates is YYYYMMDD, defined as:

- YYYY represents the four-digit year.
- MM represents the month by the two-digit code
- DD represents the day of the month in a two–digit code.

Table 12 Water Rights Information

Water Right ID Number	Control Point	Authorized Annual Diversion	Use Type	Priority Date
60504665301	E4665A	2500	MUN	19250630
60504665302	E4665A	1659	MUN	19511109
60504665303	E4665A		MUN	19910925
60504666301	E4666A		REC	19721127
60504667001	E4667A	250	IRR	19561127
60504668301	E4668A		REC	19750929
60504670301	E4670A	207675	MUN	19550912
60504670302	E4670A	21283	MUN	19550912
60504670303	E4670A	1792	MUN	19550912
60504670304	E4670A	4592	MUN	19850813
60504670305	E4670A	2758	MUN	19860521
60504671301	E4671A	100	MUN	19731210
60504671302	E4671A	200	MUN	19840515
60504672301	E4672A		REC	19760601
60504673301	E4673A	160	MUN	19270316
60504673302	E4673A	10	IND	19270316
60504674301	E4674A		REC	19761206
60504675001	E4675A	50	MUN	19540419
60504675301	E4675B	1500	MUN	19700105
60504676301	E4676A	12	MUN	19290731
60504677301	E4677A		REC	19740304
60504678301	E4678A	83	MUN	19511231
60504678302	E4678A	100	MUN	19520813
60504678303	E4678A		MUN	19760524
60504678304	E4678A	134	MUN	19830425
60504679301	E4679A	399	MUN	19260205
60504680301	E4680A		REC	19750714
60504681301	E4681A	33	IRR	19660630
60504682301	E4682A	27	IRR	19641231
60504683301	E4683A		REC	19500807
60504684301	E4684A	0	IRR	19721106
60504684302	E4684B	27	IRR	19721106
60504685301	E4685A		REC	19760830
60504686301	E4686A		REC	19740219
60504687301	E4687A		REC	19740819
60504687302	E4687B		REC	19740819
60504687303	E4687C		REC	19740819
60504688301	E4688A	20	IRR	19730108
60504689301	E4689A	251	MINING	19750421
60504690301	E4690A		REC	19601219
60504691301	E4691A		REC	19720313
60504692301	E4692A		REC	19760329

Water Right ID Number	Control Point	Authorized Annual Diversion	Use Type	Priority Date
60504693301	E4693A	150	MUN	19490201
60504693302	E4693A	250	MUN	19760927
60504694301	E4694A		REC	19660801
60504694302	E4694A		REC	19760927
60504695301	E4695A		REC	19770103
60504696301	E4696A		REC	19720501
60504697301	E4697A		REC	19730924
10504293301	E4293P		REC	19850416
10505229001	E5229P	9	IRR	19890414
60504669301	E4669A	20000	MUN	19740626
60504669302	E4669A	6720	MUN	19740626
60504669303	E4669A	2720	MUN	19740626
60504669304	E4669A	15500	IND	19740626
60504669305	E4669A	120000	MUN	19830228
60504669306	E4669A	18672	MUN	19850813
60504669307	E4669B	5048	MUN	19920416
60504699301	E4699A	19	IRR	19690508
60504700301	E4700A	25	IRR	19510530
60504701001	E4701A	249	IRR	19550531
60504702301	E4702A	75	IRR	19740930
60504703301	E4703A	1	IRR	19770627
60504704301	E4704B	87	IRR	19580430
60504704302	E4704A	50	IRR	19610530
60504705301	E4705A		REC	19711213
60504707301	E4707A		REC	19750113
60504708301	E4708A		REC	19601219
60504709301	E4709A		REC	19760223
60504709302	E4709B		REC	19760223
60504709303	E4709C		REC	19760223
60504709304	E4709D		REC	19760223
60504709305	E4709E		REC	19760223
60504709306	E4709F		REC	19760223
60504709307	E4709G		REC	19760223
60504709308	E4709H		REC	19760223
60504709309	E4709I		REC	19760223
10505046301	E5046P		REC	19860227
10505217301	E5217P		DOM	19890210
60504749301	E4749A		REC	19601219
60504749302	E4749A		REC	19651115
60504750301	E4750A	1	IRR	19550731
60504751301	E4751A		REC	19750422
60504751302	E4751B		REC	19750422

Table 12 Water Rights Information (Continued)

Water Right ID Number	Control Point	Authorized Annual Diversion	Use Type	Priority Date
60504752401	E4752A	30	IRR	19560731
60504753301	E4753A		REC	19750106
60504753302	E4753B		REC	19750106
60504754301	E4754A		REC	19800204
60504754302	E4754A	500	IRR	19830418
60504755301	E4755A	86	IRR	19720131
60504756301	E4756A		REC	19730911
60504757301	E4757A		REC	19750728
10503942401	E3942P	200	IRR	19821122
10503969001	E3969P	200	MINING	19830124
10505419301	E5419P		REC	19920601
10505419302	E5419Q		REC	19920601
60504698001	E4698B	273	IRR	19620730
60504698002	E4698G	0	IRR	19620730
60504710001	E4710A	17	IRR	19480630
60504711301	E4711A		REC	19750120
60504712301	E4712A		REC	19750127
60504713301	E4713A		REC	19750113
60504713302	E4713B		REC	19750113
60504713303	E4713C		REC	19750113
60504713304	E4713D		REC	19750113
60504713305	E4713E		REC	19750113
60504713306	E4713F		REC	19750113
60504713307	E4713G		REC	19750113
60504714301	E4714A	10	IND	19730828
60504715301	E4715A		REC	19740701
60504716301	E4716A	20	IND	19431231
60504717301	E4717A		REC	19750120
60504718301	E4718A		IRR	19620630
60504718302	E4718B		IRR	19620630
60504718303	E4718C		IRR	19620630
60504718305	E4718E		IRR	19620630
60504718304	E4718D	30	IRR	19620630
60504719301	E4719A		REC	19760112
60504720301	E4720A		REC	19740610
60504721301	E4721A		REC	19750630
60504722301	E4722A	38	IRR	19501231
60504723301	E4723A		REC	19760601
60504723302	E4723B		REC	19760601
60504723303	E4723C		REC	19760601
60504723304	E4723D		REC	19760601
60504723305	E4723E		REC	19780206

Water Right ID Number	Control Point	Authorized Annual Diversion	Use Type	Priority Date
60504724301	E4724A		CONST	19670523
60504724302	E4724A	180	IRR	19700720
60504724303	E4724A	179	IRR	19941223
60504724304	E4724B		REC	19680520
60504725301	E4725A		REC	19800107
60504726301	E4726A		REC	19711115
60504727301	E4727A	218	IRR	19630630
60504727302	E4727B	107	IRR	19630630
60504728001	E4728A	23	IRR	18711231
60504729301	E4729A		REC	19720207
60504730301	E4730A		REC	18831231
60504731301	E4731A		REC	19631216
60504733301	E4733A		REC	19780501
60504734301	E4734A		REC	19750113
60504734302	E4734B		REC	19850521
60504735301	E4735A		REC	19750317
60504736301	E4736A		REC	19601219
60504736302	E4736A		REC	19651115
60504737301	E4737A	8	IRR	19610731
60504738301	E4738A	44	IRR	19601231
60504739301	E4739A	750	IRR	19560227
60504739302	E4739A		IRR	19700601
60504740301	E4740A	8	IRR	19561231
60504741301	E4741A		REC	19750422
60504742301	E4742A	25	IRR	19521009
60504743001	E4743A	5	IRR	19511231
60504744301	E4744A		REC	19730115
60504745001	E4745A	15	IRR	19450731
60504746301	E4746A	20	IRR	19531231
60504747301	E4747A	20	IRR	19511231
60504748301	E4748C	0	IRR	19550731
60504748001	E4748B	120	IRR	19550731
60504758301	E4758C	0	REC	19650503
60504758302	E4758B	200	MUN	19650503
60504758303	E4758B	200	MUN	19670911
60504758304	E4758B	150	IRR	19670911
60504758305	E4758B	200	IRR	19761220
60504758306	E4758C	0	REC	19761220
60504759301	E4759B	730	MUN	19350424
60504759302	E4759B	2070	MUN	19420313
60504759303	E4759B	2600	MUN	19450713
60504759304	E4759B	100	IND	19450713

Table 12 Water Rights Information (Continued)

Water Right ID Number	Control Point	Authorized Annual Diversion	Use Type	Priority Date
60504759305	E4759B	100	IRR	19450713
60504760301	E4760A		REC	19750113
60504762301	E4762A	1679	MUN	19510517
60504763301	E4763A	100	IRR	19630630
60504769301	E4769A	40	IRR	19541231
60504770301	E4770A		REC	19161231
60504771301	E4771A		REC	19021231
60504771302	E4771A	10	REC	19501231
10503899001	E3899P	80	IRR	19820607
10503931301	E3931P		REC	19821018
10504202001	E4202P	750	IRR	19841107
10504248001	E4248Q	1.8	IRR	19850604
10504248301	E4248P		IRR	19850604
10504248302	E4248Q	15.2	IRR	19850604
10504248303	E4248P	0	IRR	19850604
10504248304	E4248Q	100	IRR	19960801
10505287301	E5287P		REC	19900321
60504622301	E4622A		REC	19741104
60504623001	E4623A	5	MINING	19311231
60504624301	E4624A	1087	MUN	19150707
60504624302	E4624A		MUN	19760412
60504625301	E4625B		DOM	19760412
60504626301	E4626A	17	IRR	19550630
60504627301	E4627A		REC	19760412
60504627302	E4627A	80	IRR	19840124
60504628301	E4628A	37	IRR	19631231
60504628302	E4628A	6	IND	19631231
60504629301	E4629A	28	IRR	19530831
60504630301	E4630A	39	IRR	19521231
60504631301	E4631A	81014	IND	19490919
60504631302	E4631A	18518	IND	19490919
60504631303	E4631A	34968	IND	19490919
60504631304	E4631C		IND	19570107
60504631305	E4631D		IND	19570107
60504631306	E4631E		IND	19750428
60504631307	E4631E		REC	19671231
60504632301	E4632A	51	IRR	19361231
60504632302	E4632A	75	IRR	19970604
60504633001	E4633A	3	IND	19551231
60504634001	E4634A	69	IRR	19630331
60504635301	E4635A	18	IRR	19630331
60504636301	E4636A		DOM	19751103
60504637301	E4637A	15	IND	19750818
60504638001	E4638A	37	IRR	19630731
60504638002	E4638A	0.2	IND	19630731
60504639001	E4639A	50	IRR	19460531
60504640301	E4640A	16	IRR	19221231
60504641301	E4641A	0.1	IND	19441231
60504642301	E4642A	16000	MUN	19461005
60504642302	E4642A	3360	MUN	19461005
60504642303	E4642A	2000	IND	19461005
60504642304	E4642A	2000	IND	19461005
60504642305	E4642A	39040	MUN	19461005
60504643301	E4643A		REC	19750303
60504644301	E4644A		REC	19251231
60504644302	E4644B		REC	19251231
60504644303	E4644C		REC	19600331
60504645301	E4645A	118	IRR	19600331
60504646301	E4646A	9	IRR	19371231
60504647301	E4647A	11000	IND	19780821
60504647001	E4647A	0	CONST	19780821
60504732301	E4732A	202	IRR	19610331
60504761301	E4761A	7	IND	19730702
60504764301	E4764A		REC	19740708
60504765301	E4765A		REC	19741209
10505082301	E5082P	5	IND	19860807
10505082302	E5082Q	5	IND	19860807
10505090001	E5090P	13860	5090	19860826
10505124301	E5124P	5	IND	19870323
10505124302	E5124Q	5	IND	19870323
10505124303	E5124R	5	IND	19870323
10505158301	E5158P	0	IND	19870928
10505158401	E5158Q	0	IND	19870928
10505158302	E5158R	0	IND	19870928
10505158303	E5158S	0	IND	19870928
10505158304	E5158T	0	IND	19870928
10505158305	E5158U	0	IND	19870928
10505158306	E5158V	0	IND	19870928
10505158001	E5158T	0	CONST	19870928
10505158002	E5158U	0	CONST	19870928
10505158003	E5158V	0	CONST	19870928
10505158004	E5158S	0	CONST	19870928
10505177301	E5177P	100	IND	19880428
10505246301	E5246P	100	IND	19890714

Table 12 Water Rights Information (Continued)

Water Right ID Number	Control Point	Authorized Annual Diversion	Use Type	Priority Date
10505382301	E5382P	100	IND	19910909
10505439301	E5439P	100	IND	19921203
10505441301	E5441P	100	IND	19921202
10505441302	E5441Q	100	IND	19921202
10505454301	E5454P	100	IND	19930305
10505468301	E5468P	0	IND	19930818
10505491001	E5491P	0	MINING	19940601
10505519301	E5519P	245	MINING	19950816
10505578301	E5578P	10	MUN	19970304
10505607001	E5607P	0	CONST	19980324
60504648301	E4648A	4	IND	19841023
60504648302	E4648B	0	IND	19650331
60504649301	E4649A	25000	IND	19710719
10505492301	E5492P	0	MINING	19940617
10505504301	E5504P	0	MINING	19940914
10505526301	E5526P	0	MINING	19950404
60504653001	E4653A	50	IRR	19640416
60504654301	E4654A	21280	MUN	19560719
60504654302	E4654A	1120	IND	19560719
60504655301	E4655A	229	IND	19480426
10505380401	E5380P	0	IND	19910823
60504650301	E4650A		REC	19751110
60504651301	E4651A		REC	19730507
60504652301	E4652A	286	IND	19720110
60504656001	E4656A	118	IRR	19550620
10504226301	E4226P	70	IRR	19850103
10504238001	E4238P	77	IRR	19850416
10505219001	E5219Q	0	IND	19890320
10505219301	E5219P	129	IND	19890320
10505643301	E5643P		REC	19990817

Water Right ID Number	Control Point	Authorized Annual Diversion	Use Type	Priority Date
60504657301	E4657A	330	MUN	19220804
60504657302	E4657A	1130	MUN	19520814
60504658301	E4658A	2215	MUN	20001231
60504658302	USRBU	87785	MUN	20001231
60504658303	USRBU	10000	MUN	20001231
60504658304	USRBU	530000	IND	20001231
60504658305	USRBU	70000	IND	20001231
60504658306	USRBU	50000	IRR	20001231
TBLA North LA	E4658A	500000	MUN	20001231
TBLA DS MUN IND	USRBU	200000	MUN	20001231
TBLA DS IRR	USRBU	50000	IRR	20001231
60504658307	E4658A	65700	HYDROE	20001231
10505207301	E5207P		REC	19881118
60504659001	E4659A	235	IND	19691117
60504660301	E4660A	50	IRR	19741202
60504661301	E4661A		REC	19691106
60504662001	E4662A	24643	IND	19260224
60504662002	E4662A	17922	IND	19260224
60504662003	E4662A	4480	IND	19260224
60504662004	E4662A	2800	IND	19260224
60504662005	E4662A	3360	IND	19260224
60504662006	E4662A	840	IND	19260224
60504662007	E4662A	16355	IND	19260224
60504662008	E4662A	30000	IND	19460607
60504662009	E4662A	46700	IRR	19781113
60504663001	E4663A	67	IRR	19380531
60504664401	E4664A	0	IND	19450619

4.2.3.2 Treatment of Reservoir Storage

The maximum amount a reservoir may impound is specified in the TNRCC water right permit or certificate of adjudication. For reservoirs having multiple priority dates for storage, WRAP requires multiple WR and WS records to represent the different priority dates assigned to reservoir storage. Storage in a reservoir is filled only after meeting the needs of senior water rights. Incorporating these different reservoir storage levels by priority date allows the WRAP (VER 11/26/01) model to fill a reservoir only when flow is available based on the specific priority date(s) of the water right.

WRAP has a number of different ways to simulate storage in a reservoir including setting the bottom of the active pool, setting two zones of storage as well as setting the priority by which storage is removed from each zone of storage. By allowing the bottom of the active pool to be set, WRAP constrains the amount of water left in reservoir storage during the critical period. This option was utilized to limit the available water for diversion from the hydropower right at Toledo Bend Reservoir (i.e. top of the power pool was set at El. 162.2 ft, below which no releases were made to generate hydropower).

4.2.3.3 Return Flows

Return flows were assigned to all municipal, industrial and mining water rights unless specific information or assumptions indicated otherwise. Return flow percentages were calculated for municipal and industrial water use categories. Historical water use and discharge records were reviewed for the last five years. The year with the minimum annual return flow percentage in this five-year period was used as the minimum return flow factor for that water right. WRAP (VER 11/26/01) allows the user to input a single return flow percentage that is used throughout the year or to specify 12 monthly values for return flow percentages. No significant trend of monthly varying return flow factors was observed, and therefore a constant monthly return flow factor is used for water rights in this study.

Return flow factors were also calculated for facilities whose discharge originates from both surface water and groundwater. For these facilities, the total water used (surface water and groundwater) was compared to the total return flow to determine return flow factors. The analysis of data was for the last five years and the minimum percentage of return flow for these years was selected. The groundwater component of the return flow is simulated as constant inflows using the gain/loss CI Card.

For the Sabine River Basin, return flow factors were aggregated by use types. This was necessary because the majority of the water rights did not have distinct return flow locations which would allow for accurate computation of return flow factors. Industrial rights were assigned a return flow factor of 0.66 based on historical use and discharge data for industrial rights. Municipal rights were assigned a return factor of 0.58 based on similar rights located in the basin. Mining rights were assigned a return flow factor of 0.70 based on mining use for the adjacent Neches River Basin. Table 13 summarizes the return flow factors for the Sabine River Basin. Appendix M includes the calculations of return flow percentages in the Sabine River Basin. Return flows from agricultural users were assumed to be zero.

Table 13 Return Flow Summary for the Sabine River Basin

Use	Method	Return Flow Factor
Municipal	Calculated [a]	0.58
Industrial	Calculated [b]	0.66
Irrigation	WAM Resolved Technical Issues	0.00
Mining	Neches River Basin WR 3222 [c]	0.70

(a) Municipal return flow coefficient is based on the average of last 5 years driest year return flow factors for City of Carthage, City of Longview and City of Gladewater.
(b) Industrial return flow coefficient is based on the average of the last 5 years return flow factors for Firestone and Bayer.
(c) Mining return flow factor is based upon return flow for Permit 3969 (WR 3222) in the Neches River Basin.

4.2.3.4 Multiple Diversion Locations

There are a number of water rights in the Sabine River Basin, which have multiple diversion locations. Water rights with multiple diversion points include:

05-4626	05-4653	05-4698	05-4748	P-5124
05-4629	05-4658	05-4704	05-4752	P-5158
05-4631	05-4659	05-4710	05-4758	P-5219
05-4638	05-4669	05-4718	05-4759	P-5441
05-4642	05-4675	05-4727	P-4248	
05-4648	05-4684	05-4728	P-5082	

In general, the authorized diversion for a water right was made at the most downstream diversion point. For water rights with diversion points on multiple streams, the “BACKUP” feature in WRAP (VER 11/26/01) was utilized to allow diversions to be made from more than one stream. For water rights with diversions authorized from storage in multiple reservoirs, the water right was modeled with diversions met from a system of reservoirs.

4.2.3.5 Rights Requiring Special Consideration

Appendix N contains a brief discussion of the assumptions utilized in representing selected water rights in WRAP.

4.2.4 Data for Basin-Specific Features Added to WRAP (VER 11/26/01)

Not Applicable.

4.3 Significant Assumptions Affecting Water Availability Modeling

The single most significant assumption in this study regarding water availability is the manner in which naturalized flows are distributed from gaged to ungaged sites. The key assumptions in this case are the parameters which are used to distribute the flows, as described earlier in section 2.5. Another impact on water availability is the inability of WRAP (VER 11/26/01) to simulate subordinate conditions exactly as stated within water rights.

Water rights 05-4669 and 05-4670 authorized interbasin transfers from Lake Fork and Lake Tawakoni. Each of these water rights has multiple priority dates such that the priority for diversions subject to the interbasin transfers are junior to use of the same amount of water in the basin. These water rights are described further in section 4.3.5. For scenarios three and six, in which no return flows occur, and the diversions are equal to the full authorized amount, these two the water rights are modeled with the most senior priority date allowed, such that interbasin transfers are not fully simulated.

Additional modeling assumptions which have a significant impact on water availability are described in the following sections.

4.3.1 Reuse

Wastewater reuse in the model was formulated for 100 percent, 50 percent, and 0 percent reuse of return flows. It was assumed that all existing reuse projects are included in the historical return flow data obtained from the TNRCC and TWDB. This data was analyzed for the past five to six years for all water rights with permitted diversions. The manner in which return flows were calculated is described in section 4.2.3.3.

4.3.2 Return Flow/Constant Inflow Assumptions

The gain/loss CI Card is utilized by the WRAP (VER 11/26/01) model to account for inflow into the basin from groundwater as well as water imported from other basins. Appendix M-2 lists which control points had constant inflows to represent groundwater or interbasin transfer sources.

4.3.3 Off-Channel Reservoirs

There are numerous off-channel reservoirs in the Sabine River Basin. Generally, for those water rights with multiple off-channel reservoirs, a single reservoir representing the sum total of all capacities was simulated. A total of 13 off-channel reservoirs were modeled in the Sabine River Basin. WRAP (VER 11/26/01) simulates off-channel reservoirs by limiting the streamflow depletions which are made to meet diversions and refill storage. These constraints are defined as annual limits, which limit the cumulative annual streamflow depletion, and monthly limits, which define the maximum streamflow depletion for any given month, based on the maximum diversion rate as specified in the water right. Appendix N, Water Right Assumptions for the Sabine River Basin, includes the water rights with off-channel reservoirs and the manner in which they were modeled.

4.3.4 Term Permits

Water rights containing term permits are to be included only in scenario eight of the model runs and only for the maximum amount used in the last 10 years. Two water rights in the Sabine River Basin have term permits on all or part of the right. These water rights, and the manner in which they are simulated are:

05-4670 Special Condition B: The authorization to use 3500 acre-feet of water per annum for industrial purposes shall expire on July 1, 1991, after which date the use shall revert to municipal use.

This permit was modeled with the assumption that the term permit portion expired and the use is municipal.

P 4202 Use B. Permittee is authorized to divert and use not to exceed 750 acre-feet per annum of its total authorization on a perpetual basis. The authorization to annually use the remaining 600 acre-feet of water shall expire and become null and void on December 31, 1995 unless prior to that date owner applies for an extension hereof and such application is granted for an additional term or in perpetuity.

This permit was modeled with the assumption that the term permit for 600 acre-feet per year has expired.

4.3.5 Interbasin Transfers

The TNRCC maintains a list of interbasin transfers in the State of Texas. According to the list there are fourteen permitted interbasin transfers in the Sabine River Basin. Five interbasin transfers potentially export water from the basin and nine interbasin transfers potentially import water into the basin. The fourteen interbasin transfers that occur in the Sabine River Basin are described below:

Exports

1) 05-4658 – Sabine River Authority (Toledo Bend Reservoir): The water right includes authorization of up to 80,000 acre-feet per year of the municipal and industrial diversions to be used in the Neches River Basin. This transfer is simulated to the full extent for model scenarios one, two, three, four and six as diversions of 80,000 ac-ft/yr with no return flows. For scenarios five, seven and eight (max use from last ten

years), no interbasin transfer is simulated as the limited historical use has been within the basin.

2) 05-4662 – Sabine River Authority (Run of River): The water right includes authorization of up to 30,000 ac-ft/yr of the municipal and industrial diversions to be used in the Neches River Basin. In addition, 46,700 ac-ft/yr of diversions are authorized for irrigation of 14,000 acres in the Sabine River Basin and 4000 acres in the Neches River Basin. This transfer is simulated to the full extent for model scenarios one, two, three, four and six. For scenarios five, seven and eight, interbasin transfers that represent the water supplied to North Star Steel and the City of Rose City are modeled with no return flows. Irrigation water rights are modeled with no return flows, regardless of basin of use.

3) 05-4669 – Sabine River Authority (Lake Fork): The water right includes authorization of up to 120,000 ac-ft/yr of the municipal, and industrial diversions to be transferred to the Trinity River Basin. This water right also authorizes an interbasin transfer of up to 5,048 ac-ft/yr of the municipal water to the Neches River Basin. These transfers are simulated to the full extent for model scenarios one, two and four. For scenarios three and six, which have full authorized diversions and no return flows, no interbasin transfer is simulated because the transbasin diversion of water is junior to in-basin use. For scenarios five, seven and eight, no interbasin transfer is modeled, as the historical use for this water right for the ten year period from 1989-1998 did not include any diversions for use outside of the Sabine River Basin. Although in 2000, a small amount of water was supplied to the City of Henderson, located in the Neches River Basin in Rusk County.

4) 05-4670 – Sabine River Authority (Lake Tawakoni): The water right includes authorization of up to 227,675 ac-ft/yr of interbasin transfers to the Trinity River Basin and up to 8,396 ac-ft/yr of interbasin transfers to the Sulphur River Basin. The total authorization is for diversions of 238,100 ac-ft/yr. The total amount of committed water in the Sabine River Basin is 27,759 ac-ft/yr. The remaining 210,341 ac-ft/yr is simulated as interbasin transfers for scenarios one, two, and four. For scenarios four and six, the water right is simulated at its most senior priority dates. This limits the interbasin transfer to not exceed 207,675 ac-ft/yr, which is the amount of interbasin transfer authorized at the most senior priority date. For scenarios five, seven and eight, an interbasin transfer of 134,350 ac-ft/yr is simulated to the Trinity River Basin, and an interbasin transfer of 1,781 ac-ft/yr is simulated to the Sulphur River Basin based upon the maximum amount of water supplied for interbasin uses between 1989 and 1998.

5) 05-4693 – City of Van, Smith County: The TNRCC list indicates an interbasin transfer of 400 ac-ft/yr for municipal use. While the written water right does not implicitly include authorization for interbasin transfer of any amount of water, the diversion point is located near the basin divide. Since the return flows for this water right are less than 0.5 mgd, the location of the return flow was not determined. (The

water right is for up to 400 ac-ft/yr for municipal purposes.) In all model scenarios, no interbasin transfer is simulated.

Imports

1) 03-4811 – Sulphur Springs Water District: The TNRCC list indicates an interbasin transfer of 9800 ac-ft/yr from Lake Sulphur Springs in Hopkins County to Sulphur Springs for municipal use. However, the water right database does not include any comment referring to interbasin transfer. There are no return flows attributable to this water supply above the 0.35mgd threshold (the same threshold for inclusion of groundwater based return flows). Only a small percentage of Sulphur Springs is located in the Sabine Basin, and it is assumed that all return flows go the Sulphur Basin.

2) 04-4560 – Franklin County Municipal Water District: The TNRCC list indicates an interbasin transfer of 5,000 ac-ft/yr from Lake Cypress Springs in Franklin County to Winnsboro. The water right database comment states that 5,000 ac-ft/yr may be diverted to the Sabine River Basin. The five-year minimum return flow for the City of Winnsboro WWTP is 488 ac-ft/yr and is input as a CI card in scenarios one, four, five and eight. For scenario two, the 50 percent reuse scenario, the CI card is reduced to an annual amount of 244 ac-ft/yr. For the scenarios with 100 percent reuse, no interbasin transfer is simulated.

3) 04-4590 – Northeast Texas Municipal Water District: The TNRCC list indicates an interbasin transfer from Lake O' the Pines of 18,000 ac-ft/yr to SWEPCO for industrial use, and 20,000 ac-ft/yr to City of Longview for municipal and industrial use. The water right database also indicates interbasin transfers of 18,000 and 20,000 ac-ft/yr. The transfer to SWEPCO is used to maintain the water level in Brandy Branch Cooling Pond. This transfer is simulated in all model runs by making the necessary depletions from a hypothetical control point in the Cypress Basin to keep the Cooling Pond full. The interbasin transfer to the City of Longview was not in place during the five-year period from 1994 to 1998 from which minimum return flows are determined. Therefore, this interbasin transfer is not modeled in any of the scenarios.

4) 04-4614 – City of Marshall, Harrison County: The TNRCC list indicates an interbasin transfer from Big Cypress Bayou to Marshall of 16,000 ac-ft/yr for municipal use. The five-year minimum return flow for the City of Marshall WWTP is 4,125 ac-ft/yr, and is input as a CI card in scenarios one, four, five and eight. In scenario two, the CI card is for 2,063 ac-ft/yr, and in scenarios three, six and seven, no interbasin transfer is simulated.

5) 06-4404 – City of Center, Shelby County: The TNRCC list indicates an interbasin transfer from Lake Pinkston to the City of Center of 3,800 ac-ft/yr for municipal purposes. Water right 05-4657, owned by the City of Center, authorizes 1,460 ac-ft/yr of municipal diversions. However, reported use for 05-4657 has varied from zero

use to just under 400 ac-ft/yr between 1989 and 1998. City of Center also supplies water to Tyson Farms. The five-year minimum return flows at City of Center WWTP and Tyson Farms WWTP are 613 ac-ft/yr and 936 ac-ft/yr, respectively. Due to the significant variability in 05-4657 reported use, the source of return flows is simulated as from the interbasin transfer only. The interbasin transfer is represented as CI cards for 613 ac-ft/yr at the City of Center WWTP and 936 ac-ft/yr at Tyson Farms WWTP for scenarios one, four, five and eight. For scenario two, the amounts are reduced by 50 percent, and for scenarios three, six and seven, no interbasin transfer is simulated.

6) 06-4415 – City of Beaumont: The TNRCC list states implied service area of Jasper and Orange County, both of which have portions in the Sabine and Neches River Basins. No significant return flows in the Sabine River Basin are attributed to this water right. No interbasin transfer is modeled for any scenario.

7) 06-4537 – Angelina-Neches River Authority: The TNRCC list indicates an interbasin transfer of 2200 ac-ft/yr for municipal and domestic use. The water right database also states 2,200 ac-ft/yr to the Sabine River Basin. This water right is associated with Lake Eastex which has not been constructed. No interbasin transfer is modeled for any scenario.

8) 06-4853 – City of Tyler, Smith County: The TNRCC list indicates an interbasin transfer of 40,325 ac-ft/yr for municipal, industrial and domestic purposes. To date, no interbasin transfers have been made under this water right, thus no interbasin transfer is modeled for any scenario.

9) 08-2410 – North Texas Municipal Water District – The TNRCC list indicates an interbasin transfer from Lake Lavon to Royse City and others of 100,000 ac-ft/yr for municipal purposes and 4000 ac-ft/yr for irrigation. The five-year minimum return flow for the City of Royse City WWTP is less than 0.35mgd. No other return flows are attributed to this water right. (Most of the customers supplied in the Sabine River Basin use septic tanks.) No interbasin transfers are modeled for any scenarios.

4.3.6 Sabine River Compact

The most significant assumption specific to the Sabine River Basin is the treatment of the Sabine River Compact within the parameters of the WRAP (VER 11/26/01) model. There are two aspects of the Compact which are simulated in the water availability model. These are the division of all free water in the Stateline reach equally between the two states, and the requirement of minimum flow at the Stateline of 36 cfs.

The division of all free water in Stateline reach is simulated using the instream flow features in WRAP (VER 11/26/01). The intent of the instream flow requirement is to reserve 50 percent of the free water for Louisiana, and allow Texas the ability to make streamflow depletions from the other 50 percent of water in Stateline reach. Because Toledo Bend Reservoir is jointly owned and operated by the two States, and includes hydropower operations, the reservoir is simulated with diversions to represent the use by both States. Each State owns one-half of the project, including the yield of the reservoir. The Texas water appropriation from Toledo Bend Reservoir is for 750,000 ac-ft/yr, while Louisiana water law does not stipulate a specific appropriation. The Louisiana contracts from the reservoir are on the order of 30,000 ac-ft/yr. Thus in order to maintain an equal split of water, diversions from Louisiana are simulated as 750,000 ac-ft/yr.

Downstream of Toledo Bend Reservoir, no Louisiana water rights are simulated. Instead, 50 percent of the flow is reserved for Louisiana. This is accomplished using instream flow (IF) cards with a series of target option (TO) cards. The TO cards allow the instream flow requirement to be calculated within WRAP (VER 11/26/01) as a function of any number of parameters, including naturalized flows, regulated flows, unappropriated flows, water right streamflow depletions, reservoir storage withdrawals, and reservoir storage. For the purpose of simulating the Sabine River Compact, the instream flow requirement is built as a function of naturalized and regulated flows, as well as water right streamflow depletions and withdrawals from storage.

The 50/50 instream flow requirement is set at the mouth of the Sabine River at Sabine Lake, and applies to all water rights which are downstream of Toledo Bend Reservoir, including water rights on tributaries downstream of Toledo Bend Reservoir.
The instream flow requirement is built in a manner which reserves one-half of the regulated streamflows at the Sabine River near Burkeville gage plus one-half of the incremental naturalized flows between the Burkeville gage and Sabine River at Sabine Lake for Louisiana. The Burkeville gage is selected as the point at which the division of flow starts because it is located downstream of Toledo Bend Reservoir which is jointly operated. All releases from Toledo Bend Reservoir, which are diverted downstream of the reservoir, are simulated as diverted just upstream of the Burkeville gage, in order to not impact the 50/50 split of flows.

Additionally, any return flows that enter the watersheds downstream of the Burkeville gage are subject to the 50/50 split. Thus one-half of the quantity of return flows represented by CI cards are input in the IF card directly. In order to split the availability of return flows which result from water right diversions, the water rights are referenced in TO cards, with coefficients to represent one-half of the return flow factor, which are applied to the water rights' streamflow depletions or reservoir withdrawals.

The Sabine River Compact does not require that the basin, upstream of Stateline, pass any flows other than 36 cfs minimum flow at Stateline. Therefore the instream flow requirement for the 50/50 split is only "on" when water rights in the Stateline reach are being processed in WRAP. This is accomplished in the water right input deck by placing the calculated instream flow requirement just senior to each downstream water right, and following the water right with an instream flow requirement of zero. The instream flow requirement is turned "on" after the most junior water right, such that the reported unappropriated flows represent only the portion of flow available for Texas.

The Compact provision requiring the 36 cfs minimum flow at Stateline is simulated as an instream flow requirement with a priority date of January 1, 1953, located at Stateline.

This instream flow requirement does not require any releases from storage in any of the upper basin reservoirs, and only applies to water rights with priority dates junior to January 1, 1953.

4.3.7 Toledo Bend Reservoir

Water right 05-4658, issued to the Sabine River Authority of Texas, authorizes impoundment in and diversions from Toledo Bend Reservoir. The water right includes priority dates of March 5, 1958 for the impoundment, diversion and release of water at a certain flow rate for hydroelectric power generation, and a subsequent priority date of January 22, 1986 for release of water at a higher flow rate for hydropower generation. The water right includes the following special condition:

> This certificate of adjudication is subordinate to the present and future water requirements of that portion of the Sabine River Watershed lying upstream of the point known as Stateline. The Commission's granting of future permits for waters upstream from Stateline will be made without any claim being made on such waters by virtue of this certificate, and the certificate shall not seem to perfect and appropriation of such waters.

In order to simulate water right 05-4658 as subordinate to all water rights in the upper basin, the priority date has been adjusted such that it is the most junior water right in the model simulation. In doing so, 05-4658 is simulated not only as junior to all upper basin water rights, but also as junior to all lower basin water rights. However there are very few water rights in the lower basin, and only five that have priority dates that are junior to March 5, 1958. These water rights may report reliabilities that are higher than if the water right had been simulated as junior to 05-4658.

5.0 WATER AVAILABILITY IN THE BASIN

5.1 Description of Scenarios Models

A total of nine water availability scenarios were developed for the Sabine River Basin: eight TNRCC "Base" scenarios and one basin specific scenario. The nine different scenarios include: three simulating various levels of reuse, four simulating partial/total cancellation, a current conditions scenario (which includes term permits) and a firm yield determination for all permitted reservoirs with capacities greater than 5,000 ac-ft per year. Table 14 describes the parameters simulated in each of the nine scenarios. Scenario nine determines the firm yield of the major existing reservoirs in the basin based on the priority date of impoundment. There are three different annual diversion amounts entered into the modeling scenarios. The three amounts are: 1) Full authorized diversions as defined in the water rights (excluding term permits); 2) Total cancellation of water rights (simulated for those water rights reporting 0 use in the last 10 years); and 3) Partial cancellation of water rights (partial cancellation of water rights simulated by limiting the modeled diversion amount to the maximum use in the last 10 years).

Table 14 TNRCC Sabine River Basin Water Availability Model Scenarios

Scenario	Title	Diversion Amount	Area - Capacity	Return Flows	Term Water Rights
Re-Use					
1	0% Reuse	A	A	All	No
2	50% Reuse	A	A	50%	No
3	100% Reuse	A	A	None	No
Cancellation					
4	Total	M	A	All	No
5	Partial	MAX	A	All	No
6	Total	M	A	None	No
7	Partial	MAX	A	None	No
Current Conditions					
8	Current	MAX	Yr 2000	All	Yes
Basin Specific					
9	Firm Yield	A/Yld	A	No	No

Definition

A	Authorized area-capacities (original) and Authorized diversion amounts (full permitted)
M	Modified diversion amounts (10 years nonuse = 0)
MAX	Modified diversion amounts (Max use for last 10 years)
Yr 2000	Year 2000 area-capacity curve
All	Return Flow factor determined based on minimum historical flows
50%	50% of computed return flow above
None	No return flow
No	Term water rights not included
Yes	Term water rights included
Yld	Diversions at reservoir set to firm yield amounts, which do not exceed the Authorized Diversions

5.1.1 Reuse Scenario

Scenarios one, two, and three evaluate the impact of wastewater reuse on water availability in the basin. This is accomplished by varying the return flow percentage between each model scenario while using permitted diversion amounts, authorized reservoir area-capacity relationships, and not allowing term permit holders to divert water.

Scenario one assumes existing levels of reuse based on the levels of return flow for the past five years. The full return flow factor was utilized to estimate return flows occurring from surface water diversions and no adjustment were made to return flows which appear as a result of groundwater use and/or interbasin transfers (CI records). Scenarios two and three assume 50 percent and 100 percent reuse, respectfully. The 50 percent reuse in scenario two was calculated by decreasing return flow factors and constant return flows originated by groundwater and/or interbasin transfers to half the initial value as set in scenario one. In scenario three, all return flows were assumed to be zero to represent the full reuse of diverted water.

5.1.2 Cancellation Scenario

Scenarios four, five, six and seven evaluate the impact of simulated cancellation of water rights, in addition to wastewater reuse on water availability in the basin. Water rights which have not been used within the last 10 years (the statutory minimum) have been simulated as being canceled in the four model scenarios listed above. Those water rights which reported a partial use of permitted diversions were *not* canceled in any of the scenarios. Table 15 lists the water rights authorized diversion amount, maximum 10-year use, and whether the right was simulated as being canceled.

Scenario four simulates water availability if specific water rights were hypothetically canceled (no reported use in 10 years). In this scenario, all remaining rights were set to permitted authorized diversions and return flows were based on no reuse. Scenario five is identical to scenario four, with the exception that the diversion amounts for those water rights which were not canceled were set to the maximum reported use in the last 10 years (limited to not exceed the authorized diversion amount). For water rights with multiple priority dates, the maximum reported use was allocated to the portions of the water right with the most senior priority.

Scenarios six and seven are similar to scenarios four and five in terms of diversion amount, but no return flows were included, in order to represent 100 percent wastewater reuse.

Table 15 Cancellation of Water Rights in the Sabine River Basin (excluding recreational rights)

Water Right Identifier	Control Point	Authorized Diversion	10 yr. Max Use	Use Type	Priority Date	Cancel
60504665301	E4665A	2500	2500	MUN	19250630	N
60504665302	E4665A	1659	1659	MUN	19511109	N
60504667001	E4667A	250	0	IRR	19561127	Y
60504670301	E4670A	207675	136131	MUN	19550912	N
60504670302	E4670A	21283	8368	MUN	19550912	N
60504670303	E4670A	1792	8043	MUN	19550912	N
60504670304	E4670A	4592	0	MUN	19850813	N
60504670305	E4670A	2758	0	MUN	19860521	N
60504671301	E4671A	100	100	MUN	19731210	N
60504671302	E4671A	200	200	MUN	19840515	N
60504673301	E4673A	160	0	MUN	19270316	Y
60504673302	E4673A	10	0	IND	19270316	Y
60504675001	E4675A	50	50	MUN	19540419	N
60504675301	E4675B	1500	1500	MUN	19700105	N
60504676301	E4676A	12	0	MUN	19290731	Y
60504678301	E4678A	83	83	MUN	19511231	N
60504678302	E4678A	100	100	MUN	19520813	N
60504678304	E4678A	134	100	MUN	19830425	N
60504679301	E4679A	399	0	MUN	19260205	Y
60504681301	E4681A	33	0	IRR	19660630	Y
60504682301	E4682A	27	0	IRR	19641231	Y
60504684302	E4684B	27	0	IRR	19721106	Y
60504688301	E4688A	20	0	IRR	19730108	Y
60504689301	E4689A	251	80	MINING	19750421	N
60504693301	E4693A	150	0	MUN	19490201	Y
60504693302	E4693A	250	0	MUN	19760927	Y
10505229001	E5229P	9	6	IRR	19890414	N
60504669301	E4669A	20000	5600	MUN	19740626	N
60504669302	E4669A	6720	2240	MUN	19740626	N
60504669303	E4669A	2720	2720	MUN	19740626	N
60504669304	E4669A	15500	5584	IND	19740626	N
60504669305	E4669A	120000		MUN	19830228	N
60504669306	E4669A	18672		MUN	19850813	N
60504669307	E4669B	5048		MUN	19920416	N
60504699301	E4699A	19	0	IRR	19690508	Y
60504700301	E4700A	25	25	IRR	19510530	N
60504701001	E4701A	249	86	IRR	19550531	N
60504702301	E4702A	75	0	IRR	19740930	Y
60504703301	E4703A	1	1	IRR	19770627	N
60504704301	E4704B	87	32	IRR	19580430	N

Table 15 Cancellation of Water Rights in the Sabine River Basin (excluding recreational rights) (Continued)

Water Right Identifier	Control Point	Authorized Diversion	10 yr. Max Use	Use Type	Priority Date	Cancel
60504704302	E4704A	50	0	IRR	19610530	N
60504750301	E4750A	1	0	IRR	19550731	Y
60504752401	E4752A	30	24	IRR	19560731	N
60504754302	E4754A	500	459	IRR	19830418	N
60504755301	E4755A	86	86	IRR	19720131	N
10503942401	E3942P	200	100	IRR	19821122	N
10503969001	E3969P	200	158	MINING	19830124	N
60504698001	E4698B	273	273	IRR	19620730	N
60504710001	E4710A	17	0	IRR	19480630	Y
60504714301	E4714A	10	0	IND	19730828	Y
60504716301	E4716A	20	0	IND	19431231	Y
60504718304	E4718D	30	0	IRR	19620630	Y
60504722301	E4722A	38	0	IRR	19501231	Y
60504724302	E4724A	180	180	IRR	19700720	N
60504724303	E4724A	179	76	IRR	19941223	N
60504727301	E4727A	218	145	IRR	19630630	N
60504727302	E4727B	107	75	IRR	19630630	N
60504728001	E4728A	23	0	IRR	18711231	Y
60504737301	E4737A	8	8	IRR	19610731	N
60504738301	E4738A	44	0	IRR	19601231	Y
60504739301	E4739A	750	0	IRR	19560227	Y
60504740301	E4740A	8	0	IRR	19561231	Y
60504742301	E4742A	25	0	IRR	19521009	Y
60504743001	E4743A	5	0	IRR	19511231	Y
60504745001	E4745A	15	0	IRR	19450731	Y
60504746301	E4746A	20	0	IRR	19531231	Y
60504747301	E4747A	20	0	IRR	19511231	Y
60504748001	E4748B	120	40	IRR	19550731	N
60504758302	E4758B	200	173	MUN	19650503	N
60504758303	E4758B	200	0	MUN	19670911	N
60504758304	E4758B	150	137	IRR	19670911	N
60504758305	E4758B	200	0	IRR	19761220	N
60504759301	E4759B	730	730	MUN	19350424	N
60504759302	E4759B	2070	2070	MUN	19420313	N
60504759303	E4759B	2600	2600	MUN	19450713	N
60504759304	E4759B	100	100	IND	19450713	N
60504759305	E4759B	100	100	IRR	19450713	N
60504762301	E4762A	1679	1479	MUN	19510517	N
60504763301	E4763A	100	1	IRR	19630630	N
60504769301	E4769A	40	8	IRR	19541231	N

Table 15 Cancellation of Water Rights in the Sabine River Basin (excluding recreational rights) (Continued)

Water Right Identifier	Control Point	Authorized Diversion	10 yr. Max Use	Use Type	Priority Date	Cancel
60504771302	E4771A	10	0	REC	19501231	Y
10503899001	E3899P	80	0	IRR	19820607	Y
10504202001	E4202P	750	0	IRR	19841107	Y
10504248001	E4248Q	1.8	1.8	IRR	19850604	N
10504248302	E4248Q	15.2	15.2	IRR	19850604	N
10504248304	E4248Q	100	11	IRR	19960801	N
60504623001	E4623A	5	0	MINING	19311231	Y
60504624301	E4624A	1087	838	MUN	19150707	N
60504626301	E4626A	17	0	IRR	19550630	Y
60504627302	E4627A	80	0	IRR	19840124	Y
60504628301	E4628A	37	0	IRR	19631231	Y
60504628302	E4628A	6	0	IND	19631231	Y
60504629301	E4629A	28	0	IRR	19530831	Y
60504630301	E4630A	39	0	IRR	19521231	Y
60504631301	E4631A	81014	43648	IND	19490919	N
60504631302	E4631A	18518	9977	IND	19490919	N
60504631303	E4631A	34968	18840	IND	19490919	N
60504632301	E4632A	51	51	IRR	19361231	N
60504632302	E4632A	75	75	IRR	19970604	N
60504633001	E4633A	3	0	IND	19551231	Y
60504634001	E4634A	69	69	IRR	19630331	N
60504635301	E4635A	18	18	IRR	19630331	N
60504637301	E4637A	15	15	IND	19750818	N
60504638001	E4638A	37	6	IRR	19630731	N
60504638002	E4638A	0.2	0	IND	19630731	Y
60504639001	E4639A	50	0	IRR	19460531	Y
60504640301	E4640A	16	16	IRR	19221231	N
60504642301	E4642A	16000	14000	MUN	19461005	N
60504642302	E4642A	3360	975	MUN	19461005	N
60504642303	E4642A	2000	24	IND	19461005	N
60504642304	E4642A	2000	1850	IND	19461005	N
60504642305	E4642A	39040	575	MUN	19461005	N
60504645301	E4645A	118	0	IRR	19600331	Y
60504646301	E4646A	9	0	IRR	19371231	Y
60504647301	E4647A	11000	11000	IND	19780821	N
60504732301	E4732A	202	0	IRR	19610331	Y
60504761301	E4761A	7	0	IND	19730702	Y
10505082301	E5082P	5	5	IND	19860807	N
10505082302	E5082Q	5	5	IND	19860807	N
10505090001	E5090P	13860	2084	5090	19860826	N

Table 15 Cancellation of Water Rights in the Sabine River Basin (excluding recreational rights) (Continued)

Water Right Identifier	Control Point	Authorized Diversion	10 yr. Max Use	Use Type	Priority Date	Cancel
10505124301	E5124P	5	0	IND	19870323	Y
10505124302	E5124Q	5	0	IND	19870323	Y
10505124303	E5124R	5	0	IND	19870323	Y
10505177301	E5177P	100	0	IND	19880428	Y
10505246301	E5246P	100	0	IND	19890714	Y
10505382301	E5382P	100	0	IND	19910909	Y
10505439301	E5439P	100	0	IND	19921203	Y
10505441301	E5441P	100	0	IND	19921202	Y
10505441302	E5441Q	100	0	IND	19921202	Y
10505454301	E5454P	100	0	IND	19930305	Y
10505519301	E5519P	245	0	MINING	19950816	Y
10505578301	E5578P	10	0	MUN	19970304	Y
60504648301	E4648A	4	4	IND	19841023	N
60504649301	E4649A	25000	20970	IND	19710719	N
60504653001	E4653A	50	0	IRR	19640416	Y
60504654301	E4654A	21280	2866	MUN	19560719	N
60504654302	E4654A	1120	0	IND	19560719	N
60504655301	E4655A	229	0	IND	19480426	Y
60504652301	E4652A	286	270	IND	19720110	N
60504656001	E4656A	118	0	IRR	19550620	Y
10504226301	E4226P	70	0	IRR	19850103	Y
10504238001	E4238P	77	72	IRR	19850416	N
10505219301	E5219P	129	129	IND	19890320	N
60504657301	E4657A	330	330	MUN	19220804	N
60504657302	E4657A	1130	47	MUN	19520814	N
60504658301	E4658A	2215	1488	MUN	20001231	N
60504658302	USRBU	87785	0	MUN	20001231	N
60504658303	USRBU	10000	0	MUN	20001231	N
60504658304	USRBU	530000	0	IND	20001231	N
60504658305	USRBU	70000	0	IND	20001231	N
60504658306	USRBU	50000	0	IRR	20001231	N
TBLA North LA	E4658A	500000	29745	MUN	20001231	N
TBLA DS MUN IND	USRBU	200000	0	MUN	20001231	N
TBLA DS IRR	USRBU	50000		IRR	20001231	N
60504658307	E4658A	65700	65700	HYDROE	20001231	N
60504659001	E4659A	235	235	IND	19691117	N
60504660301	E4660A	50	0	IRR	19741202	Y

Table 15 Cancellation of Water Rights in the Sabine River Basin (excluding recreational rights) (Continued)

Water Right Identifier	Control Point	Authorized Diversion	10 yr. Max Use	Use Type	Priority Date	Cancel
60504662001	E4662A	24643	14210	IND	19260224	N
60504662002	E4662A	17922	17922	IND	19260224	N
60504662003	E4662A	4480	4480	IND	19260224	N
60504662004	E4662A	2800	2800	IND	19260224	N
60504662005	E4662A	3360	3252	IND	19260224	N
60504662006	E4662A	840	694	IND	19260224	N
60504662007	E4662A	16355	13150	IND	19260224	N
60504662008	E4662A	30000	1970	IND	19460607	N
60504662009	E4662A	46700	5391	IRR	19781113	N
60504663001	E4663A	67	0	IRR	19380531	Y

5.1.3 Current Conditions Scenario

Scenario eight, a TNRCC base scenario, was performed to estimate water availability under current conditions of water use and storage capacity. This scenario is the only scenario to include term permits. However, for the Sabine River Basin, the term permit portion of all water rights with term permits had expired. Other conditions utilized in this scenario include:

- Setting the annual diversion amounts to the maximum reported use in the last 10 years (limited to not exceed the authorized diversion amount)
- Basing return flows on no wastewater reuse.
- Developing area-capacity relationships for all major reservoirs to reflect year 2000 conditions, as a result of sedimentation.

Appendix O contains the tables showing the original and the estimated area-capacity relationship as of the year 2000 for each major reservoir in the Sabine River Basin.

5.1.4 Firm Yield Scenario

As outlined in the TNRCC Resolved Technical Issues document-Issue No. 10 dated August 12, 1999, firm yields were determined for those major reservoirs experiencing shortages under scenario three assumptions. Major reservoirs not experiencing shortages in scenario three are reported with firm yields equal to authorized diversion amounts. Firm yields were not determined for reservoirs which are authorized for recreational use only.

Demands for reservoirs experiencing shortages were reduced, until the volume remaining in storage was less than one percent of that authorized, while maintaining all other water rights at their authorized diversion amounts.

5.2 Results of Water Availability Model

Appendix P provides the results from the various WRAP (VER 11/26/01) models and illustrates the reliability of individual water rights. The tables in Appendix P list all water rights in the Sabine River Basin with permitted diversions along with their period and volume reliability. Period reliability, expressed in percent is defined as the ratio of number of months for which no shortages occurred to the total number of months in the simulation period. Volumetric reliability, expressed as a percent, represents the ratio of the mean actual annual diversion divided by the corresponding authorized annual diversion amount.

Water right 05-4658, which authorizes Toledo Bend Reservoir impoundment and diversions, includes a special condition that the water right is “subordinate to all present and future water requirements of that portion of the Sabine River watershed lying upstream of the point known as Stateline.” This special condition is simulated in WRAP (VER 11/26/01) by assigning water right 05-4658 the most junior priority date in the basin. While this modified priority date satisfies the special condition, by making 05-4658 junior to all upper basin water rights, the water right is also forced to be junior to all lower basin water rights. Additionally this modification results in an overestimation of the reliability of those water rights downstream of Toledo Bend which are actually junior, however the increased reliability is minor.

There are five water rights in the lower basin with priority dates junior to 05-4658, three of which have authorized diversions, while the remaining two are authorized for recreational use only. Of the three water rights with authorized diversions, only one water right, 05-4662 appears to have benefited from the modified priority date simulated for 05-4658. Water right 05-4662 is authorized to divert an annual total of 147,100 ac-ft, 100,400 ac-ft of which is senior to 05-4658 while the remaining 46,700 is junior to 05-4658. It is that portion of 05-4662 (46,700 ac-ft) that is junior on paper to 05-4658 which experiences in an increase in reported volumetric reliability, as a result of modifying the priority date. For scenario one, the volumetric reliability reported for 05-4662 without a modified priority date is 97.4%, while the same is reported to be 99.4% with the modified priority date. The simulation does not impact the reliability of 05-4658, as it is 100 percent reliable in all scenarios. However, the simulation does decrease the End-Of-Period storage in Toledo Bend Reservoir, resulting in a slight reduction in hydropower generation.

Specific large water rights were analyzed to supplement the reliability results shown in Tables P-1 through P-3. For this effort three reservoirs were selected:

- Lake Fork located on Lake Fork Creek
- Lake Tawakoni located on the Sabine River
- Toledo Bend Reservoir located on the Sabine River

The monthly storage for these reservoirs under scenarios two through eight are compared to the monthly storage for scenario one, considered here only as a baseline scenario.

In order to discuss the impacts of wastewater reuse and water rights cancellation on the availability of water, plots representing End-of-Period storage for the three above referenced reservoirs, as well as unappropriated and regulated flows at two control points, STLINE (representing Stateline, a reference point for the Sabine Compact) and SRSL (representing the terminus point of the Sabine River Basin), were developed and are shown in Figures P-1 through P-28. The following sections discuss the results as shown in Figures P-1 through P-28. Figures P-29 through P-66 include graphs of regulated and unappropriated flows at all primary control points for scenarios one, three and eight, as requested by the TNRCC. These plots principally show the amount of water potentially available at each primary control point for future appropriations under a perpetual (scenario three) or temporary (scenario eight) basis.

Regulated flows are defined as the actual streamflows at that control point, including releases from upstream reservoirs for downstream water rights and instream flow requirements that are not available for appropriation. To simulate the equitable distribution of “free flowing water” as required by the Sabine River Compact, a portion of the regulated flows are reserved for Louisiana diversions through the use of an IF card in WRAP (VER 11/26/01). With the exception of the Sabine River Authority of Louisiana diversion (750,000 ac-ft/yr) from Toledo Bend Reservoir, Louisiana water rights were not simulated in this study. As a result the actual regulated flows reported in this study do not represent the actual streamflows assuming Louisiana’s full appropriations.

Unappropriated flows are those streamflows at a given control point which remain after all water rights in the simulation have made their depletions and instream flow requirements have been satisfied. The reported unappropriated flows in this study are the amount of flow available for future use by the State of Texas. The portion of streamflow which is available for Louisiana has been reserved using an IF card as described above. Unappropriated flows and regulated flows under scenario two through eight are compared to those streamflows for scenario one. Future appropriations are subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code. Environmental flow needs, including instream flows and freshwater inflows to Sabine Lake, will be considered when granting new water rights or amending existing water rights, thereby affecting the amount of water available for appropriation.

5.2.1 Reuse

The results showing the reliability of supply for scenarios one, two, and three are presented in Table P-1. Graphical plots for selected reservoirs and control points are presented in Figures P-1 through P-7. The Reuse scenarios show that rainfall-runoff volumes significantly exceed the volume of flows resulting from wastewater discharges. Although reliability is decreased for some water rights, the overall reliability, unappropriated flows and regulated flows are very close for all three scenarios.

5.2.1.1 Specific Large Rights

The effects of wastewater reuse on the three selected reservoirs are similar, as shown in Figures P-1 through P-3. Varying the levels of reuse causes Lake Tawakoni to have lower minimum End-of-Period storage volumes to the extent that the reservoir storage drops to less than 2,000 acre-feet in the 100 percent reuse scenario. The impacts on Lake Fork are slightly lower End-of-Period storage volumes, and a slight increase in shortages. The impact of reuse on Toledo Bend Reservoir is a minor reduction in End-of-Period storage, however there are no shortages, mostly due to the large watershed contributing runoff into the reservoir.

5.2.1.2 Unappropriated Flows at Selected Locations

Annual unappropriated flows using varying levels of wastewater reuse are shown in Figures P-4 and P-5 for control points Stateline and Sabine River at Sabine Lake. Figures P-29 through P-47 include scenarios one and three for all primary control points. The impact of reuse on average unappropriated flows is shown in Table 16. In summary, wastewater reuse causes a seven percent reduction in average unappropriated flows at Stateline and a 12 percent reduction in average unappropriated flows at Sabine River at Sabine Lake.

Table 16 Change in Average Unappropriated and Regulated Flows Due to Reuse

	Average Unappropriated Flows			Average Regulated Flows		
Control Point	**Scenario 1**	**Scenario 3**	**% change**	**Scenario 1**	**Scenario 3**	**% change**
CF_GV	18,184	16,185	-11%	46,577	46,591	0%
SR_WP	120,299	108,018	-10%	159,098	141,539	-11%
SR_MN	285,555	268,439	-6%	475,648	456,303	-4%
LF_QT	91,669	83,848	-9%	138,516	121,451	-12%
BS_BS	70,575	67,054	-5%	134,767	134,185	0%
SR_GW	613,472	578,343	-6%	1,064,205	1,026,026	-4%
SR_BE	856,535	794,425	-7%	1,520,843	1,431,352	-6%
MC_TT	45,605	43,421	-5%	62,682	62,682	0%
MB_GR	41,877	39,630	-5%	55,783	55,011	-1%
Stateline	1,124,825	1,044,013	-7%	2,182,123	2,073,810	-5%
SR_LP	1,133,067	1,051,433	-7%	2,176,570	2,068,419	-5%
TC_SV	40,936	38,850	-5%	67,944	67,944	0%
BT_TR	118,903	118,572	0%	119,173	119,173	0%
SR_BU	1,896,013	1,725,337	-9%	2,498,254	2,390,643	-4%
BA_RP	375,795	371,148	-1%	377,040	375,780	0%
SR_BW	2,253,850	2,033,610	-10%	3,251,868	3,115,218	-4%
SR_RL	2,443,153	2,157,952	-12%	4,379,958	4,241,087	-3%
CB_MV	82,931	82,811	0%	83,283	83,283	0%
SR_SL	2,448,322	2,158,388	-12%	5,054,196	4,466,864	-12%

5.2.1.3 Regulated Flows at Selected Locations

Annual regulated flows using varying levels of wastewater reuse are shown in Figures P-6 and P-7 for control points Stateline and Sabine River at Sabine Lake. Figures P-48 through P-66 include scenarios one and three for all primary control points. The impact of reuse on average regulated flows is shown in Table 16. The effects of wastewater reuse on regulated flows at the selected control points are consistent with those on unappropriated flows described in the previous section. In summary, wastewater reuse causes a five percent reduction in average regulated flows at Stateline and a 12 percent reduction in average regulated flows at Sabine River at Sabine Lake.

5.2.2 Cancellation Scenarios

There are 57 water rights with authorized diversions amounts of approximately 5,450 ac-ft/yr, which were simulated as being canceled in the total cancellation scenarios. (See Table 15.) The total cancellation scenarios include water rights of all use types, located throughout the basin. However none of the canceled water rights has an authorized diversion amount of greater than 1,000 ac-ft/yr. There are 86 water rights with maximum reported use amounts which are less than the authorized diversion amounts. The total reduction in diversions by Texas water rights in the maximum use scenarios as compared to the full authorized diversions is approximately 1,240,800 ac-ft/yr. The largest reductions are due to water rights 05-4658, 05-4662, 05-4669 and 05-4670, for Toledo Bend Reservoir, Run-of-River, Lake Fork, and Lake Tawakoni diversions owned by the Sabine River Authority. Additional water rights with significant reductions in diversion amounts for the max use runs include: 05-4631 – Texas Eastman; 05-4642 – Cherokee Water Company (Lake Cherokee); 05-4654 – Panola Co. FWSD No. 1 (Lake Murvaul); and P5090 – City of Longview.

5.2.2.1 Specific Large Rights

The reliability of supply for water rights in scenarios four, five, six and seven is shown in Table P-2. Reservoir storage, unappropriated flows and regulated flows for the cancellation scenarios are illustrated in Figures P-8 through P-21. The cancellation scenarios had the following effects on reservoirs:

- Lake Tawakoni – The maximum reported use for Lake Tawakoni is approximately 64 percent of the authorized diversion. Due to the minimal amount of water rights subject to total cancellation, scenario four results are nearly identical to scenario one. Scenario five has a significant increase in End-of-Period storage due to the reduced diversions. Scenario six is similar to scenario three (no return flows), and the reservoir nearly goes dry, resulting in some shortages during the drought of record. In scenario seven, although there are no return flows, the reduced diversion amounts result in a significant increase in End-of-Period storage volumes as compared to scenario one.

- Lake Fork – The maximum reported use for Lake Fork is approximately 10 percent of the authorized diversion. As was the case for Lake Tawakoni, the results of scenarios four and six are nearly identical to scenarios one and three. Scenarios five and seven have significant increases in End-of-Period storage volumes due to the minimal amount of diversions being made from Lake Fork in these scenarios.
- Toledo Bend Reservoir – The maximum reported water supply use for Toledo Bend Reservoir by both Texas and Louisiana is less than five percent of the authorized diversion amount. Scenarios four and six produce results nearly identical to scenarios one and three. In scenarios five and seven, the reservoir storage stays above 65 percent of being full for the entire simulation period, again due to minimal diversions for water supply.

5.2.2.2 Unappropriated Flows at Selected Locations

Figures P-11 and P-12 for scenarios four and five, and Figures P-18 through P-19 for scenarios six and seven, illustrate the flows at Stateline and Sabine River at Sabine Lake which may be available for appropriation. The effect on annual unappropriated flows in scenarios four and six is again more a function of return flows than cancellation, with scenario four being almost identical to scenario one and scenario six nearly identical to scenario three. The increase in average unappropriated flows in scenario four as compared to scenario one is less than one percent at both Stateline and Sabine River at Sabine Lake. Scenarios five and seven have significant increases in unappropriated flows at Stateline and Sabine River at Sabine Lake, reflecting the impact of reduced diversions such that Toledo Bend Reservoir End-of-Period storage stayed close to capacity in these scenarios. The increase in average unappropriated flow in scenario five as compared to scenario one is approximately 56 percent at Stateline and 31 percent at Sabine River at Sabine Lake. The effects on unappropriated flows of the different scenarios can be summarized as follows: wastewater reuse has a moderate impact on unappropriated flows, total cancellation of water rights for non-use has a negligible effect, and cancellation to a maximum reported use has a significant impact.

5.2.2.3 Regulated Flows at Selected Locations

Annual regulated flows under the four cancellation scenarios are shown in Figures P-13 and P-14 for scenarios four and five, and Figures P-20 and P-21 for scenarios six and seven. The effects of the different levels of wastewater reuse, water right cancellation and diversions on regulated flows at the four control points are similar to those shown for unappropriated flows in the previous section. Comparing scenario one to scenario four, the increase in average regulated flows at both Stateline and Sabine River at Sabine Lake is again less than one percent. The increase in average regulated flows in scenario five as compared to scenario one is 13 percent at Stateline and 28 percent at Sabine River at Sabine Lake.

5.2.3 Current Conditions Scenario

As shown in Table P-3, scenario eight illustrates water availability as it exists under current conditions. Figures P-22 through P-28 represent graphical plots for reservoir storage and streamflow comparing scenario eight to scenario one.

5.2.3.1 Specific Large Rights

There are significant differences in the reservoir End-of-Period storage between scenario one and scenario eight, as shown in Figures P-22 through P-24. The reasons for these differences include:

- The varying levels of diversions between the two scenarios. Specifically, the difference between the maximum historical use and that which is authorized under the water rights.
- The reduction in reservoir capacity due to use of year 2000 area-capacity curves in scenario eight.
- For Lake Fork, Lake Tawakoni and Toledo Bend Reservoir, the maximum historical use, as simulated in scenario eight, is significantly less than for scenario one. In scenario eight, each of these reservoirs has End-of-Period storage amounts much higher than in scenario one.

5.2.3.2 Unappropriated Flows at Selected Locations

The annual amount of unappropriated flows at Stateline and Sabine River at Sabine Lake increased from scenario one to scenario eight, as shown in Figures P-25 and P-26. Additionally, Figures P-29 through P-47 show scenarios one and eight at all primary control points. The left-hand column of Table 17 summaries the impact of current conditions on average unappropriated flows. There is a significant increase in unappropriated flows throughout much of the basin, particularly along the Sabine River and at Lake Fork Creek near Quitman. The increase in average unappropriated flows is 167 percent at Lake Fork Creek near Quitman, 52 percent at Stateline, and 30 percent at Sabine River at Sabine Lake. There is a less pronounced increase in unappropriated flows for some of the tributaries and no apparent increase in unappropriated flows for the streams in Louisiana and for Cow Bayou near Mauriceville, where no diversions are modeled in either scenario.

5.2.3.3 Regulated Flows at Selected Locations

Annual regulated flows for scenario one and scenario eight at Stateline and Sabine River at Sabine Lake are shown in Figures P-27 and P-28. Figures P-48 through P-66 show the regulated flow for scenarios one and eight at all primary control points. The right-hand column of Table 17 compares the average regulated flow under full authorized diversions versus current conditions. The effect of varying the diversion amounts in the two model scenarios is consistent with the effect on unappropriated and regulated flows described in section 5.2.3.2, with an increase in regulated flows of 12 percent at Stateline, and 28 percent at Sabine River at Sabine Lake.

Table 17 Change in Average Unappropriated and Regulated Flows Due to Current Conditions

	Average Unappropriated Flows			Average Regulated Flows		
Control Point	**Scenario 1**	**Scenario 8**	**% change**	**Scenario 1**	**Scenario 8**	**% change**
CF_GV	18,184	27,888	53%	46,577	46,474	0%
SR_WP	120,299	208,336	73%	159,098	226,103	42%
SR_MN	285,555	452,080	58%	475,648	542,371	14%
LF_QT	91,669	244,476	167%	138,516	286,780	107%
BS_BS	70,575	99,364	41%	134,767	134,767	0%
SR_GW	613,472	987,182	61%	1,064,205	1,281,041	20%
SR_BE	856,535	1,332,436	56%	1,520,843	1,773,683	17%
MC_TT	45,605	60,913	34%	62,682	66,630	6%
MB_GR	41,877	64,528	54%	55,783	74,684	34%
Stateline	1,124,825	1,710,826	52%	2,182,123	2,448,091	12%
SR_LP	1,133,067	1,723,497	52%	2,176,570	2,442,487	12%
TC_SV	40,936	56,696	38%	67,944	68,909	1%
BT_TR	118,903	119,110	0%	119,173	119,173	0%
SR_BU	1,896,013	2,955,026	56%	2,498,254	4,210,457	69%
BA_RP	375,795	376,683	0%	377,040	377,040	0%
SR_BW	2,253,850	3,126,799	39%	3,251,868	4,968,380	53%
SR_RL	2,443,153	3,188,740	31%	4,379,958	6,099,085	39%
CB_MV	82,931	83,275	0%	83,283	83,283	0%
SR_SL	2,448,322	3,188,740	30%	5,054,196	6,446,231	28%

5.2.4 Firm Yield Scenario

Table 18 summarizes the firm yield of each reservoir, based on parameter assumptions outlined in the TNRCC Resolved Technical Issues document-Issue No. 10 dated August 12, 1999.

As mentioned in section 4.3 a significant assumption affecting water availability for some water rights is the manner in which the subordination of water right 05-4658 is simulated in WRAP (VER10/00). The special condition specifies that the water right is subordinate to present and future water resources development upstream of Stateline. The inability of WRAP (VER 11/26/01) to simulate this subordination condition correctly, would cause significant errors in the yield estimates those water rights upstream of Toledo Bend. As a result, the priority date for water right 05-4658, as simulated in this study was modified so as to be subordinate to the entire basin. The yields of reservoirs upstream of Stateline are consistent with the special condition. The model run to estimate the yield of Toledo Bend Reservoir is based upon the modeling assumption that the water right is junior to all water rights (in the upper and lower basin). The firm yield of the reservoir is unaffected, due to the limitation of this analysis that the yield not exceed the authorized diversion amount. However the assumption does limit streamflow depletions and results in slightly lower End-Of-Period storage values.

Table 18 Firm Yield Determination

Reservoir	Priority Date(s)	Authorized Capacity (ac-ft)	Authorized Diversion (ac-ft/yr)	Yield (ac-ft/yr)
Lake Tawakoni	09/12/1955 08/13/1985 05/21/1986	927,440	238,100	234,800
Lake Fork	06/26/1974 02/28/1983 08/13/1985	675,819	188,660	176,800
Lake Quitman [(a)]	12/19/1960	7,440	-	NA
Lake Winnsboro [(a)]	12/19/1960 11/15/1965	8,100	-	NA
Lake Holbrook [(a)]	12/19/1960	7,990	-	NA
Lake Hawkins [(a)]	12/19/1960 11/15/1965	11,890	-	NA
Lake Gladewater	05/17/1951	6,950	1,679	1679
Lake Cherokee	10/05/1946	62,400	62,400	43,700
Brandy Branch Cooling Pond [(b)]	08/21/1978	29,513	11,000	NA
Martin Lake	07/19/1971	56,500	25,000	25,000
Lake Murvaul	07/19/1956	44,650	22,400	22,400
Toledo Bend	03/05/1958 01/22/1986	4,477,000	750,000	750,000

(a) Reservoirs authorized for recreational use only. No yield determined.
(b) Reservoir requires interbasin transfers. No yield determined.
(c) To simulate subordination of Toledo Bend Reservoir to all water rights in the upper basin, the model priority date of Toledo Bend was set as 12/31/2000.

5.2.5 Sabine Lake Inflows

Sources of freshwater inflows into Sabine Lake include the Sabine and Neches Rivers and other minor tributaries. The freshwater inflows into Sabine Lake reported in this study only represent the Sabine River contribution to the estuary. Tables P-4 through P-13, presented in Appendix P, show the statistical distribution of flows from the Sabine River into Sabine Lake under various scenarios. These tables are intended to illustrate the statistical seasonal distribution of inflows as well as the annual summation for each percentile distribution.

Table P-4 shows the statistical distribution of inflows into Sabine Lake for the "naturalized conditions". On average, under natural conditions the Sabine River inflows into Sabine Lake are approximately 6.86 million acre-feet.

Table P-5 shows the statistical distribution of inflows into Sabine Lake for reuse scenario one. On average, under authorized diversions and 0% reuse of wastewater, the Sabine River inflows into Sabine Lake are approximately 5.05 million acre-feet.

Table P-6 shows the statistical distribution of inflows into Sabine Lake for reuse scenario two. On average, under authorized diversions and 50% reuse of wastewater the Sabine River inflows into Sabine Lake are approximately 4.76 million acre-feet.

Table P-7 shows the statistical distribution of inflows into Sabine Lake for reuse scenario three. On average, under authorized diversions and 100% reuse of wastewater the Sabine River inflows into Sabine Lake are approximately 4.47 million acre-feet.

Table P-8 shows the statistical distribution of inflows into Sabine Lake for cancellation scenario four. On average, under the modified diversions and 0% wastewater reuse the Sabine River inflows into Sabine Lake are approximately 5.06 million acre-feet.

Table P-9 shows the statistical distribution of inflows into Sabine Lake for cancellation scenario five. On average, under the maximum reported diversions and 0% wastewater reuse the Sabine River inflows into Sabine Lake are approximately 6.46 million acre-feet.

Table P-10 shows the statistical distribution of inflows into Sabine Lake for cancellation scenario six. On average, under the modified diversions and 100% wastewater reuse the Sabine River inflows into Sabine Lake are approximately 4.47 million acre-feet.

Table P-11 shows the statistical distribution of inflows into Sabine Lake for cancellation scenario seven. On average, under the maximum reported diversions and 100% wastewater reuse the Sabine River inflows into Sabine Lake are approximately 6.34 million acre-feet.

Table P-12 shows the statistical distribution of inflows into Sabine Lake for the current condition scenario eight. On average, under the maximum reported diversions, current reservoir capacities and 0% wastewater reuse the Sabine River inflows into Sabine Lake are approximately 6.45 million acre-feet.

Table P-13 shows the statistical distribution of historical inflows (1941-1997) into Sabine Lake and the TWDB TxEMP model solutions, representing the Estuary inflow targets for Sabine Lake. The approximate annual inflow targets estimated using the TWDB TxEMP model for Sabine Lake are; MINQ-SAL = 4.71million ac-ft, MINQ = 7.01million ac-ft and MAXC = 9.60 million ac-ft.

5.3 Comparison to Existing River Basin Model

There is no known existing water availability model for the Sabine River Basin aside from this current model.

5.4 Factors Affecting Water Availability and Modeling Results

As mentioned in section 2.5 the foundation of this water availability model is the naturalized flows which are used to project flows from gaged (USGS gaging stations) to ungaged sites (water rights diversion). In this study three watershed parameters - drainage areas, curve numbers and mean annual precipitation were developed in order to be considered in the flow distribution process. These watershed parameters have a direct effect on the results of the WAM model since they are the key to distributing flows from primary control points to secondary control points.

During this study, the TNRCC has discovered problems in some river basin simulations with implementing the WRAP model-option that uses curve numbers (CN) in the distribution of naturalized flows to secondary control points. The average curve numbers supplied by CRWR apparently introduced some precision errors when cascading information across major watershed boundaries that contributed to the problem.

The TNRCC is currently working with Texas A&M University and the CRWR toward resolution of this issue. In the interim, TNRCC directed all WAM consultants to review their projects and stated they would accept use of the model-option which distributes naturalized flows on the basis of drainage area ratios but to retain the curve number values in the model input.

While this issue does not appear to have affected the Sabine River Basin WAM, the BRS team considers it prudent to distribute flows by drainage area only (as indicated in WRAP method 7). We have included the CRWR-supplied average curve numbers in our input decks, as they may be used in the future if the curve number flow distribution problem can be resolved.

The inability of WRAP (VER 11/26/01) to simulate subordination conditions resulted in changing of the priority date for water right 05-4658 to make it junior to the entire basin. As described in section 5.2 this resulted in increased reliability for water right 05-4662.

Future appropriations are subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code. Environmental flow needs, including instream flows and freshwater inflows to Sabine Lake, will be considered when granting new water rights or amending existing water rights, thereby affecting the amount of water available for appropriation.

An additional factor, affecting the results, is the structure of the model and what options are selected. In the WRAP (VER 11/26/01) model, senior water rights do not have access to upstream return flows that occur in the same month. Therefore, in this study, return flows were returned in the following month. A similar issue involves junior hydropower releases, which are not shown to be available for senior water rights streamflow depletions unless hydropower releases are returned the following month. To resolve these potential errors, the model developed in this study returned wastewater discharges and hydropower releases in the following month in order to make those flows available to senior water rights at the beginning of each water rights loop.

5.5 Requirements for Model Re-run and/or Model Update

The following input records were used in the Sabine WRAP models and depending upon the change may or may not require updating:
Records for defining control point connectivity and other related information

CP - Control Point connectivity and references naturalized flows and evaporation data
FP - Flow Distribution specifications transferring flows from gaged to ungaged control points
WP - Watershed Parameters used in flow distribution
CI - Constant Inflows or outflows, entering or leaving system

Records used for characterizing Water Rights information in WRAP (VER 11/26/01)

WR - Basic Water Rights information
UC - Monthly water Use distribution Coefficients
SO - Supplemental water rights Options
IF - Instream Flow requirements
TO - Target Options

Records for defining Reservoir related information

WS - Water right reservoir Storage
OR - Operating Rules for multiple reservoir operations
SV, SA - Storage Volume, Surface Area characteristics of reservoirs
PV, PE - Storage Volume, Surface Elevations used for hydropower

The intent of this section is to assist the future modeler in modifying or updating the WRAP files in this report as a result of future changes to the Sabine River Basin. While this report includes all water rights as of September 2000, any future application requires obtaining watershed parameters for the new water right, and making changes to the WRAP (VER 11/26/01) data files. This section defines the required steps for updating the WRAP (VER 11/26/01) models, however the WRAP Users Manual should be consulted for a thorough understanding of each record and associated variables. This section assumes the future modeler has a general understanding of WAM issues and concepts. There are multiple versions of WRAP and future modelers should reference the following when updating Sabine WAM files: 1) WRAP (VER 11/26/01); and, 2) the Reference and Users Manual for the Water Rights Analysis Package (WRAP), Second Edition, dated October, 2000.

There are two fundamental steps in developing and executing a water availability model for the Sabine River Basin: 1) Obtaining data necessary for simulating hydrology; and 2) Obtaining and developing data representing water rights. WRAP (VER 11/26/01) has the capability to distribute flow from gaged to ungaged control points in addition to performing the water rights simulation. The following sections outline those procedures to be followed when a Sabine WRAP model is to be updated, using the example of an application for a new water right, with a single diversion location at a new secondary control point. The procedures will describe the steps to update the model for Reuse scenario 1. These procedures will need to be repeated for additional scenarios as necessary.

The hypothetical new water right will have a diversion point E9999A, located immediately downstream of control point SRBU (see Appendix K for model schematic). The water right is for the diversion of 100 acre-feet per year for irrigation, with a priority date of December 31, 2001. The water right does not include the right to impound water. The watershed parameters for the new secondary control point have been obtained and they are: drainage area of 7,550 square miles, a curve number of 69.95 and mean precipitation of 46.65 inches.

5.5.1 Updating the Hydrology Data

WRAP (VER 11/26/01) develops the hydrology records (IN and EV) for secondary control points from given IN and EV records at primary control points as necessary to run the model simulation. All hydrology parameters are stored in the following files: Sabine1C.DAT contains control point connectivity data; Sabine1C.DIS contains data for distributing flow from gaged to ungaged control points; Sabine1C.INF contains the naturalized streamflows for primary control points; Sabine1C.EVA contains the evaporation data for select control points. Because the new water right is at a secondary control point, additional hydrology will be simulated at this point, based on the existing primary control points. Thus the files to be updated are the *.DAT and *.DIS files, using the following procedures:

1. In the file Sabine1C.DAT, locate within the CP records, the existing control point (SRBU) which is upstream of the new control point. The next control point in the CP records (E4659B) is on a tributary of the Sabine River. Thus insert a new CP record between SRBU and E4659B. The variables in the new CP record should be set using the following values:

2. For the CP record of SRBU, change the downstream control point, CPID(cp,2) from SRBW to E9999A, in order to reflect the change in model configuration (connectivity). If there were additional control points which were located with E9999A as their downstream control points, those CP records would require changing as well.

3. In the Sabine1C.DIS file, insert a new FD record at the same relative location as the new CP record was inserted (between the same two control points). Because SRBU

is a primary control point, it will not be found in the FD records, thus insert the new record before E4659B.

4. For the new FD record, enter the ID as E9999A and the IDDS (downstream primary control point) as SRBW. The variable NGAGE should be set to “1” as there is one primary control point upstream of SRBW which is also upstream of E9999A. The UGID(I) variables are for identifying all primary control points upstream of SRBW (the downstream control point), and should be in order such that any upstream primary control points which are upstream of E9999A are listed first, according to the variable NGAGE. Thus enter SRBU for UGID(1). As BARP is the only other primary control point upstream of SRBW, it should be listed for UGID(2), and remaining UGID(I) variables should be left blank.

5. In the Sabine1C.DIS file, insert a new WP record at the same relative location as the new CP record.

6. For the new WP record, enter the ID as E9999A. For variable DA, the drainage area of 7,550 square miles should be entered. For the curve number variable (if used), CN, enter the value 69.95. For the mean precipitation, MP, enter the value 46.65. Leave the drainage area factor, DAF, blank, as the value for drainage area is already in square miles.

5.5.2 Updating the Water Rights Data

WRAP (VER 11/26/01) performs the water rights simulation for the modeled configuration. The water rights data is stored in the Sabine1C.DAT file. The following changes should be made to the *.DAT file:

1. Add a new set of UC records for the monthly use factors, to be referenced in the WR card. If an existing set of UC records is representative of the new water right, a new set of UC records is not required. For the example, the existing UC record “IRR” will be applied.

2. Add a new set of RF records to represent the monthly return flow factors to be referenced in the WR card. If the new water right has a constant return flow factor, or if an existing set of return flow factors is representative, no new RF records are required. For the example, no RF records are necessary.

3. Add a new set of CI records to represent any new constant inflows at the new control point. For the example, no new CI records are necessary.

4. Add a new WR record to represent the new water right. The variable CP should be set to the new control point, E9999A. The variable AMT is the authorized diversion amount 100 acre-feet per year for the new water right. For the variable USE, enter the value “IRR” to reference the monthly use coefficients for irrigation. The variable WRNUM (wr,7) is the priority date of the new water right, 20011231. The variable

WRNUM(wr,5) should be set to 1, as the water right may make diversions from streamflows. The variable WRID(wr) should be set as 10509999001, a unique number for the diversion location and the water right. If the water right allowed multiple use types, separate WR records should be created for each use type, and the WRID(wr) values would be 10509999002, 10509999003 etc. The additional WR variables, including return flow specifications and additional identifiers should be left blank for this example. Consult the WRAP users manual for more information on using these features.

5. A new WS record may be added if there is a reservoir at the new control point location. The reservoir storage-area relationship may be described using coefficients in the WS record, or using a set of SA and SV records. For the example, no reservoir is included.

The executable WRAP-SIM program "SIM.exe" (VER 11/26/01) must be run separately for each model scenario. The model output can be examined using the TABLES program, which will provide reliability information for the new water right.

6.0 SUMMARY AND CONCLUSIONS

A water availability model was developed for the Sabine River Basin using the revised WRAP (VER 11/26/01) model. The model contains two basic data sets: naturalized flows and water rights information for all water rights issued by the TNRCC through September 2000.

Naturalized flows were developed for a select number of USGS gages for the 59-year period, from 1940 through 1998.

A total of nine scenarios were performed: eight base scenarios and one basin specific scenario. The conclusions of this water availability study are as follows:

- The Sabine River Basin, located in southeastern Texas, drains an area of approximately 9,756 square miles. There are a total of 183 water rights simulated with authorized annual diversions totaling 1,886,424 acre-feet per year (ac-ft/yr).
- Shortages occur frequently for a number of water rights; but the vast majority of these rights are located in the upper reaches of tributaries where streamflows are limited.
- Comparisons of the three reuse scenarios show that varying levels of wastewater reuse does impact water supply. The reliability of a water right generally decreases as the level of reuse increases. Reuse of wastewater decreases the amount of storage in a reservoir; but the magnitude of the decrease is much more pronounced for reservoirs in the upper basin.
- There are 57 water rights with authorized diversions totaling 5,450 ac-ft/yr, approximately 0.3 percent of the total authorized diversions in the basin, which were simulated as being canceled. Thus hypothetical cancellation of water rights has a negligible effect on the reliability of water supply for most rights in the basin. Limiting diversions in the maximum use scenarios reduces the diversion amount by approximately 1,240,800 ac-ft/yr and shows that water use in the basin is approximately 20 percent of the total authorized amount.
- The amount of unappropriated flows varies based on the location of the control point. In general, wastewater reuse has a greater effect on unappropriated flows for those locations in the upstream portions of the basin.
- The amount of regulated flows varies based on the location of the control point. In general, wastewater reuse has a greater effect on regulated flows for those locations in the upstream portions of the basin.
- Over a 59-year period of record, the average naturalized flows discharging into Sabine Lake from the Sabine River are approximately 6,857,000 ac-ft/yr, with a minimum annual inflow of 2,492,000 ac-ft/yr. Results of the Freshwater Inflow Analysis for Sabine Lake Estuary, completed by TPWD and TWDB in February of 2001, are included and the historical percentile distribution of inflows along with the agencies' recommendations are shown in Figure P-13.

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