1.0 INTRODUCTION

1.1 Basin Description

Water availability analyses are being conducted for 22 basins within the State of Texas. This particular study covers the Lavaca River, Colorado-Lavaca Coastal, and Lavaca-Guadalupe Coastal Basins. These three basins are located in southeastern Texas. The Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins border Matagorda Bay. There are ten counties that lie completely or partially within the three basins. These counties are Calhoun, Colorado, DeWitt, Fayette, Gonzales, Jackson, Lavaca, Matagorda, Victoria, and Wharton. The three basins are mostly rural in nature and the economy relies primarily on agriculture. The primary crop grown in these basins is rice. Other crops grown include cotton, sorghum, soybeans, wheat, and peanuts. Near the bay areas, several industries exist. Four of the larger industries are the Aluminum Company of America, Central Power and Light Company, Formosa Plastics Corporation, and Union Carbide Corporation. Finally, there is one major reservoir located in the Lavaca River Basin and none in either of the coastal basins. The reservoir, Lake Texana, discussed in Section 4.2.3.4, is located on the Navidad River and provides water for municipal, industrial, and recreation purposes.

Rainfall in the basin is relatively high. Annual average precipitation ranges from approximately 36 inches in the northwest portion of the basin to approximately 44 inches in the southeast portion. Because of the high rainfall some farmers in the basin do not need to irrigate and may likely not have any rights to surface water.

1.2 Objectives

Pursuant to Senate Bill 1, the State of Texas must develop new river basin simulation models to determine available water in accordance with the Texas Water Code. It is intended that these models provide information that will assist existing water right holders, prospective water right applicants, regional water supply planning entities, and state water and environmental regulatory agencies in determining the quantity of water available for future use throughout the basins under varying climatic and hydrologic conditions. This process takes into consideration the Prior Appropriation Doctrine, which dictates the priorities by which limited water supplies are allocated among water right holders.

1.3 Study Approach

The procedure for analyzing water availability in a river basin involves simulating the ability of water rights to receive their authorized diversion amount (from naturalized streamflow) in accordance with the Prior Appropriation Doctrine. Naturalized streamflows are used in the analysis so that diversions and storage amounts for water rights can be satisfied without double accounting for their effects on the historic streamflow. Naturalized streamflows were determined for the years 1940 through 1996 for all relevant streamflow gages. Naturalized streamflows for other control points designated by the Bureau of Reclamation (USBR) and the Texas Natural Resource Conservation Commission (TNRCC) were developed using the Texas A&M Water Rights Analysis Package (TX-WRAP). Data collected to complete the naturalized streamflow analysis and the results of the naturalized streamflow calculations will be used as input to the TX-WRAP. The TX-WRAP Model was designed to allocate water among users on a priority based allocation system. The simulation routine in this model balances available streamflows at specified control points against specified demands associated with water rights.

The process for determining water availability for water rights involves several steps with the output from one task providing the input for subsequent tasks. The first task involves the compilation of all available data on existing water rights, cropping patterns, irrigation practices, historical streamflows, reservoir conditions, surface water diversions, return flows, rainfall, and reservoir evaporation. Data collected was used both in the naturalized streamflow computations and as input for the model.

2.0 EXISTING WATER AVAILABILITY DATA

2.1 Water Rights

The locations of the existing water rights in the Lavaca, Colorado-Lavaca, and Lavaca-Guadalupe Basins are shown in Figure 1 (Page 4). These water right locations are either associated with a diversion, return flow, on-channel reservoir, or off-channel reservoir. The following table summarizes the water right uses within the three basins.

TABLE 1

Use Summary – From Water Rights Data Base

Use	Number Of Rights	Allocated Amount (ac-ft/yr)	Percent Of Total
Municipal	3	88358	7.78
Industrial	13	959074.5	84.41
Irrigation	86	87488.4	7.70
Recreation	7	1180	0.10
Other	1	110	0.01
Total	110	1136210.9	100.00

Each existing water right is listed in Table 2 by water right number. Information provided in the table includes the water right number, type, water right issue date, owner name, use, priority number, county, allocated amount, acreage, rate, basin, reservoir capacity, river order, and stream name.

2.2 Historical Water Use

According to the "Land and Water Resource Management Plan for Lake Texana and Associated Project Lands Report" provided by the Lavaca Navidad River Authority (LNRA), the total water use for municipal, industrial, irrigation, mining, and livestock purposes in the Lavaca River Basin and adjoining Colorado-Lavaca and Lavaca-Guadalupe Coastal Basin was 542,382 acre-feet in 1990. Projected total water demand for these purposes in 2050 for the three basins is estimated to decline to 402,744 acre-

feet. (LNRA, 1997) It is expected that the irrigation water use will decrease as a result of improvements in irrigation water use efficiencies, but that the municipal and industrial water use will increase. Table 2, summarizing the water demand projections, was provided in this report.

Irrigation water use data for both surface and groundwater and for each basin and county was obtained from the Texas Water Development Board (TWDB) for the years 1985 through 1996 and is further described in Section 3.2.2.2a. Additional data for all water use in each county was obtained from the USGS for the years 1985, 1990, and 1995 and is shown in Tables A-1a through A-1c in Appendix A. After studying all of the available water use data, no trends were observed.

2.3 Historical Return Flows

There are several irrigation return flow and wastewater discharge locations in the three basins. Figure 2 (Page 7) shows all of the wastewater discharge locations. Some wastewater discharge data was available from the TNRCC, but no data was available for irrigation return flows. The estimation of irrigation and wastewater return flow values are explained in Sections 3.2.2.3 and 3.2.2.7, respectively, as well as Sections 3.2.3.1 and 3.2.3.2, respectively.

2.4 Previous Studies

2.4.1 Water Availability

One water availability study has been completed on the Lavaca River Basin to date and none have been completed on the two coastal basins. The results from the one study were obtained from the "TNRCC Documentation for Legacy Water Availability Models Used for Water Rights Permitting" (referred to in this report as Legacy Model) document and covered the period of 1940 through 1979. Data provided with this document consists of baseflow, diversion, unappropriated water, outflow, reservoir content, reservoir evaporation, storm runoff, total runoff, and total inflow. In accordance with the documentation, naturalized flow data is referred to as the total runoff values.

Table 2

Water Demand Projections for the Lavaca River, Colorado-Lavaca Coastal, and Lavaca-Guadalupe Coastal Basins

	Water Demand Projections in Acre-Feet						
Use	**1990**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Lavaca							
Municipal	6,892	8,331	8,258	8,120	8,279	8,437	8,778
Industrial	4,591	15,430	20,268	20,396	22,687	24,006	26,330
Irrigation	271,342	224,533	206,700	186,539	168,637	155,985	144,406
Mining	1,110	1,849	1,541	1,455	1,364	1,441	1,560
Livestock	3,848	4,122	4,122	4,122	4,122	4,122	4,122
Subtotal	287,783	254,265	240,889	220,632	205,089	193,991	185,196
Colorado-Lavaca							
Municipal	3,483	3,830	3,894	3,961	4,145	4,356	4,700
Industrial	2,263	2,673	2,540	4,749	5,200	6,842	7,678
Irrigation	169,311	135,703	126,035	114,394	104,766	97,574	90,878
Mining	250	329	278	255	245	242	249
Livestock	992	955	955	955	955	955	955
Subtotal	176,299	143,490	133,702	124,314	115,311	109,969	104,460
Lavaca-Guadalupe							
Municipal	6,775	7,726	8,037	8,304	8,790	9,264	10,051
Industrial	17,963	46,069	56,704	62,813	69,603	76,905	84,738
Irrigation	52,320	38,375	31,371	26,133	21,809	18,540	15,967
Mining	167	779	803	877	951	1,051	1,177
Livestock	1,075	1,155	1,155	1,155	1,155	1,155	1,155
Subtotal	78,300	94,104	98,070	99,282	102,308	106,915	113,088

Six different scenarios estimating the parameters listed in the above paragraph were evaluated. Run number six modeled return flows from the Garwood Irrigation Company's diversion from the Colorado River Basin, included water rights up to 1982, and modeled Stage I for Lake Texana only. This run is most similar to the naturalized streamflow calculations completed for the present study and thus used for comparison. There are six locations where the flows from both studies could be compared. These locations correspond to the USGS gaging stations 08164000, 08163500, 08164500, 08164350, 08164300, and 08164450.

The results at stations 08164000 and 08163500 in the current study are very similar to the values presented in the Legacy Model. At station 08164000, the minimum, maximum, and average differences in monthly naturalized flow values are 6.2, 482.5, and 131.8 acre-feet, respectively. At station 08163500, the minimum, maximum, and average differences in monthly naturalized flow values are 2.8, 62.5, and 32.8 acre-feet, respectively. It was observed, for these stations, that there were very little to no adjustments made in the flow to account for human influence in the Legacy Model. In other words, the naturalized flows differed very little from the historic streamflows. The present study determined larger adjustments or variations from historic flows. Adjustments possibly not accounted for in the Legacy Model were agricultural return flows and wastewater discharges. No documentation on the procedures or assumptions used to determine the total runoff/naturalized flow for the Legacy Model exists.

At USGS gage station 08164300, the naturalized flows were again very similar between the two models where there was historic streamflow data. For those months and years where there was no historic streamflow data and the naturalized streamflow values had to be correlated with other gage stations, the differences in naturalized streamflow were large. For stations 08164350 and 08164450, no historic streamflow data existed for the years 1940 through 1979. As a result, all of the naturalized streamflow values were derived from correlation and thus differences occurred between the two calculations. Station 08164500 located downstream of stations 08164350 and 08164450 also differed largely from the Legacy Model since it is partially a combination of the flows at these stations. Because this study had more years worth of data to base the correlations on, it will be assumed that these calculations are more accurate.

2.4.2 Reservoir Firm Yield

As previously mentioned, there is only one major reservoir within the three basins – Lake Texana. Initially, the LNRA and TWDB jointly held a TNRCC water right permit, which set the firm yield of the reservoir at 79,000 acre-feet per year for municipal and industrial water supply. The permit was amended (16-2095B) to provide freshwater pass through requirements for bay and estuary needs. This amendment reduced the yield available for municipal and industrial use to 74,500 acre-feet per year. However, the remaining 4,500 acre-feet per year could be made available for municipal and industrial use on an interruptible basis – when the reservoir is full and inflows to the reservoir are in excess of pass through requirements. At this time, no firm yield studies on Lake Texana have been found.

2.4.3 Existing Reservoir Operation and Other Management Plans

One management plan is available for Lake Texana. This plan is the "Land and Water Resource Management Plan for Lake Texana and Associated Project Lands" and was completed for the LNRA in August of 1997 by HDR Engineering.

2.4.4 Reservoir Sedimentation Studies

The Bureau of Reclamation completed a reservoir sedimentation study on Lake Texana in June 1991. (USBR, 1992) Another survey is to be conducted on the reservoir in the fall of 2000. At the beginning of reservoir operations in 1980, the surface area and total capacity at the top of the conservation pool (elevation 44.0 feet) were 10,141 acres and 167,293 acre-feet, respectively. The reservoir space allocations included 20,700 acre-feet allowance for 100 years of sediment deposition between the streambed and elevation 44.0 feet of which 15,200 acre-feet would be in active storage above elevation 15.0 feet. The capacity of the reservoir in June of 1991 was determined to be 163,506 acre-feet with a surface area of 10,134 acres at the top of the conservation pool. The volume of sediments that had accumulated in the reservoir during the period from initial operation to June of

1991 amounted to a total volume of 3,790 acre-feet below the maximum water surface elevation of 47.0 feet or 3,787 acre-feet below the conservation elevation. This indicated a loss in capacity of about 2.3 percent and an average sediment accumulation rate of 341 acre-feet per year. According to the report published on this study, this rate should not be used for making long term projections of storage loss, because the annual inflow for five of the 11.1 years of operation was about 1.9 times the long term mean annual inflow, and the average annual inflow for the period was 1.3 times the long term mean annual inflow. The sediment yield rate from the drainage area was calculated as being 0.243 acre-feet per square mile per year (USBR, 1992).

3.0 HYDROLOGIC DATA

3.1 Control Point Description

Naturalized streamflows were computed at both gaged and ungaged locations. Control points set at USGS gaging stations, having historic streamflow records (primary control points), are referred to as gaged locations and are shown in Figure 3 (Page 12). All other control points (secondary control points) are referred to as ungaged locations. Figure 4 (Page 13) shows all of the control point locations used in this simulation. Naturalized streamflows for the gaged locations have been computed in the manner described in the next section. Naturalized streamflows at ungaged locations were determined by the TX-WRAP Model.

All control points were assigned a unique identifier. The identifiers range from 7 to 9 characters in length. The first two to three characters represent the stream on which the control point is located (for example for the Lavaca River, LR is the first two characters and for a tributary of the Lavaca River, LRT is the first three characters). Table 3 (Page 14) shows a list of all the streams and their character designation. The second two characters represent the type of control point. These different types are diversion point (DV), return flow (RF), on-channel reservoir (OS), off-channel reservoir (SO), wastewater discharge (WW), USGS gage station (GS), and combine point (CB). The last three to four characters are numbers. The control points set at all USGS gaging station sites were assigned a consecutive number between 100 and 1700 divisible by 100 (except for one which is divisible by 50). Control points placed at confluences of a main stream and one of its tributaries where on the tributary there were water right requirements, irrigation ponds, and/or wastewater discharges (combine point) were assigned a number divisible by ten (except for a couple which are divisible by 5). The final control points were placed at all water right, known return flow, and on-channel reservoir locations, and wastewater discharge locations discharging a minimum of one million gallons per day. These control points were assigned a number divisible by one.

3.2 Naturalized Streamflow at Gaged Locations

3.2.1. Naturalized Streamflow Computation Methodology

The purpose of conducting the naturalized streamflow analysis is to determine how much water would exist in the stream networks without influences of humans and to determine the impacts these influences have had. Not all influences can be accounted for, though. Particular influences of concern are diversions and return flows from and to the stream networks, respectively, import of water from other basins, changes in flow due to artificial storage, and evaporation from open water surfaces created by man. This analysis encompasses a large range of historical data (1940 through 1996) that includes wet, dry, and normal flow periods. The traditional methodology for updating, determining, and distributing naturalized streamflow at all gaged locations within the three basins was used. The traditional method uses the following general equation:

Naturalized Streamflow	=	Historic (gaged) Flow	
		+	Irrigation Depletions (i.e. diversion for irrigation)
		-	Agricultural Return Flows
		+	Major Reservoir Evaporation
		+	Change in Major Reservoir Storage
		+	Minor Reservoir Depletions (evaporation)
		+	Domestic Depletions (i.e. municipal use diversions)
		-	Wastewater Discharges
		+	Groundwater Depletions (reduced baseflow due to over pumping of groundwater)
		+	Exports
		-	Imports

The NRCS-CN Method can then be applied in the TX-WRAP model to distribute the naturalized streamflows to ungaged locations. The following sections describe the parameters in the traditional method equation.

3.2.2 Naturalized Streamflow Data Description

3.2.2.1 Historic Gage Data

There are ten gage stations at which naturalized streamflow calculations were made. Historic stream gage data exists at several other locations but these gages do not have data dating prior to 1996 or are stage only. Of the ten stations where calculations were made, two are located on the Lavaca River, three on the Navidad River, and one on each of the following: Sandy, West Mustang, Tres Palacios, Garcitas, and Placedo Creeks as shown in Figure 4. A list of all the gages and their period of historic record is shown in Table 4 (Page 17). Also, shown in Tables A-2a through A-2j in Appendix A, are the actual streamflow data obtained for each station.

3.2.2.2 Irrigation Depletions

3.2.2.2a Consumptive Use Determination

The number of irrigated acres by crop, in each county, was collected for as many years as possible. Some of this data was obtained from the Texas Water Development Board (TWDB) and other from the state agricultural statistic reports. The data collected was for the years 1959, 1964, 1969, 1974, 1979, and 1984 through 1996; 1959, 1964, and 1968 through 1996, or some variation of the two depending on the county. Also, for the years 1959, 1964, 1969, 1974, 1979, and 1984 through 1996, information was collected on the number of acres irrigated by surface and groundwater. Finally, for the years 1985 through 1988, 1990 through 1993, 1995, and 1996 the irrigated acres were provided for each county and basin. The percent of irrigated acres in each basin and county for these years was used to develop data for those years where no data was available. This data along with the percent of each crop type irrigated in each county was entered into a text document for use as input to the program XCONS. (USBR, 1992) XCONS is a computer package developed by the Bureau of Reclamation to compute crop consumptive use, among other parameters. This program uses the Soil Conservation Service Modified Blaney-Criddle (USDASCS, 1967) method for computation of the irrigation water requirements. The program computes net irrigation depletions (net irrigated crop consumptive use) by applying a crop growth stage coefficient to the calculated monthly consumptive use factor to estimate the net monthly consumptive use rate in inches per acre for each crop. A copy of the XCONS users guide including the input deck format and the actual input file for this study are provided in Appendix B.

Other data needed for the computation of irrigated consumptive use and input into the text document were planting and harvest dates for each crop, the average temperature at

the times of the plant and harvest dates, the number of days of irrigation, the mean monthly temperature, and monthly precipitation totals for every year that irrigated acres data exist. The temperature and precipitation data used were obtained for cities within each county from the Hydrodata diskettes published by Hydrosphere Data Products, Incorporated. These cities included: Port Lavaca for Calhoun County, Columbus for Colorado County, Cuero for DeWitt County, Flatonia for Fayette County, Danevang for Jackson County (Danevang is located in Wharton County but the station in Edna had insufficient data), Hallettsville for Lavaca County, Palacios for Matagorda County, Victoria for Victoria County, and Danevang for Wharton County.

The net irrigated consumptive use (from both surface and groundwater sources) computed for each basin and county was then projected to the individual sub-basins associated with the gage stations. These projections were made through the use of ArcView shape files showing the irrigated farmland in each county obtained from the Texas Natural Resources Information System (TNRIS) web site. The attribute data provided with these shape files included the area of the irrigated land polygons and the number of irrigated acres in 1994. Shape files showing the basins and sub-basins associated with the gage stations could then be laid over the irrigated farmland shape files to determine which irrigated lands were in each sub-basin. The percent of irrigated acres in each sub-basin in comparison to the total irrigated acres in each basin and county was computed, and is shown on Table A-5 in Appendix A. These values were then multiplied by the net irrigated consumptive use determined by XCONS to come up with the net irrigated consumptive use for that sub-basin. Finally, the percentage of surface and groundwater within each basin and county were calculated and then multiplied by the total net irrigated consumptive use in each sub-basin to determine the amount of surface and groundwater being consumed in the sub-basins.

3.2.2.2b Irrigation Water Right Diversions

Once the net irrigated consumptive use was computed, the amount of flow diverted to meet the crop demands could be estimated. According to individuals at both the Lower Colorado and Guadalupe Blanco River Authorities (LCRA and GBRA, respectively), rice irrigation is about 60% efficient. Since the majority of all the crops grown in the three basins is rice, it was assumed that all of the irrigated lands were 60% efficient. The required diversion amount was then determined by dividing the surface water required for net irrigated consumptive use by 60%. Some actual diversion data was obtained but was very sparse and thus not used. Tables A-6a through A-6j in Appendix A show the total diversion requirements upstream of each gaged location. There are three basins in which there are irrigated lands receiving water from imports: WMCGS800, SCGS1000, and TPRGS1300. Tables A-6k through A-6m in Appendix A show the stream diversion requirements only (total diversion requirements minus the imports) for these basins where some of the water demands are being met by imported water.

3.2.2.3 Agricultural Return Flows

In order to determine return flows, the required groundwater pumping also had to be determined. Groundwater irrigation is more efficient than surface water irrigation because there is less loss of water through seepage, water surface evaporation, and evapotranspiration associated with canals used to deliver surface water. For groundwater, the efficiency was assumed to be 85% and the total pumped groundwater required was determined in a similar manner as the surface water diversions. Tables A-7a through A-7j in Appendix A show the estimated total groundwater withdrawals.

Flow diverted from a surface water source or pumped as groundwater will not be entirely consumed or lost. For the acres irrigated by surface water, it was assumed that 15% of the flow diverted would return. For acres irrigated by groundwater, it was assumed that 5% of the water being pumped would return. The values of 15% and 5% are common values used in hydrologic practice in the western United States though there is no literature backing them up. A lower value is used for groundwater because there is more flexibility in the water withdrawn and when irrigation occurs. Tables A-8a through A-8j in Appendix A show the estimated return flows at each gaged location.

3.2.2.4 Major Reservoir Depletions

A major reservoir is any reservoir with a capacity greater than 5,000 acre-feet. There is only one major reservoir, Lake Texana, located within the three basins included in this study. Lake Texana was constructed and completed in 1982. When first constructed it had a firm yield of 79,000 acre-feet, but has since been reduced to 74,500 acre-feet. An amendment to the certificate of adjudication associated with the reservoir requires releases for the bay and estuary system. It was found by the Texas Water Commission (now TNRCC) that these releases could impact the firm yield by reducing it by 4,500 acre-feet. However, according to the Land and Water Resource Plan for Lake Texana, part of the 4,500 acre-feet per year difference could be made available for municipal and industrial use on an interruptible basis; i.e. when the reservoir is full and inflow to the reservoir is in excess of pass through requirements. (LNRA, 1997)

Shown on Tables A-9, A-10a, A-10b, and A-11 in Appendix A are the historic monthly change in storage, Stages I and II – Options 1 and 2 area-capacity, Stage I sediment study area-capacity, and estimated year 2000 area-capacity, respectively. This data was obtained from Bureau of Reclamation. The Stage II – Options 1 and 2 shown in the tables refer to two different area-capacity curves available for this reservoir stage.

Lake Texana water is used to meet municipal and industrial needs as well as provide recreation. Three streams flow into the Stage I reservoir: the Navidad River and Sandy and Mustang Creeks. The Stage II reservoir involves extending the dam embankment to the west so that Lavaca River water is captured. In doing so, it also captures the flow from Dry Creek and its tributary, Post Oak Branch.

3.2.2.4a Evaporation and Precipitation Data

Lake evaporation and precipitation data was obtained from the Lavaca Navidad River Authority (LNRA). The evaporation data provided was gross evaporation. To determine the net evaporation, the precipitation was subtracted from the gross evaporation values. The gross evaporation, precipitation, and net evaporation are shown on Tables A-12, A-13, and A-14 in Appendix A.

3.2.2.4b M&I Diversions and Releases

Municipal and industrial diversion and release data was also obtained from the LNRA. The data provided includes M&I diversions and releases from the spillway and river outlet works as well as seepage, operation testing, bay and estuary releases and flood releases. These diversions and releases were accounted for in the computed inflow and are shown on Tables A-15 and A-16 in Appendix A.

3.2.2.4c Inflow

Computed inflow data to the reservoir was obtained from the USBR's HydroMet site and is shown on Table A-17 in Appendix A. A USGS gaging station existed downstream of the confluence of the Navidad River and Sandy Creek prior to the reservoir. The HydroMet inflow data was adjusted by an area ratio so that the USGS gage data and the HydroMet data could be combined to make a complete set of historic streamflow data. A control point has been placed at this USGS gage station and is designated NRGS500.

3.2.2.5 Minor Reservoir Depletions

There are several small reservoirs within the three basins; most of which are used as irrigation ponds. An attempt was made to retrieve area-capacity data for these reservoirs from the TNRCC and the NRCS without success. Net evaporation from these reservoirs was determined by using the gross lake evaporation and precipitation data obtained from the TWDB. Tables showing the TWDB gross evaporation and precipitation are shown on Tables A-18a through A-18d and A-19a through A-19d, respectively, in Appendix A. The water surface area for the majority of these reservoirs was found either from water right records or the TNRCC Dam Safety Inventory. The naturalized streamflow accounted for the net evaporation from each small reservoir by multiplying the difference between the gross evaporation and precipitation by the water surface areas.

3.2.2.6 Domestic Depletions

Domestic depletions account for any municipal or industrial water rights. Within the gaged basins, there was one municipal and no industrial water rights aside from those at

Lake Texana. The municipal water right belongs to the City of Moulton. No data existed for this water right and as a result had to be estimated. The manner in which it was estimated is explained in Section 3.2.3.3.

3.2.2.7 Wastewater Discharge

Limited wastewater discharge data was available from the TNRCC. This discharge is considered a return flow whether the water initially came from a surface or groundwater source. Except for the City of Moulton, the entities discharging water to a stream do not have a water right but there are records that they have drilled wells. From these records, it could be determined when the entities began pumping water and thus return flows began. Where discharge data was known, it was used in computations. All missing municipal return flow data was filled in as described Section 3.2.3.2. The data used in the naturalized flow computations is shown in Tables A-20a through A-20j.

3.2.2.8 Groundwater Depletions

The Baseflow Index Program written by the USBR (USBR, 1996) was used to analyze the effects groundwater pumping may have on streamflows within the basins. A copy of the user manual including a description of the input is provided in Appendix C. This program determines the baseflow using daily historic gage data. After running the program at several gage locations, it was determined that groundwater pumping has not had an effect on the streamflow and thus was not included in the naturalized streamflow computations. This conclusion was made by plotting the computed baseflow with time and finding that there have been no decreasing trends.

3.2.2.9 Exports

There are no exports from any of the gaged basins and thus there was nothing to be accounted for in the naturalized streamflow calculations.

3.2.2.10 Imports

There are several imports into the three basins of study. Some of these imports had to be accounted for in the naturalized streamflow calculations while others did not. Following is a list of these imports by water right number. For each water right, a brief description of the water right and an explanation of the assumptions used in the calculations are provided.

Certificate of Adjudication – 18-2074:

The owner of this water right is the GBRA and is authorized to divert and use water from Canyon Reservoir located on the Guadalupe River for municipal, irrigation, recreation, domestic, and industrial use. The City of Port Lavaca and several of the industries along the canal system have purchased Canyon conservation water for times of drought. These entities normally receive all their water under other surface water right permits. To date, no Canyon water has been delivered to them.

Certificate of Adjudication – 16-2095:

This water right belongs to the Lavaca-Navidad River Authority (LNRA) and the Texas Water Development Board (TWDB) and is associated with Lake Texana. Some of the water diverted from Lake Texana under this right is distributed to the Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins, among others. Because there are no diversions from the reservoir made for irrigation use, it was assumed that all water imported into either of the two coastal basins is completely consumed and thus none enters the stream systems. According to the LNRA, the only imported water getting into the reservoir is from secondary sources, such as return flows from acres being irrigated by Garwood Irrigation District water.

Certificate of Adjudication – 16-2098:

The owner of this water right is Larkin T. Thedford, et al. and is authorized to divert water from the Lavaca River to the Lavaca-Guadalupe Coastal Basin. There are several water rights at this location/control point (LRDV214). This one has the right to divert water to serve a maximum irrigated area of 226.25 acres. The actual water right location and diversion point is within an ungaged basin. From what can be seen on the irrigated acreage shape file, the parcel of land being irrigated from this diversion also lies within an ungaged basin. For this reason, no data needed to be collected for the naturalized streamflow calculations.

Permit – 18-3606:

The permittee of this water right is Gulf Oil and Chemicals Company and is authorized to divert water from the Guadalupe River to the Lavaca-Guadalupe Coastal Basin. The permittee is authorized to divert water into an off-channel reservoir and circulate it through a chemical plant. The consumptive use of this plant is not to exceed 4,676 acre-feet per year for industrial purposes. The water diverted but not consumed is discharged into the Victoria Barge Canal tributary of the Gulf Coastal Waterway, Lavaca-Guadalupe Coastal Basin. This company and its off-channel reservoir are located in an ungaged basin and thus it will be assumed that the return flow location is also in an ungaged basin. For this reason, no data needed to be collected for the naturalized streamflow calculations.

Certificate of Adjudication – 18-3861:

The owner of this water right is E. I. Du Pont de Nemours and is authorized to divert water from the Guadalupe River to the Lavaca-Guadalupe Coastal Basin. The amount of flow diverted is not to exceed 60,000 acre-feet per year with a consumptive use not to exceed 33,000 acre-feet for industrial purposes. According to the water right, the owner must return all water not consumed back to the Guadalupe River. Because the use is industrial and all water not consumed is being returned to the Guadalupe River Basin, no data needed to be collected.

Permit – 16-3978:

The owner of this water right is J. H. Robinson and is authorized to divert water from the Lavaca River for use in both the Lavaca River and Lavaca-Guadalupe Coastal Basins. According to the water right, “water diverted but not consumed shall be returned to Arenosa Creek and tributaries of the Lavaca River in the Lavaca-Guadalupe Coastal Basin at various points”. From the ArcView drawings, the water right is located in the Lavaca River Basin and it appears as though the off-channel impoundment associated with this water right is located in the Lavaca-Guadalupe Coastal Basin. This pond is located on a parcel of irrigated land that is entirely within the Lavaca-Guadalupe Coastal Basin. This pond and parcel of irrigated land are located in an ungaged portion of the Lavaca-Guadalupe Coastal Basin and thus no data needed to be collected for the naturalized streamflow calculations.

Permit – 18-4276:

The owners of this water right are Del and Gloria Williams – Crawfish Isle Plantation – and are authorized to divert water from the Guadalupe River for industrial purposes (crawfish farming). This water is diverted to a series of five off-channel reservoirs located in the Lavaca-Guadalupe Coastal Basin. More specifically, the reservoirs are located approximately 15 miles southwest of Port Lavaca in Calhoun County. Water diverted and not consumed is returned to Schwings Bayou, a tributary of Mission Lake, in the very southwest portion of the Lavaca-Guadalupe Coastal Basin. The ponds and return flow locations are within an ungaged basin and thus no data needed to be collected for the naturalized streamflow calculations.

Certificate of Adjudications – 18-5173, 5174, 5175, 5176, 5177, 5178:

The owners of these water rights, GBRA and Union Carbide, are authorized to divert water from the Guadalupe River, Mission Bay, and Green Lake for municipal, industrial, and irrigation use. The water rights mention nothing about return flow requirements. All of the diversion points are located in ungaged basins or in the Guadalupe River Basin and thus it is assumed that the water is used and returned in ungaged portions of the basin. At least one of the diversion locations is from a saline source (Mission Bay) and this point is not included in the model as explained in Section 3.5.3.

Certificate of Adjudication – 14-5434:

The owner of this water right, Garwood Irrigation District, is authorized to divert water from the Colorado River Basin to irrigate a maximum of 32,000 acres of land as well as divert water for municipal and industrial purposes. These authorizations are documented in the original water right and Amendment A. The water diverted is for use in both the

Colorado and Lavaca River Basins. By the instrument entitled "Division of Water Right" dated as of January 30, 1997, the owner divided the Garwood Rights into two separate and distinct portions referred to as Corpus Christi's Rights and Garwood's Remaining Rights. Under Corpus Christi's Right, the owner is authorized to divert and use 35,000 acre-feet of water per year for irrigation, municipal, and industrial purposes. Under Garwood's Remaining Right, the owner is authorized to divert and use 133,000 acre-feet per year for irrigation purposes. These rights are associated with Amendments B and C, respectively. Import data for this district was obtained from the LCRA.

Permit – 15-5466:

The owner of this water right, the City of Port Lavaca, is authorized to divert water from the Guadalupe River for subsequent municipal use in Victoria County in the Guadalupe River and Lavaca-Guadalupe Coastal Basins. All return and surplus flow including treated effluent shall be returned to the Guadalupe River downstream of the diversion point. This water right was not issued until January of 1996 (the very end of the study period) and should not have any impact on the streams within the Lavaca-Guadalupe Coastal Basin since all flows are for municipal use and either consumed or returned to the Guadalupe River Basin. For these reasons, no data needed to be collected.

Certificate of Adjudication – 14-5475:

The owner of this water right is the LCRA and is authorized to divert and use water from the Colorado River to irrigate 25,000 acres of land located within the Authority's Lakeside Division Service Area in Colorado and Wharton Counties. The diversions for this water right are located both on the east bank of the Colorado River and on Eagle Lake located east of the Colorado River. According to LCRA, this water right allows export to the Brazos-Colorado Coastal Basin but not west to either the Lavaca River or Colorado-Lavaca Coastal Basins. For this reason, no data needed to be collected.

Certificate of Adjudication – 14-5476:

The owner of this water right is the LCRA and is authorized to divert water from the Colorado River to irrigate land located within the Authority's Gulf Coast Water Division

Service Area in Matagorda and Wharton Counties. According to LCRA, this water right allows export from the Colorado River Basin to both the Brazos-Colorado and Colorado-Lavaca Coastal Basins. There are three authorized diversion points: one at Lane City in Wharton County and the other two at Bay City in Matagorda County. The latter points each send water to the west and east of the river. Import data for this water right was obtained from the LCRA.

Certificate of Adjudication – 14-5477:

The original owner of this water right was Pierce Ranch. Later amendments (Amendments A and B) split the water right such that there are two owners – Pierce Ranch and the LCRA. This water right is currently owned in its entirety by the LCRA. Pierce Ranch was initially authorized to divert water from the Colorado River to irrigate land within the Pierce Ranch boundaries. Amendment A authorizes Pierce Ranch to divert and use water from the Colorado River for municipal, irrigation, industrial, and recreational purposes. This water is all used in the Colorado Basin and none goes to the Lavaca or Colorado-Lavaca Basins. Amendment B authorizes the LCRA to divert and use water from the Colorado River for irrigation and municipal purposes. The LCRA diverts the water to serve land in the Colorado and Brazos-Colorado Basins. None of the water goes to the Lavaca or Colorado-Lavaca Basins and thus no data needed to be collected.

Permit 5584:

The owner of this water right is the County of Jackson. The water is authorized for use in both the Lavaca River Basin and the Lavaca-Guadalupe Coastal Basin. This water right request was filed in April 1997 and issued in October 1997. The scope of this study only extends to 1996 and thus this water right does not need to be accounted for in any calculations of naturalized streamflow.

In summary, there are two water rights with imports that had to be considered in the naturalized streamflow calculations. One import is from the Garwood Irrigation Canal (W.R. – 14-5434). This flow enters the Lavaca River Basin in the northeast section of the basin and affects the flow at three of the gage stations – SCGS1000, NRGS500, and WMCGS800 or 08164450, 08164500, and 08164503, respectively. LCRA was able to provide the USBR with the total import and estimated return flow values for the years 1976 through 1996 as shown in Tables A-21a and A-21b, respectively, in Appendix A. According to the LCRA, 40 % of the Garwood Irrigation Canal imported water returns; 90% of which returns to the Lavaca River Basin and the remaining 10% back to the Colorado River Basin. These values were distributed into each gaged station sub-basin based on the number of acres irrigated in each. Approximately 75% of the irrigated acres are in sub-basin SCGS1000 and the remaining in sub-basin WMCGS800. Control point NRGS500 is located downstream of SCGS1000 and thus the naturalized streamflows are effected by this import.

The other import allows export from the Colorado River Basin to both the Brazos-Colorado and Colorado-Lavaca Coastal Basins. The water right associated with this import (W.R. – 14-5476) has three authorized diversion points: one at Lane City in Wharton County and the other two at Bay City in Matagorda County. The latter points each send water to the west and east of the river. LCRA provided the USBR with the total import to the Colorado-Lavaca Coastal Basin and estimated return flow values for the years 1976 through 1996. According to the LCRA, 40 % of the imported water returns; 40% of which returns to the Colorado-Lavaca Coastal Basin and the remaining 60% back to the Colorado River Basin. Tables A-22a and A-22b in Appendix A show the imported and estimated return flow provide by LCRA. This flow enters the Colorado-Lavaca Coastal Basin on its east side and affects the flow at one gage station – TPRGS1300 (08162600). It was estimated that 17% of the land being irrigated by this imported water is within sub-basin TPRGS1300. The remaining imported water is delivered to ungaged basins.

3.2.3 Filling in Missing Data

3.2.3.1 Crop Consumptive Use

Irrigated acres data existed for the years 1984 through 1996, consecutively, for all of the counties. Some of the counties had consecutive data dating back earlier than 1984, while others only had data prior to 1984 in 5-year increments as mentioned earlier in Section 3.2.2.2a. No data was found for years prior to 1959. For the four years between the incremental data, the net irrigated crop consumptive use was estimated to be the same as the previous years. The annual consumptive use for each year prior to 1959 was determined by finding a best-fit linear trend between the year and known annual net irrigated crop consumptive use. It was observed from the existing data that for each year data existed, the monthly data had a normal trend with the peak consumptive use occurring in July and zero consumptive use in the months of January, February, November, and December. To determine the monthly consumptive use for years prior to 1959, the average for the known data was determined and then the percent of each month's average related to the peak month average was determined. The monthly percentages were then multiplied by the peak month value (July), which was adjusted until the total for the year equaled the annual value estimated from the best-fit linear trend. This was completed for each county and subwatershed.

3.2.3.2 Wastewater Discharge

The majority of the wastewater discharges come from small cities. Population data for the cities, dating back to 1940, was collected to assist in filling in the missing data. Population data could only be found for the census years – every ten years. The population between these years was estimated by assuming a linear trend between the known population data. Similarly, linear trends were assumed for the quantity of wastewater discharge each month as it correlated to the estimated annual population. For those wastewater discharges not associated with a city, the missing data was filled in by observing and following the trends of the existing data for these locations.

3.2.3.3 Water Rights

The majority of the water rights within the three basins are for irrigation purposes. The data obtained for the irrigation water rights was minimal and thus not used. Rather, the calculated values described in Section 3.2.2.2 were used. From the LCRA web page, information on its municipal water use and wastewater discharge was obtained. Using this data, a ratio of the demand versus discharge was computed and the diversion estimated by multiplying the wastewater discharge by this ratio. Finally, there were two recreational water rights within the gaged basins. No water use estimates need to be made for these.

3.2.3.4 Imports

According to the Legacy Model, described in Section 2.4.1, return flows for the Garwood Irrigation Company between the years 1940 and 1979 were 9% of the flow diverted. For the period 1940 to 1950 and 1958 to 1979, the average annual return flow was estimated to be 9,600 acre-feet annually. For the drought years of 1951 through 1957, the average annual return flow was estimated to be 6,048 acre-feet annually. The corresponding import values are 106,667 and 67,200 acre-feet per year, respectively. These import values, for the years 1940 through 1975, were distributed into the SCGS1000 and WMCGS800 basins in the manner described in Section 3.2.2.10. The monthly values were determined in the same manner as the missing consumptive use values.

For basin TPRGS1300, no estimates of import data for the years 1940 through 1975 were available. Historic streamflow data for this gaging station only exists for the years 1970 through the present and thus the naturalized streamflow for all the years prior to this were determined through correlation. For this reason, no estimates of the missing import data were made and correlations were used to determine the naturalized streamflow for this basin up through the year 1975.

3.2.4 Completion of Naturalized Streamflow Records

Once all of the missing data was filled in, the naturalized streamflows could be computed for each year that historic stream gage data existed. This was done by summing all of the adjustments (irrigation depletions, minor reservoir depletions, etc.) for each subwatershed. For those subwatersheds with a gaged basin upstream, the adjustments at the station and the one upstream were summed to come up with a total adjustment. These adjustments and the historic streamflow records were then added to come up with the naturalized streamflow. Gage 08164000 (control point LRGS300) had a complete set of data (1940 to 1996) and gages 08163500 and 08164500 (control point LRGS400 and

LRGS500, respectively) were very close to complete (1940 to 1993 and 1940 to 1995, respectively). These gage stations were used for correlation between those stations with incomplete sets of data. The sets of data were correlated by computing the slope, intercept, and r-squared of their naturalized streamflow for each month of the year. The data sets that had the highest r-square value were used for filling in the missing naturalized streamflow data. The missing data was filled in by multiplying the known data by the slope and adding the intercept. The slope, intercept, and r-squared values used are shown on Table A-23 in Appendix A. There were a few instances where the r-squared values were low and determined inappropriate for use in computing the missing values in this manner. In these instances, an area ratio was used between the gage with the best r-square value and that with the missing data. For station 08164350 (control point NRGS550), area ratios were used for every month. Using the correlation method at this station would have resulted in several annual flows lower than those at the upstream station 08164300 (control point NRGS600). Tables A-24a through A-24j in Appendix A show the naturalized streamflows for each gaged location. These tables show numbers that have either normal or italic font styles. The normal font numbers are the actual calculated values using historic streamflow data and the italic font numbers are those values determined through correlation or area ratios.

3.2.5 Statistical Assessment of Historic and Naturalized Flows

The minimum, median, maximum, and 10, 25, 75, and 90 percentile historic and naturalized monthly streamflows for each gaged location were computed and are shown in Tables A-25a through A-25j. The differences between these flows are also shown in Tables A-25a through A-25j. The differences occur due to the adjustments made to account for the human impacts described in Section 3.2. The percentiles were determined by utilizing the percentile function in the Excel spreadsheet package. The input required for this function was the range of data to be used in the calculation and the decimal percent to be determined. The ranges of monthly data input were for the entire set of years – 1940 through 1996.

3.3 Reach Gains and Losses

There were only three control points for which it was applicable to compute reach gains and losses. In other words, there were only three control points that had other gaged control points upstream of them. These control points were LRGS300 with LRGS400 upstream of it, NRGS500 with NRGS550 and SCGS1000 upstream of it, and NRGS550 with NRGS600 upstream of it. The reach gains and losses were determined by subtracting the upstream naturalized flows from the downstream naturalized flows and are shown in Tables A-26a, A-26c, and A-26d. These values are important because they are a measure of the groundwater accretions and depletions and intervening surface flows. As shown in these tables, some values are significant in magnitude and because they tend to be positive indicates that there are groundwater accretions and/or intervening surface flows. Intervening surface flows do not represent a stream gain since the main stream itself increases in flow due to tributary streams delivering flow to it. It is believed that the amount of groundwater accretions, which would be considered a gain, is minimal compared to the amount of intervening flow and there has been no indication of any significant stream losses. These assumptions were made for all three of the basins.

3.4 Naturalized Streamflow at Ungaged Locations

For ungaged subwatersheds, the NRCS-CN method as described in the technical investigation “Comparative Evaluation of Methods for Distributing Naturalized Streamflows from Gaged to Ungaged Sites” (Wurbs, 1999) will be used. This methodology will be used for all three basins. This method uses total drainage areas, curve numbers, and mean annual precipitation to distribute the flows from gaged to ungaged control points. These parameters for all control points are being determined by the TNRCC with the assistance of the University of Texas Center for Research in Water Resources (CRWR).

3.5 Bay and Estuary Inflows, Needs, and Tidal Influences

3.5.1 Bay and Estuary Freshwater Inflows

Freshwater inflows are vital to continued health of natural ecosystems in and around bays and estuaries. Most species demonstrate a negative response to freshwater inflows during winter months and positive responses to freshwater inflow in summer months. The salinity conditions in the upper Lavaca Bay and the eastern end of Matagorda Bay have been found to be largely dependent on the freshwater inflows from the Lavaca and Colorado Rivers, respectively. Freshwater inflow comes primarily from precipitation over each estuary's drainage basin. Monthly surface inflow and fresh water balance for the years 1941 through 1994 have been published by the TWDB on their web site. The fresh water balance differs from the surface inflow in that it accounts for the evaporation and precipitation occurring on the water surface of the estuary. Tables A-27a and A-27b in Appendix A show the surface inflows and fresh water balance, respectively, for the Matagorda Bay System, which includes the Lavaca and Matagorda Bays.

3.5.2 Expected Bay and Estuary Needs

The TPWD has provided the report "Freshwater Inflow Needs of the Matagorda Bay System" on their web site. This report provided a nutrient budget for this estuary, which showed that a minimum annual freshwater inflow of 1.7 million acre-feet was needed to replenish the estimated nutrient losses from the estuary. It also estimated for two levels of inflow needs: Target and Critical. The Target inflow need from all sources was calculated to be 2.0 million acre-feet per year with the inflow needs from the Lavaca and Colorado River being estimated at 346,200 and 1,033,100 acre-feet per year, respectively. The remaining areas were estimated to provide an additional 620,700 acre-feet annually. A total annual freshwater inflow of about 287,400 thousand acre-feet was found to meet the Critical inflow needs with approximately 27,100 and 171,000 acre-feet annually provided from the Lavaca and Colorado River Basins, respectively, and 89,200 acre-feet coming from the remaining areas.

3.5.3 Tidal influences and Water Rights with a Saline Source

An ArcView shape file showing the tidal influences along the southeast shorelines of Texas was obtained from the Texas General Land Office (GLO). The GLO produced this file by extracting arcs in the TNRCC's stream segments data base according to their tidal influences as indicated in the Texas Water Commission's Segment Identification Maps. Shoreline arcs in the Coastal State-Owned Submerged Tracts were extracted according to their coding as bay or river tracts. These two files were combined to represent the tidal influences shape file.

Any control point that is located within a tidally influenced area or any water right that retrieves its water directly from a saline source cannot be modeled with TX-WRAP since it allocates fresh water only. For this reason, the tidal influences shape file was laid over the control point shape files to determine which are influenced by tidal action. Following is a list of the water rights that are influenced by tidal actions or retrieve water from a saline source and therefore, are not modeled.

Permit – 15-4207:
This water right, located in the Colorado-Lavaca Coastal Basin, is owned by Don A. Culwell and is authorized to divert water from two tidally influenced locations – one from the Buttermill Slough and the other from Turtle Bay. Both locations divert water for industrial purposes – redfish (a saltwater fish) farming. All water diverted but not consumed is returned to an unnamed tributary of Turtle Bay. The owner is also authorized to impound water in three reservoirs located on an unnamed tributary of Turtle Bay.

Permit – 15-4223:
This water right, located in the Colorado-Lavaca Coastal Basin, is owned by Ocean Ventures, Incorporated and is authorized to divert water from a single location on the Carancahua Bay for industrial purposes or more specifically shrimp farming. The owner is authorized to impound this water in an off-channel reservoir. Any water diverted but not consumed shall be returned to Carancahua Bay.

Certificate of Adjudication – 15-4789:
This water right, located in the Colorado-Lavaca Coastal Basin, is owned by the Texas Park and Wildlife Department (TPWD) and is authorized to divert water from a single location on Matagorda Bay. The water diverted is to be used for industrial purposes –

research on saltwater fish. The owner is authorized to impound the water diverted in twenty-one off-channel reservoirs.

Certificate of Adjudication – 15-4793:

This water right, located in the Colorado-Lavaca Coastal Basin, is owned by the Central Power and Light Company and is authorized to divert water from a single location on the Lavaca Bay. The owner of this water right is authorized to divert and use water from the Bay for industrial/cooling purposes. Water diverted but not consumed shall be returned to Cox Bay.

Certificate of Adjudication – 15-4794:

This water right, located in the Colorado-Lavaca Coastal Basin, is owned by the Aluminum Company of America and is authorized to divert water from three locations on the Lavaca Bay. The water diverted is used for industrial purposes or more specifically sluicing and cooling. Any water diverted but not consumed is to be returned to the Lavaca Bay.

Permit – 15-5099:

This water right, located in the Colorado-Lavaca Coastal Basin, is owned by the Matagorda Bay Aquaculture Incorporation and is authorized to divert water from the Tres Palacios Bay for industrial – fish farming – purposes. Water diverted but not consumed is returned to a tributary of Tres Palacios Bay. The owner is authorized to impound water in an off-channel reservoir complex.

Certificate of Adjudication – 16-2101:

This water right, located in the Lavaca River Basin, is owned by Francis Koop and is authorized to divert water from a single location from the Lavaca River for irrigation purposes. Because the use is for irrigation, it is likely that the owner can, at times, divert fresh water. For this reason, this water right was modeled but will have an overall low reliability.

Permit 5584:

This water right, located within the Lavaca River Basin and Lavaca-Guadalupe Coastal Basin, is owned by the County of Jackson and is authorized to divert water from three location within the Lavaca River Basin and six locations within the Lavaca-Guadalupe Coastal Basin for industrial (road construction and maintenance) purposes. Two of the diversions in the Lavaca River Basin are located within the zone of tidal influence. All three diversions are on the Lavaca River. Because the two diversions within the tidal influence zone are located below the Certificate of adjudication 16-2101, which diverts water for irrigation purposes when fresh water is available, it is likely that fresh water at times is diverted from these two locations as well. For this reason, these diversions were modeled but will have an overall low reliability.

Certificate of Adjudications – 18-5173, 5174, 5175, 5176, 5177, 5178:

The owners of these water rights are GBRA and Union Carbide and are authorized to divert water from the Guadalupe River, Mission Bay, and Green Lake for municipal, industrial, and irrigation use. At least one of the water right's diversion locations diverts water from a saline source – that being Mission Bay.

4.0 WATER AVAILABILITY MODEL

4.1 Description of TX-WRAP Model

The Water Rights Analysis Package (TX-WRAP, December 17, 2001) was used to simulate the water resources of the Lavaca River, Colorado-Lavaca Coastal, and Lavaca-Guadalupe Coastal Basins under the priority based water allocation system used in the State of Texas. The TX-WRAP model was developed by Ralph A. Wurbs of Texas Water Resources Institute, Texas A&M University. A detailed description of the model and its function can be found in its Reference and Users Manual (Wurbs, 1999/2000). The model was designed to provide information on regulated flows, unappropriated flows, reservoir storage levels, reliability indices for meeting water use requirements, and other measures of water supply capabilities.

4.2 Development of TX-WRAP Water Rights Input File

4.2.1 Control Points

Each water right within the three basins of study was designated as a control point. Other features such as reservoirs, return flow locations, wastewater discharge locations, and stream confluences were also designated as control points. Control point information is provided on input records to describe the spatial configuration of the river system. A complete set of the input decks for all model runs for each of the three basins can be found in Appendix H. A description of how the system features were assigned a control point name was described earlier in Section 3.1.

Naturalized streamflows are provided as input for all primary control points (control points located at USGS gaging stations with historic streamflow discharge data). For the secondary control points (all other control points), the model computed naturalized streamflow. The model allows the user to specify the means by which the naturalized streamflows for the secondary points are to be determined. The method chosen, as mentioned in Section 3.2.1, is the NRCS-CN method (INMETHOD 4). In the computations, the computed flow at the ungaged control point is limited so as not to exceed the flow at the gaged control point. INMETHOD 5 was selected for ungaged control points located downstream of the gaged control points. This method is the same as INMETHOD 4 except that the computed flows at the ungaged control point are not constrained to not exceed the flows at the gaged control point.

There are 171 control points in the Lavaca River Basin, 96 in the Colorado-Lavaca Coastal Basin, and 86 in the Lavaca-Guadalupe Coastal Basin. Of the 171 control points in the Lavaca River Basin, there are 28 hydrologic combine points, 65 water right diversion points, one end point at the Lavaca Bay, 11 USGS gage station points, 12 on-channel reservoir points, 43 return flow location points, 5 water quality points, and 6 wastewater discharge location points. Of the 96 control points in the Colorado-Lavaca Coastal Basin, there are 16 hydrologic combine points, 33 water right diversion points, 15 end points, 3 USGS gage station points, 9 on-channel reservoir points, 12 return flow location points, 2 water quality points, and 6 wastewater discharge location points. Of the 86 control points in the Lavaca-Guadalupe Coastal Basin, there are 7 hydrologic combine points, 23 water right diversion points, 22 end points, 4 USGS gage station points, 3 on-channel reservoir points, 19 return flow point locations, one water quality point, and 7 wastewater discharge location points. Figures A-1a through A-1c in Appendix A show flow charts of these points for each of the three basins.

4.2.2 Monthly Demand Distribution Factors

In the TX-WRAP model, demand distribution factors for each month of the year are input to describe the monthly variations of individual water demands associated with water rights. These monthly distribution factors are multiplied by the annual diversion amount or instream flow requirements for a given water right to determine the monthly diversions and flow requirements. Five different demand distributions for water right diversions were input into the model: municipal, industrial, irrigation, recreational, and other (assigned the numbers 1, 2, 3, 7, and 8, respectively). Demand distributions were also input for every water right with an instream flow requirement. The demand distributions for the three basins are shown in Tables 5a-c. The uses starting with an IF in this table represent instream flow requirements. The numbers following IF are the last digits of the water right identification number with the flow requirement.

Monthly water use data available for each water right was used to assist in determining the appropriate demand distribution factors. Industrial water use data obtained from the TNRCC was used to compute the average monthly water use as a percent of the annual value. These values were used as the monthly demand distribution factors. This same procedure was also used for the irrigation water use type but the data was obtained from the Texas Water Development Board (TWDB) and state agricultural statistic reports. Because there was no municipal water use data available and there were very few water right holders using surface water for municipal use, the demand distribution factors used in the Brazos River Basin Study - March 1999 Modified Version of WRAP Input for Base Run described in TWRI TR-165, March 1994, Wurbs, Sanchez-Torres, Dunn, Reservoir System Reliability Considering Water Rights and Water Quality – which are very similar to those used in the Water Availability Model for the Neches River, were also used here. For recreational and other uses, the distribution was set the same for each month. For the instream flow requirements, the monthly requirements were stated in each water right, which was then used to determine the monthly factors as a percentage of the annual amount.

4.2.3 Water Rights

Water right data input into the model included the annual diversions, water use types, priority dates, return flow locations and percent of flow estimated to return, reservoir storage (input on reservoir storage records associated with that water right), and instream flow requirements (input on instream flow requirement records associated with that water right.

4.2.3.1 Priority Dates

Water rights may have a single or multiple priority dates establishing their time priorities for diverting and/or impounding water. If a right has more than one priority date, it is most likely due to an amendment to the original permit. Amendments are often written to increase the diversion amount, change the type of use, increase the storage capacity of a reservoir, or add a reservoir. Each water right priority date was input into the model to define the original rights and any amendments so that water could be properly allocated to senior and junior water right holders as mandated by the doctrine of prior appropriation.

4.2.3.2 Annual Diversions

The TX-WRAP model has been designed such that the maximum diversion amount associated with each water right, along with its monthly distribution factors, cannot be exceeded in any given month or year. In this study, four different annual diversion scenarios were input into the model. Runs 1,2,and 3 utilized the fully authorized diversion amounts and did not include term water rights. Runs 4 and 6 utilized the full diversion amount for all water rights that reported water use in the last ten years and the diversion amount was set to zero for all water rights that did not report water use. No term water rights were included in these runs. Runs 5 and 7 utilized the maximum annual diversion amount for the last ten years for all water rights that reported water use and the demand was set to zero for all water rights with no reported use. There were no term water rights included in these runs. Run 8 utilized the maximum annual diversion amount for the last ten years and included term permits.

4.2.3.3 Reservoir Storage

In the TX-WRAP model, the reservoir storage record directly follows the water right record with which it is associated. Data entered on the reservoir record for all the minor reservoirs (those reservoirs with a capacity less than 5,000 acre-feet) included storage-area relationship parameters. The storage-area relationship parameters include a multiplier, exponent, and constant as shown in the equation below.

$$\text{Surface Area} = A*\text{Storage}^B + C$$

No area-capacity data was available on any of the minor reservoirs. Thus, in order to come up with appropriated values for the storage-area relationship parameters, the parameters used in other basin studies were examined. It was found that the most common values used, and thus used in this study, were 1.00, 0.727, and 0.00 for the exponent, multiplier, and constant, respectively.

4.2.3.4 Lake Texana

The only reservoir that had actual storage-area data entered into the model was Lake Texana. Certificate of Adjudication No. 16-2095 authorizes the owner to store 170,300 ac-ft of water in Stage I of the reservoir and 93,340 ac-ft of water in Stage II of the reservoir. Owner is authorized to divert and use 79,000 ac-ft of water per year from the Stage 1 reservoir and 48,122 ac-ft of water per year from the Stage II reservoir. Of the 79,000 ac-ft per year authorized for diversion from Stage I, the Texas Natural Resource Conservation Commission found that releases for bays and estuaries could impact the firm yield of the Stage I reservoir by reducing it up to 4,500 ac-ft per year. Additionally, as part of an agreement between various water right owners, the Texas Water Development Board, the Lavaca-Navidad River Authority and the Texas Natural Resource Conservation Commission, diversions of certain upstream irrigators were limited to those times when the level of Lake Texana was in excess of 43 msl.

Presently, only Stage I of Lake Texana is complete. The permitted conditions involved incorporating Stage II of Lake Texana. Stage II of Lake Texana involves extending the existing dam embankment to the west, without increasing the height of the dam, so that the Lavaca River flow is captured in the reservoir. For Runs 1-7, the actual permitted conditions were modeled with diversion from Stage II set to zero in Runs 4-7. Stage II of Lake Texana is commented out in Run 8, which simulates current conditions. Area capacity curves used in the model for Stage I of Lake Texana are based on data compiled from the Texas Water Development Board and provided by the Lavaca Navidad River Authority on March 14, 2001. The area capacity curve for Stage II of Lake Texana is based on information provided to the Region P Planning Group on October 19, 1999.

A water release schedule has been set for Stage I of Lake Texana to maintain the Lavaca-Matagorda Bay and Estuary System. This schedule is set such that “when 78.18% or more of the reservoir’s capacity contains stored inflows, all inflows into the reservoir up to the historical monthly median flow during the months of January (84.5 cfs), February

(142.4 cfs), March (86.8 cfs), July (126.5 cfs), November (68.3 cfs), and December (79.3cfs), and all inflows up to the historical monthly average flow in the months of April (806.8 cfs), May (1,169.3 cfs), June (1,191.4 cfs), August (265.7 cfs), September (1,027.3 cfs), and October (708.3 cfs) shall be passed through the reservoir and shall not be subject to diversion for other uses" and "when less than 78.18% of the reservoir's capacity contains stored inflows, all inflows up to the annual median daily flow for the drought period January 1954 through December 1956 (5 cfs) shall be passed through the reservoir and shall not be subject to diversion for other uses".

Prior to the commencement of Stage II, a schedule for the release of fresh water inflows from this stage for the maintenance of the Lavaca-Matagorda Bay and Estuary System must be established. Amendment B of the Certificate of Adjudication 16-2095 authorizes an annual use of 18,122 acre-feet of inflow from the Lavaca River for the maintenance of the Lavaca-Matagorda Bay and Estuary System. Because no schedule has been established, it was assumed in the model that this flow would be treated as a diversion from control point WQ002 using the same distribution as the Stage I bay and estuary releases with 100% of the diverted volume returned immediately downstream of the Stage II reservoir in each time step of the simulation. Input file is as follows:

```
**begin Stage 2 of Texana Project
WR WQ002     7150        119720515    1    1     0.00                             61602095_3
TEXANA2
WSSTAGE2   62454
WR WQ002    22850        219720515    1    1     0.00                             61602095_4
TEXANA2
WSSTAGE2   62454
WR WQ002   18122  BAYES119931006   1   1     1.0   20955                     2095_5
```

In order to simulate the Stage I bay and estuary release schedule, Lake Texana was modeled as follows:

```
IFDV221B    3570        19720515   1    2       1             IF2
IFDV221A  346972  BAYEST19720515   1    2       2             IF1
WRDV221A   74500       TA19720515   1    1     0.00                           61602095_1
TEXANA1
WSTEXANA  151919
WRDV221A        0       TA19820524   1    2     0.00   RSRTRN                  61602095_2
TEXANA1
```

```
WSTEXANA  151919
WRDV221A       0        19850501   1
WSTEXANA  170300
WRDV221A   34560        20010501   1   1     1.0    NOUT                INTURUP1
WSTEXANA  170300                             151919
WR       NOUT          34560                            20010501          1           1
INTURUP2INTURUPT
SO          2880   4500
WR  NOUT   99000        20010501   1   1     1.0  DV221A                 PAYBACK
** FINAL FILLUP FOR LAKE TEXANA
WRDV221A       0        20010504   1
WSTEXANA  170300
** DROUGHT INDEX RECORDS for B&E when below 78.18% conservation
DI     1   0   1  TEXANA
IS     6       0   10000  100000  133140  133141  170300
IP           100     100     100     100       0       0
**
** DROUGHT INDEX RECORDS for B&E when above 78.18% conservation
DI     2   0   1  TEXANA
IS     6       0   10000  100000  133140  133141  170300
IP             0       0       0       0     100     100
**
** DROUGHT INDEX RECORDS water rights that have the 43 ft msl restriction.
DI     3   0   1  TEXANA
IS     6       0   10000  100000  151919  151920  170300
IP             0       0       0       0     100     100
```

a. Two control points, DV221A and DV221B, reflecting the different release schedules were inserted downstream of the reservoir and instreamflow restrictions representing the different release schedules were assigned to these control points with priority dates the same as Lake Texana, May 15, 1972. IFDV221B represents the release schedule applied when the level of Lake Texana drops below 78.18%. IFDV221A represents the release schedule for those times when the level of Lake Texana is at or above 78.18%.

b. The diversion of 74,500 ac-ft (Lake Texana’s firm water) from Control Point DV221A was modeled with a priority date of May 15, 1972.

c. To provide for diversions by upstream junior irrigators when the stage of Lake Texana is above 43 msl, the WS card (WSTEXANA) associated with WRDV221A, was set at the capacity of Lake Texana at 43 msl, 151,919 ac-ft.

d. After the upstream irrigators have diverted flow available at their respective control points, Lake Texana is refilled to 45 msl or 170,300 ac-ft. The priority date of the refill is modeled as one day junior to the most junior upstream irrigator. (May 1, 1985).

e. After the refill is completed, the model begins diversion of the 4,500 ac-ft of interruptible water. A diversion of 2,880 ac-ft per month (34,560 ac-ft per year) is taken (by Water Right INTURUP1) and returned to a phantom control point NOUT. A second direct diversion (by Water Right INTURUP2) then occurs for any available flow at NOUT constrained by 2880 ac-ft per month and 4,500 ac-ft per year. After the diversion is made, all unused water at NOUT is re-diverted by Water Right PAYBACK and returned to storage in Lake Texana. This sequence starts and finishes in every month of the model time step. For modeling purposes, the priority date assigned to the diversion of water by INTURUP1, INTURUP2 and PAYBACK was May 1, 2001. This ensured that diversion of the 4,500 ac-ft of interruptible water would not negatively impact the reliabilities of the upstream irrigators.

4.2.3.5 Return Flows

Return flows associated with water rights have been specified as fractions of the authorized diversion amounts. For all of the irrigation water rights, the fraction used when there is no reuse was 15%. This was the same value used in the naturalized streamflow calculations. The irrigation return flows associated with the imported flows from the Garwood Irrigation District and the Gulf Coast Water Division also had to be accounted for. To do this, constant monthly values to be used for each year were estimated and input onto constant inflow records. The twenty years worth of data obtained from the LCRA for both these imports was used to estimate these values. It was decided that the worst-case scenario should be used, which is the minimum return flow amount. These return flows were only accounted for in Run 8.

The only municipal and industrial water right located in the Lavaca River Basin was associated with Lake Texana. From the minimal return flow data available for this water right, it was determined that the amount of flow returned is 0%. In the two coastal basins, no municipal water rights exist. However, in the Colorado-Lavaca Coastal Basin, there are seven industrial water rights and in the Lavaca-Guadalupe Coastal Basin, there are no water rights authorizing diversion for industrial use. Only four of the seven water rights authorizing industrial use in the Colorado-Lavaca Coastal Basin were input into the model. The remaining three were not modeled because they were determined to be saline water rights. From the small amount of return flow data obtained from the TNRCC, it was determined that three of the four industrial water rights modeled in the Colorado-Lavaca Coastal Basin had zero return flow and the fourth had a return flow of 77.2%. These values were input into each of the runs modeled except for those runs with reuse – in which case the 77.2% return flow was adjusted appropriately.

Wastewater return flows also had to be accounted for. According to Resolved Technical Issues numbers 14 and 17 established by the TNRCC, the minimum wastewater return flows within the last five years are to be used and entered on constant inflow records. Aside from the return flows entered on the constant inflow records, the fractions, return flow locations, and timing of the return flows were entered on the water right records. The model allows the user to input a return flow location for each diversion. If no return flow location is input, the model assumes that the flow is returned at the next downstream control point. The timing of the return flow can be specified either as returning in the same month as the associated water right diversion or during the next month. For all three basins, it was assumed that the flow would return during the next month, since the primary crop in the basin is rice which requires “ponding” time before excess water is released as return flow. This was the same assumption made in the naturalized streamflow calculations. The TX-WRAP model determines the return flows by multiplying the computed monthly diversion by the assigned return flow factor specified on the water right record. For the return flows associated with imported water and wastewater discharges, the location of their returns were entered on the constant inflow records.

4.2.3.6 Multiple Diversion Locations

There are several water rights with multiple diversions in the three basins of study. Water rights with multiple diversions and the number of diversions associated with each are shown in Table 6.

Table 6

Water Rights with Multiple Diversion Locations

Lavaca River Basin		Colorado-Lavaca Coastal Basin		Lavaca-Guadalupe Coastal Basin	
Water Right Number	Number of Diversions	Water Right Number	Number of Diversions	Water Right Number	Number of Diversions
61602077	2	61504776	2	11705584	6
61602085	2	61504778	2	61805173	2
61602086	2	61504781	4	61805174	2
61602094	2	61504783	2	61805175	2
61602096	2	61504790	2	61805176	2
11603876	2	61504791	2	61805177	2
11603907	2	11505487	2	61805178	2
11603911	2			61703864	2
11604252	3				
11605584	3				

4.2.3.7 Water Rights Requiring Special Consideration

A number of water rights in the Lavaca River and Colorado-Lavaca Coastal Basins have limitations based on minimum instream flow requirements and thus require special consideration. The certificates of adjudication and permits indicate which rights have instream flow requirements. These limitations require that a certain amount of flow be in the stream from which the diversion is taking place before the diversion is made. In the TX-WRAP model, these limitations were addressed by inputting an instreamflow requirement record preceding each water right with this limitation. This record requires that the annual instreamflow requirement, demand distribution or use type identifier, and priority date be input. Each instreamflow requirement was assigned different use type identifiers representing different demand distributions. Table 7 lists the water rights with instreamflow requirements, in the order in which they were entered into the model.

Table 7

Water Rights with Instreamflow Requirements

Lavaca River Basin		Colorado-Lavaca Coastal Basin
11603978	11604241	11504243
11603912	11603665	61504780
11604102	11604046	61504790
11603910	11603725	
11603905	11603876	
11604252	11603911	
11605370	11603836	
11604085	11603909	
11603906	11603727	
11603904	11603907	
11603908	11603903	

4.2.4 Data for Basin Specific Features Added to TX-WRAP Model

No basin specific modifications were made to the TX-WRAP model for the water availability study of the Lavaca River, Colorado-Lavaca Coastal, and Lavaca-Guadalupe Coastal Basins. For this reason, no special data was required in addition to that needed to run the basin TX-WRAP.

4.3 Assumptions Affecting Water Availability Modeling

4.3.1 Reuse

At this time, it is unknown as to whether there is any reuse operations occurring within the three basins. The only modifications made to reflect different levels of reuse have been those required by the TNRCC for the purpose of evaluating different reuse effects on water availability. A description of the different reuse scenarios run can be found in Section 5.1.1.

4.3.2 Return Flows/Constant Inflows

Surface water return flow was specified as a fraction of the diversion amount and thus varies monthly similar to that of the diversion when the reuse is not 100%. As discussed in Section 4.2.3.4, wastewater discharges locations and return flow locations associated with imported water were entered on constant inflow records which included the input of the control point name where the inflow occurs and the monthly distribution of flow.

4.3.3 Off-Channel Reservoirs

Several off-channel reservoirs are located within the three basins – most of which are permitted to store water diverted from a stream and do not have any basin area draining into them. The water stored in these reservoirs is typically for irrigation purposes. The water rights with off-channel reservoirs are listed in Table 8 in the order in which they appear in the model.

4.3.4 Term Permits

There is one term permit in the Lavaca River Basin, two in the Colorado-Lavaca Coastal Basin and none in the Lavaca-Guadalupe Coastal Basins. A term permit is any permit with a time limitation to it. Permittees with term permits must apply for an extension if continued use past the expiration date of the term is desired. This permit is only included in Run 8.

5.0 WATER AVAILABILITY

5.1 Description of Scenarios Modeled

The TNRCC has defined eight different modeling scenarios to evaluate water availability. There are three specific water availability issues addressed: the monthly availability for each water right over the period of record for authorized diversion with varying return flow amounts, the availability if those water rights not diverting water in the last ten years are cancelled, and the availability of water if current conditions and term water rights are modeled.

5.1.1 Reuse Runs 1, 2, and 3

The first specific water availability issue, the effect of reuse on water availability, is evaluated by comparing the output of Runs 1,2 and 3 These scenarios have been defined by the TNRCC as 0% reuse or 100% of assumed return flow (Run 1), 50% reuse and 50% of assumed return flow (Run 2), and 100% reuse or 0% of assumed return flow (Run 3). These three modeling scenarios, include full diversion amounts, Stage II authorized area-capacity parameters, and no term permits.

5.1.2 Cancellation Runs 4, 5, 6, and 7

Under the Subchapter E, Chapter 11 of the Texas Water Code, the TNRCC has the authority to cancel a permit, certified filing, or certificate of adjudication if the authorized water has not been beneficially used during the last ten years. For this reason, four different scenarios (referred to as cancellation runs) will be run to incorporate the effect of cancellation or “zeroing” out of these water rights. Two of these scenarios use the authorized diversion amounts or zero if it is subject to cancellation. Run 4 includes the authorized diversion amount for those rights with reported use in the last ten years, zero for those rights with no reported use, and no return flows. Run 5 includes the authorized diversion amount for those rights with reported use in the last ten years, zero for those rights with no reported use, and 100 % return flows. The other two scenarios incorporate modified diversion amounts equal to the maximum use in the last ten years or zero if it is subject to cancellation. Run 6 includes modified diversion amounts and no return flow and Run 7 includes modified diversion amounts and 100% return flow. All four runs are also modeled with Stage II authorized area-capacity and no term permits. The TNRCC provided all diversion data for the last ten years that was available. This data was used to determine which rights were to be assumed as cancelled as well as the maximum diversion in the last ten years. If the maximum diversion exceeded the authorized diversion, the authorized diversion quantity was input into the model.

5.1.3 Current Conditions Run 8

The third water availability issue is limited to one scenario (referred to as the current conditions run) and incorporates modified diversion amounts equal to the maximum use for the last ten years, year 2000 area-capacity parameters, 100% of the assumed return flows, and term permits. This scenario will be referred to as Run 8.

5.2 Results from the Water Availability Model Runs

The eight different scenarios were run to provide an indication of water availability for each water right in the Lavaca River, Colorado-Lavaca Coastal, and Lavaca-Guadalupe Coastal Basins. Appendix D contains the reliability summaries for all model runs for each of the three basins. Appendix E contains the summary graphs of unappropriated and regulated flow at primary control points in the Colorado-Lavaca Coastal basin. Appendix F contains the summary graphs of regulated and unappropriated flow at representative control points in the Lavaca River Basin. The representative control points in the Lavaca River Basin include two control points above Lake Texana (GS500 and GS700), one control point on the Lavaca River (GS300) and one control point downstream of Lake Texana (GS100). Because the primary control points in the Lavaca-Guadalupe Coastal Basin were not influenced by water right diversions, regulated and unappropriated flow at the primary control points in this basin were identical and summary graphs were not provided in this report. Appendix G contains graphs of the monthly reservoir storage for Lake Texana and Stage II for all scenarios (Note: Stage II was not included in Run 8, the current conditions run, therefore a summary graph was not provided).

5.2.1 Reuse Runs

The results of the WRAP simulation (see Appendix E, Figures E1-E6) indicate that reuse has little impact on unappropriated and regulated flows in the Colorado-Lavaca Coastal Basin. In the Lavaca River Basin, comparison of the reuse scenarios indicates that reuse has some impact at primary control points GS500 and GS700 located upstream of Lake Texana (Appendix F, Figures F1-F8). This impact is primarily due to the influence of upstream irrigation return flows. The effect of return flows from the upstream irrigators also affects the monthly storage in Lake Texana as shown in the summary graph in Appendix G, Figure G1.

5.2.2 Cancellation Runs

The results of the WRAP simulation (see Appendix E, Figures E7-E18) indicate that cancellation and partial cancellation have little impact on unappropriated and regulated flows in the Colorado-Lavaca Coastal Basin. In the Lavaca River Basin, cancellation and partial cancellation resulted in a slight increase in unappropriated flow at GS300 (Appendix F, Figures F12 and F20). Partial cancellation also had a slight effect on unappropriated and regulated flows at GS500 and GS700 (Appendix F, Figures F21-24). Cancellation and partial cancellation increased the monthly reservoir storage in Lake Texana (Appendix G, Figures G2 and G3) and in Stage II (Appendix G, Figures G5 and G6).

5.2.3 Current Conditions Run

Regulated and unappropriated flows for the current conditions run indicate that reduced consumptive use has little impact in the Colorado-Lavaca Coastal Basin (Appendix E, Figures E19-E24). In the Lavaca River basin, regulated and unappropriated flows are greater at GS100, GS500 and GS700 (Appendix F, Figures F25-26 and F29-32). Unappropriated flows were greater at GS300 (Appendix F, Figure F28) for the current conditions scenario. This result is due to the reduced consumptive amounts and to the fact that Stage II was not included in Run 8. Monthly storage in Lake Texana was affected by the reduced consumptive diversion amounts used in Run 8 as shown in Appendix G, Figure G4.

5.3 Comparison to Existing River Basin Model

As mentioned in Section 2.4.1, one water availability study - referred to here as the Legacy Model - has been completed on the Lavaca River Basin to date and none have been completed for the two coastal basins. In Section 2.4.1 a comparison of the naturalized streamflows was made. The Run 6 naturalized streamflows (which are the same as the Run 4 naturalized streamflows) from the Legacy Model was compared to the naturalized streamflow calculation made in this study at each gaged station, but is not appropriate here because the naturalized streamflow estimates do not include Lake Texana Stage II area-capacity. The locations where the comparisons were made are at control points GS300, GS400, GS500, GS550, GS600, and GS1000, which correspond to USGS gage stations 08164000, 08163500, 08164500, 08164350, 08164300, and 08164450, respectively. There is very little literature on the Legacy Model and thus it is very difficult to explain the differences between the two models.

5.4 Firm Yield Analysis

The firm yield analysis was based on the Run 3 dataset and assumptions which include full authorized diversion amounts, full authorized capacities for reservoirs, and 100% reuse (no return flows). Lake Texana experienced no shortages during the Run 3 simulation, therefore the firm yield for this study is equal to the full authorized diversion amount of all rights associated with the reservoir.

5.5 Factors Affecting Water Availability and Modeling Results

There are three factors that may have an effect on the water availability and/or modeling results determined by the model. These three factors are associated with naturalized streamflow, return flow values, and reservoir release schedules.

Where historic streamflow data existed, the naturalized streamflows were directly computed. Where there was no historic flow data the naturalized streamflows were estimated, as described in Section 3.2.4, through making correlations.

For agricultural return flows, fifteen percent of the diverted flow was assumed to return to a stream. Although fifteen percent is a reasonable value and one commonly used in studies throughout the western United States, further studies could be conducted to determine whether there is a more appropriate value.

As a note, 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 the Colorado-Lavaca Estuary, will be considered when granting new water rights or amending existing water rights, thereby affecting the amount of water available for appropriation.

5.6 Requirements for Model Rerun and/or Model Update

Updates to the TX-WRAP runs will have to be made when any changes occur to water rights in the Lavaca River, Colorado-Lavaca Coastal, and/or Lavaca-Guadalupe Coastal Basins. This report includes all water rights as of September 2001. Any water rights or other control points added to the basin after this date require that watershed parameters for the points be obtained and the appropriate changes be made to the input deck for all of the model runs.

6.0 Summary and Conclusions

In response to the 1996 drought, the 57th Texas Legislature, under Senate Bill 1, directed the Texas Natural Resource Conservation Commission (TNRCC) to develop water availability models for 22 of the state's 23 river basins. These models were developed to provide a more accurate determination of the reliability of authorized diversions for existing water rights and the availability of water for new permit applications, while taking into account the Prior Appropriation Doctrine. The Prior Appropriation Doctrine dictates the priority by which water supplies will be allocated among existing water right within a basin. It is based on the concept of "first in time, first in right".

The basic procedure for analyzing water availability in a river basin is to simulate, on a monthly basis, the ability of water rights to satisfy their authorized diversion amount and/or storage quantity under historic hydrologic conditions. The TNRCC adopted the Texas A&M Water Rights Analysis Package (TX-WRAP, December 18, 2001) for use in calculating water availability under the various scenarios. This model allocates streamflow depletions based on available streamflow in accordance with the Prior Appropriation Doctrine.

The simulation results do not indicate that every water right within the Lavaca River Basin or the two coastal basins will be able to divert their fully authorized amounts 100% of the time. Factors affecting a water right's reliability include the size of the contributing watershed, whether the diversion is backed by reservoir storage, if the right has access to supplemental flows (imports or return flows), the priority of the right as compared to other rights in the basin and other similar reasons.

The simulation results do indicate that reuse and cancellation have no appreciable affect on regulated or unappropriated flows in the two coastal basins. Reuse does have a slight impact on flows upstream of Lake Texana and reuse also affects the monthly reservoir storage in Lake Texana. Cancellation and partial cancellation slightly affect unappropriated flows on the Lavaca River and slightly increase the monthly reservoir storage in Lake Texana and Stage II. Partial cancellation had an effect on flows upstream of Lake Texana. The assumptions of Run 8, reduced consumptive amounts and the exclusion of Stage II from the analysis, significantly affected available flow at the control points in the Lavaca River Basin and increased the monthly reservoir storage in Lake Texana.

The TNRCC utilizes Run 3 for determining water available for appropriation on a perpetual basis and Run 8 for granting new appropriations on a term basis. It should be noted that future appropriations of water will be subject to environmental flow needs in accordance with Chapter 11 of the Texas Water Code. Environmental flow needs include protection of instream flows and freshwater inflows to bays and estuaries. Consideration of environmental flows could have a significant impact on water available for appropriation in the Lavaca River Basin and the Colorado-Lavaca and Guadalupe-Lavaca Coastal basins.

Submitted to the Texas Water Digital Library on May 2, 2014, by Grant J. Gibson, P.G., Water Availability Modeling Coordinator, Texas Commission on Environmental Quality.