EXECUTIVE SUMMARY

The Texas Natural Resource Conservation Commission (TNRCC) was required by Senate Bill 1 (SB1) of the 75th Texas Legislature to develop new reservoir/river basin simulation models in order to determine water availability in accordance with the Texas Water Code. The objective of SB1 was to create fully documented reservoir/river basin models for 22 of the 23 river basins within Texas by December 2001. The models are to be used and maintained for each basin to facilitate the evaluation of existing permits, approval of permit applications, and development or review of overall management strategies. On December 20, 2000, the TNRCC authorized Espey Consultants, Inc. (EC) to estimate naturalized inflows and develop a water availability model for the Red and Canadian River Basins in Texas.

STUDY OBJECTIVES

The TNRCC mandated by SB1, is to conduct a water availability analysis to determine the:

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

Nine different scenarios were analyzed in this study to simulate the effects of the above-described parameters. Scenarios 1 through 8 were legislatively mandated, while Scenario 9 is basin specific. The eight mandated scenarios include: three reuse scenarios, four cancellation scenarios and one current conditions scenario (which includes term permits). The basin specific scenario is a firm yield determination for all permitted reservoirs with capacities greater than 5,000 acre-feet per year (ac-ft/yr) in the Red and Canadian River Basins.

RED RIVER BASIN

The Red River Basin is surrounded by the Canadian River Basin on the north and the Brazos, Trinity, and Sulphur River Basins to the south. The Red River Basin encompasses portions of New Mexico, Texas, Oklahoma, Arkansas, and Louisiana. The basin has a total drainage area of approximately 94,450 square miles (sq. mi.), of which 73,671 sq. mi. actually contribute to flows. In Texas, the Red River Basin has a total drainage area of approximately 31,567 sq. mi. and a contributing drainage area of 25,631 sq. mi (Texas Water Development Board (TWDB), 1997). The Red River in Texas has eight major tributaries: Prairie Dog Town Fork, North Pease River, Middle Pease River, South Pease River, Wichita River, Little Wichita River, North Fork River, and Salt Fork River.

There are 271 separate existing water rights located within the Red River Basin in Texas. Locations of individual water rights are identified on the map in Appendix K, and are listed with general descriptive information, including permittee name and authorized diversion amounts, in Appendix A. The total authorized diversion amount for these water rights is approximately 642,933 ac-ft/yr as shown in the following table.

Use Category	Authorized Diversion (ac-ft/yr)
Municipal	325,639
Industrial	110,089
Irrigation	178,773
Other	28,432
Total	642,933

There are 24 major surface water reservoirs in Texas within the Red River Basin, the majority of which are water-supply reservoirs that have the potential to supply a total of over 555,000 ac-ft/yr. Permitted conservation storages range from 5,005 to 2,722,000 acre-feet (ac-ft). The Red River Basin's total permitted conservation storage in Texas is 3,951,882 ac-ft.

CANADIAN RIVER BASIN

The Canadian River begins in northeastern New Mexico, flows eastward across the Texas Panhandle into Oklahoma, and merges with the Arkansas River in eastern Oklahoma. The basin has a drainage area of approximately 22,866 sq mi, of which 12,700 sq mi lie within Texas (TWDB, 1997). The Canadian River in Texas has three major tributaries, Rio Blanca Creek, Coldwater Creek, and Palo Duro Creek.

There are 37 separate existing water rights located within the Canadian River Basin in Texas. Locations of individual water rights are identified on the map in Appendix K, and are listed with general descriptive information, including permittee name and authorized diversion amounts, in Appendix A. The total authorized diversion amount for these water rights is approximately 153,807 ac-ft/yr as shown in the following table.

Use Category	Authorized Diversion (ac-ft/yr)
Municipal	100,000
Industrial	51,490
Irrigation	2,287
Other	30
Total	153,807

There are three major surface water reservoirs within the Canadian River Basin in Texas. Two of these reservoirs are water-supply reservoirs. Lake Meredith supplies water within the basin to the cities of Borger and Pampa and Lake Palo Duro provides water to the Palo Duro River Authority's member cities. Rita Blanca Lake is operated by Dallum and Hartley counties for recreational purposes (TWDB, 1997).

PROCEDURES

Procedures and criteria for undertaking the water availability analyses for all basins in Texas have been developed by the Water Availability Modeling (WAM) Management team, consisting of representatives from the TNRCC, Texas Parks and Wildlife Department (TPWD), and the Texas Water Development Board (TWDB). These procedures include the development of naturalized streamflows from historical hydrological information, utilization of the Water Rights Analysis Package (WRAP) program, and adhering to the Texas prior appropriation system, the Texas Water Code and water management and regulatory policies set by the TNRCC.

Naturalized streamflows are the flows that would have occurred in the absence of human activities such as reservoir development, diversions, and return flows. Naturalized flows are used so that historical diversions, impoundments, and returns do not affect the water availability analysis. Naturalized flows at primary control points are based on historical hydrologic records, adjusted to remove the impact of human activities. The flows are used as input to the water availability model, which simulates the operation of existing water rights considering their location, characteristics, and priority under Texas water law. Naturalized streamflows were developed for selected United States Geological Survey (USGS) gage locations as well as specific reservoir sites in the Red and Canadian River Basins for each month over a 51-year historical period of record. The locations where naturalized streamflows were developed are called primary control points, and basically describe the spatial configuration of the river basin. Section 4.2.1 of the report gives a more detailed explanation of primary and secondary control points in WRAP (DECEMBER, 2001).

Water availability calculations were performed using the WRAP (DECEMBER, 2001) model, developed by Dr. Ralph A. Wurbs at Texas A & M University. The WRAP model incorporates the Prior Appropriation Doctrine and was selected by TNRCC in 1998 to simulate the water availability in Texas. WRAP has been used in a wide variety of different types of water rights throughout Texas. Specifically for TNRCC, the Sulphur, Neches, San Jacinto, San Antonio, Nueces and Guadalupe River Basins have been modeled to determine the water availability in accordance with SB1 time requirements. WRAP utilizes monthly time steps, historical hydrologic river basin characteristics, and the specific water right information to determine the available water. The model performs a sequential monthly water volume accounting computation by determining if TNRCC permitted water diversions can be made at a particular location during a specified hydrologic period of analysis under given historic hydrologic conditions. The model is set up to allow water rights that have seniority the first right at diversion ("first in time, first in right").

The specific steps taken to develop the Water Availability Models for the Red and Canadian River Basins were to collect, analyze and compile data needed for input into WRAP (DECEMBER, 2001). Data required for input into the model include primary and secondary control points, naturalized flows, classified stream segments, evaporation, water rights information, reservoir area-capacity curves, return flows for facilities permitted above 1 million gallons per day (MGD), locations of water rights and return flows and water use demand patterns. Nine scenarios were analyzed using WRAP (DECEMBER, 2001) to determine the effects of the parameters as outlined in the study objectives.

The principal results from the water availability analyses are:

- Reliability of existing water rights
- Monthly estimates of unappropriated water that would be available for diversion and/or storage.

The results of the water availability analysis performed for varied cancellation and reuse policies satisfies the requirements of SB1. Results presented in this draft report are only a partial summary of the complete output generated by WRAP (DECEMBER, 2001). The complete water availability outputs for existing water rights in the Red and Canadian River Basins are available from the TNRCC.

Existing data on the Red and Canadian River Basins are limited prior to 1940; therefore, this study will use hydrologic data from January 1948 through December of 1998 as the period of record. This period of record was selected because sufficient data are available to make the modeling effort reliable and because it encompasses the droughts periods including 1951-1956, 1963-1964, 1965-1967, 1980, 1984, 1988, and 1996.

RESULTS

Reliability results from the water availability analysis, for the eight base scenarios for the Red and Canadian River Basins are presented at the end of this Executive Summary in Tables ES-Red-1 through ES-Red-3for the Red River Basin and Tables ES-Canadian-4 through ES-Canadian-6. These tables list all water rights with authorized diversions and give a unique identification number for each water right in the Red and Canadian River Basins. In many cases a water right has multiple entries which result from a water right having multiple diversion locations, use types, and priority dates, all of which are used in the WRAP (DECEMBER, 2001) model to simulate the written permit. The result tables list the authorized diversion amount, the simulated mean annual shortage, and the period and volumetric reliability for the 51-year period of record. Period reliability, expressed in percent is defined as the ratio of number of months for which no shortages occurred to the total number of months in the simulation period. Volumetric reliability, expressed as a percent, represents the ratio of the mean actual annual diversion to the corresponding authorized annual diversion amount. The non-use of the diversion amount could be from a partial or total cancellation of that portion of the water right or due to a grouping of the total amount of the water right at one identification number.

There are 24 major surface water reservoirs in Texas within the Red River Basin and 3 within the Canadian River Basin with capacities over 5,000 ac-ft. The remaining permitted reservoirs in the basins (under 5,000 ac-ft) are used for impoundment for individual water rights in the basin. As mentioned previously, firm yield analysis were only performed on those reservoirs with impoundments greater than 5,000 ac-ft. Results of these firm yield simulations are not included in this report because the watershed parameters (drainage areas) for the Red and Canadian Basins used to generate these yields were estimates. TNRCC will provide the actual drainage areas, curve numbers and precipitation values developed by the University of Texas Center for Research in Water Resources (CRWR). Once these values are received, the simulation will be performed and the results will be presented in the final report.

CONCLUSIONS

The Texas A&M WRAP model (DECEMBER, 2001) has been applied to the Red and Canadian River Basins in Texas to determine the water availability. All of the 271 water rights in the Red River Basin and 37 water rights in the Canadian River Basin were included in the model. Water availability was calculated in three basic scenarios: (1) Reuse (full authorized diversions with varying return flow amounts), (2) Cancellation (varying diversion and return flow amounts based on cancellation of water rights), and (3) Current Conditions (maximum use diversions with return flows using year-2000 area-capacity reservoir relationships. All scenarios utilized:

- 51-year period of naturalized flows (1948 thought 1998).
- Water rights information for all water rights issued by the TNRCC through February 1999.

The WR, WS and OR records in WRAP (DECEMBER, 2001) characterize the written permit and other pertinent information required for input into the computer model. No system operations were modeled unless authorized in the written permit. Nine scenarios were performed; eight base scenarios and one basin specific scenario (firm yield). Primary conclusions of this water availability study are presented in general terms because of the estimated drainage areas. Specific conclusions and recommendations will be included in the final report once the final watershed parameters are received. The primary conclusions for the Red and Canadian River Basins include:

- The Red River Basin, located in northern Texas, drains an area of approximately 94,450 sq mi, of which 73,671 sq mi lie within Texas. There are a total of 271 water rights with approximately 642,933 ac-ft/yr authorized annual diversions.

- The Canadian River Basin, located in northern Texas, drains an area of approximately 22,866 sq mi, of which 12,700 sq mi lie within Texas. There are a total of 37 water rights with approximately 153,807 ac-ft/yr authorized annual diversions.

- Comparisons of the three reuse scenarios show that in general reuse has a minimal impact on the water supply in both the Red and Canadian River Basins. In the Red River Basin there few large wastewater discharge facilities that contribute substantial percentages to the streamflow in the river. Likewise, in the Canadian River Basin, there are few discharge facilities and the arid climate and groundwater interactions generally minimize any wastewater return flows. However, when small impacts did occur, the reliability of a water right generally decreases as the level of reuse increases.

- Hypothetical partial cancellation of water rights based on maximum ten years historical use (Scenario 4 and 6) had minimal impact in both the Red and Canadian River Basins. However, scenarios that utilize the ten-year maximum use as the diversion amount, Scenarios 5, 7, and 8, can significantly affect the amount of reservoir storage, unappropriated and regulated flow because the actual historical diversions during the last ten years were substantially less than the fully appropriated amounts. The diversion amount used in these scenarios (Scenarios 5, 7, and 8) was 388,411 ac-ft/yr and 70,666 ac-ft ac-ft/yr less than the demand in Scenarios 1 for the Red and Canadian River Basins, respectively. This difference represents 68% and 43% of diversion amount in Scenario 1 for the Red and Canadian River Basins, respectively. Scenarios 5 and 7 had a greater impact on the water availability (when compared to Scenario 1) than the cancellation scenarios with full-authorized amounts (Scenarios 4 and 6).

- Although there were 24 major reservoirs in the Red River Basin that were included in the firm yield analysis, only Moss Lake, Lake Texoma and Santa Rose Lake met their diversion targets during the critical period. Therefore, these three reservoirs have "permitted firm yields" equal to their authorized diversion amounts. The majority of the reservoirs in the Red River Basin had significantly lower firm yields than previous studies. Firm yields calculated in this study were expected to be lower than those calculated in previous studies because this study allowed releases of inflow from upstream reservoirs that had a junior priority date. The Canadian River Basin has three major reservoirs and none of those reservoirs met their authorized diversion amount. References to previous studies can be viewed in Appendix F. Appendix F does not contain information or comparisons of firm yield data.

- Reliabilities of the water rights located on the Red River were generally higher because of the contributing flow from Oklahoma. Flows entering the Red River from Oklahoma were modeled based on the historical streamflows.

- The Red River Compact was modeled to curtail diversions of water rights based on flow requirements outlined in the Compact. In general the flow at the Arkansas-Louisiana State border was sufficient and most of these rights were not curtailed.

Reliabilities determined in this study are dependant on the estimated watershed parameters in the Red and Canadian River Basin.

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1.0 INTRODUCTION

1.1 Description of the Basin

1.1.1 Red River Basin

The Red River Basin is surrounded by the Canadian River Basin on the north and the Brazos, Trinity, and Sulphur River Basins to the south. The Red River Basin encompasses portions of New Mexico, Texas, Oklahoma, Arkansas, and Louisiana. The basin has a total drainage area of approximately 94,450 square miles (sq. mi.), of which 73,671 sq. mi. actually contribute to flows. In Texas, the Red River Basin has a total drainage area of approximately 31,567 sq. mi. and a contributing drainage area of 25,631 sq. mi. The population in the Texas portion of the basin increased from 506,030 to 513,007 from 1980 to 1990. By the year 2050, the Texas portion of the basin population is projected to be 728,000 (Texas Water Development Board (TWDB), 1997). A schematic of the Red River Basin can be found in Figure 1.

There are 271 separate existing water rights located within the Red River Basin in Texas. The locations of these water rights are also shown in Figure 1. In terms of major basin imports or exports, portions of the City of Amarillo receive imports from the Canadian River while Lake Texoma provides exports to the North Texas Municipal Water District in the Trinity Basin (TWDB, 1997). The Red River in Texas has eight major tributaries: Prairie Dog Town Fork, North Pease River, Middle Pease River, South Pease River, Wichita River, Little Wichita River, North Fork River, and Salt Fork River. There are 24 major surface water reservoirs in Texas within the Red River Basin with permitted conservation storages ranging from 5,005 to 2,722,000 acre-feet (ac-ft), as shown in Table 1. The Red River Basin's total permitted conservation storage in Texas is 3,951,882 ac-ft.

Surface water resources supply approximately 12% of the total water use in the Red River Basin while groundwater supplies the rest. Due to an anticipated reduction in irrigation water use of about 67% below current levels, the total water use for the basin is projected do decline over the 1990-2050 planning horizon. A total water use of about 600,000 ac-ft is projected by the year 2050. Estimated declines in groundwater availability resulting in insufficient quantities of groundwater to meet current and projected future levels of irrigation water requirements and increased irrigation technology associated with irrigation water use savings is primarily responsible for the anticipated reduction in irrigation water requirements. Overall, the water use pattern of the basin is not anticipated to change significantly over the planning horizon. Currently, no additional major water supply reservoirs are proposed for the Red River Basin. Reallocation and permitting of the unappropriated portion of Texas' share of Lake Texoma is recommended to take place in the 2045-2050 planning period. As a result, additional availability of surface water from Lake Texoma (TWDB, 1997).

Figure 1 Red and Canadian River Basins

Table 1 Major Reservoirs in the Red River Basin

Reservoir	Drainage Area (square miles)	Stream	Impoundment Date	Permitted Conservation Storage (ac-ft)
Lake Nocona	94	Farmers Creek	1961	25,389
Hubert H Moss Lake	65	Fish Creek	4/1966	23,210
Lake Texoma	33,783	Red River	1/1944	2,722,000
Valley Lake	8	Sand Creek	12/1960	15,000
Randall Lake	10.3	Shawnee Creek	1909	5,400
Coffee Mill Lake	39	Coffee Mill Creek	1938	8,000
Lake Bonham	29	Timber Creek	11/1969	13,000
Pat Mayse	175	Sanders Creek	9/1967	124,500
Lake Crook	52	Pine Creek	1923	12,000
Truscott Brine	26.2	Bluff Creek	12/1982	107,000
Lake Kemp	2,086	Wichita River	1922	318,000
Lake Diversion	N/A	Wichita River	1924	45,000
Santa Rosa Lake	336	Beaver Creek	1929	9,556
Lake Electra	14.7	Camp Creek	1950	8,730
North Fork Buffalo Creek	33	North Fork Buffalo	11/1964	15,400
Lake Kickapoo	275	North Fork Little Wichita River	2/1946	105,000
Lake Arrowhead	832	Little Wichita River	1966	228,000
Bivins	62	Palo Duro Creek	1926	5,122
Buffalo Lake	575	Tierra Blanco	6/1938	18,120
Mackenzie	188	Tule Creek	4/1974	46,450
Baylor Creek	40	Baylor	12/1949	9,200
Greenbelt	356	Salt Fork Red River	12/1966	59,800
Cibola National Forest	N/A	McClellan	1938	5,005
Lake Wichita	143	Holiday Creek	1901	23,000

Red River Compact

The Red River Compact is an interstate compact between Texas, Oklahoma, Arkansas and Louisiana. The portion of the Red River Basin considered in the compact includes all of the natural drainage area of the Red River and its tributaries east of the New Mexico-Texas state boundary and above its junction with Atchafalaya and Old Rivers. There are five principle purposes of the Red River Compact:

1. To promote interstate comity and remove causes of controversy between each of the affected states by governing the use, control and distribution of the interstate water of the Red River and its tributaries;

2. To provide an equitable apportionment among the Signatory States of the water of the Red River and its tributaries;

3. To promote an active program for the control and alleviation of natural deterioration and pollution of the water of the Red River Basin and to provide for enforcement of the laws related thereto;

4. To provide the means for an active program for the conservation of water, protection of lives and property from floods, improvement of water quality, development of navigation and regulation of flows in the Red River Basin; and

5. To provide a basis for state or joint state planning and action by ascertaining and identifying each state's share in the interstate water of the Red River Basin and the apportionment thereof.

The Red River Compact divides the Red River Basin into five reaches. Reach I includes the Red River and tributaries from the New Mexico-Texas state boundary to Denison Dam. Reach II is the Red River from Denison Dam to the point where it crosses the Arkansas-Louisiana state boundary and all tributaries which contribute to the flow of the river within this reach. Reach III includes the tributaries west of the Red River which cross the Texas-Louisiana state boundary, the Arkansas-Louisiana state boundary, and those which cross both the Texas-Arkansas state boundary and the Arkansas-Louisiana state boundary. Reach IV is comprised of the tributaries east of the Red River in Arkansas which cross the Arkansas-Louisiana state boundary. Reach V is the portion of the Red River and tributaries in Louisiana not included in Reach III or Reach IV.

Reach I is subdivided into four subbasins. Subbasin 1 includes the Texas portion of Buck Creek, Sand (Lebos) Creek, Salt Fork Red River, Elm Creek, North Fork Red River, Sweetwater Creek, and Washita River, together with all their tributaries in Texas which lie west of the 100^{th} Meridian. The Red River Compact states that the annual flow within this subbasin is apportioned 60% to Texas and 40% to Oklahoma. Subbasin 2 contains all of the tributaries of the Red River in Oklahoma and portions thereof from Denison Dam upstream to the Texas-Oklahoma state boundary at longitude 100 degrees west. The Red River

Compact states that Oklahoma has free and unrestricted use of the water within this subbasin. Subbasin 3 includes the tributaries of the Red River Basin in Texas from Denison Dam upstream to and including Prairie Dog Town Fork Red River. The Red River Compact states that Texas has free and unrestricted use of the water in this subbasin. For this subbasin, the model will have no restrictions on water right diversions resulting from the Red River Compact. Subbasin 4 is the mainstream of the Red River and Lake Texoma. This subbasin includes all of Lake Texoma and the Red River beginning at the Texas-Oklahoma state boundary at longitude 100 degrees west and continuing downstream to Denison Dam. The Red River Compact states that Oklahoma and Texas are apportioned 200,000 acre-feet each, these quantities include existing allocations and uses. Additional quantities are allocated as 50% to Texas and 50% to Oklahoma.

Reach II is subdivided into five subbasins. Subbasin 1 is completely within Oklahoma and flows into Subbasin 5 and then into the Red River at the Texas-Oklahoma state boundary downstream of Denison Dam. The Red River Compact allows Oklahoma unrestricted use of the water within Subbasin 1 that would eventually flow into the Texas portion of the Red River. Subbasin 2 includes those streams and their tributaries above certain existing and authorized or proposed damsites, wholly in Texas and flowing into the Red River downstream of Denison Dam and upstream of the Texas-Arkansas state boundary. The Red River Compact states that Texas has free and unrestricted use of the water in this subbasin. Subbasin 3, within Reach II, includes Little River and its tributaries above Millwood Dam in Arkansas. This subbasin is located entirely within Oklahoma and Arkansas. The Red River Compact states that Oklahoma and Arkansas will have free and unrestricted use of the water in this subbasin. Subbasin 4, within Reach II, consists of those streams and their tributaries above certain existing authorized and proposed damsites, originating in Texas and crossing the Texas-Arkansas state boundary before flowing into the Red River in Arkansas. Subbasin 4 is primarily composed of the Sulphur River Basin in Texas. The Red River Compact states that Texas has free and unrestricted use of the water within this subbasin. Subbasin 5, within Reach II, is the portion of the Red River including its tributaries, from Denison Dam down to the Arkansas-Louisiana state boundary, excluding all tributaries included in the other four subbasins of Reach II. The Red River Compact states that the Signatory States (Texas, Oklahoma, Arkansas and Louisiana) have equal rights to the use of runoff originating in this subbasin and undesignated water flowing into this subbasin, provided that the flow of the Red River at the Arkansas-Louisiana state boundary is 3,000 cubic feet per second (cfs) or more. No state is entitled to more than 25% of the water in excess of 3,000 cfs. For this modeling effort, it is assumed that no state uses more than 25% of the water in excess of 3,000 cfs. Further restrictions for Subbasin 5 are as follows:

1. Whenever the flow of the Red River at the Arkansas-Louisiana state border is less than 3,000 cfs but more than 1,000 cfs, Arkansas, Oklahoma and Texas shall allow water equal to 40% of the total weekly runoff originating in Subbasin 5 and 40% of the undesignated water flowing into Subbasin 5 to flow into the Red River for delivery to Louisiana.

2. Whenever the flow of the Red River at the Arkansas-Louisiana state border falls below 1,000 cfs, Arkansas, Oklahoma and Texas shall allow water equal to all the weekly runoff originating in Subbasin 5 and all the undesignated water flowing into Subbasin 5 to flow into the Red River as required to maintain a 1,000 cfs flow at the Arkansas-Louisiana state boundary.

3. Whenever the flow at Index, Arkansas, is less than 526 cfs Oklahoma and Texas shall each allow 40% of the total weekly runoff originating in Subbasin 5 to flow into the Red River. This provision shall be invoked at the request of Arkansas only after Arkansas has ceased all diversions from the Red River itself in Arkansas above Index and only if the previously stated restrictions have not caused a limitation on diversions in Subbasin 5.

4. Reservoirs within Subbasin 5 with a conservation storage capacity of 1,000 ac-ft or less in existence or authorized on the date of the Red River Compact shall be exempt from all previous restrictions mentioned above for Subbasin 5. A change in purpose or use of water from these reservoirs may be authorized without losing the exemption, if the quantity of use and storage is not increased. The exemptions do not apply to direct diversions from Red River to off-channel reservoirs or lands.

Reach III is subdivided into three subbasins. Subbasin 1 is the Texas portion of those streams crossing the Arkansas-Texas state boundary and flow through Arkansas into Cypress Creek Twelve Mile Bayou watershed in Louisiana. There are on water rights in Subbasin 1 and the drainage area does not contribute to the flow at the Arkansas-Louisiana state border. Subbasin 2, within Reach III, is the Arkansas portion of the streams flowing from Subbasin 1 into Arkansas, as well as other streams in Arkansas which cross the Arkansas-Louisiana state boundary and flow into Cypress Creek-Twelve Mile Bayou watershed in Louisiana. The flow in Subbasin 2 is totally within Arkansas and Louisiana and has no effect on water rights in Texas. Subbasin 3, within Reach III, includes the Texas portion of all tributaries crossing the Texas-Louisiana state boundary and flow into Caddo Lake, Cypress Creek-Twelve Mile Bayou or Cross Lake, as well as the Louisiana portion of these tributaries. Reach III, Subbasin 3 is the Red and Canadian River Basins. Subbasin 3 does not contribute to the streamflow at the Arkansas-Louisiana state border.

Reach IV is completely within Arkansas and does not affect the water availability within the Red River Basin in Texas. Reach V is completely within Louisiana and does not affect the water availability within the Red River Basin in Texas. Appendix T provides a detailed description of the modeling of the Red River Compact.

1.1.2 Canadian River Basin

The Canadian River begins in northeastern New Mexico, flows eastward across the Texas

Panhandle into Oklahoma, and merges with the Arkansas River in eastern Oklahoma. The basin has a drainage area of approximately 22,866 sq mi, of which 12,700 sq mi lie within Texas. The population of the basin in Texas declined from 1980 to 1990 by 5,650. In the year 2050, the census population projection anticipates a reversal of the 1980-1990 trends with a population of about 210,000 (TWDB, 1997). A schematic of the Canadian River Basin can be found in Figure 1.

There are 37 separate existing water rights located within the Canadian River Basin in Texas. The locations of these water rights are shown in Figure 1. The Canadian River in Texas has three major tributaries, Rio Blanca Creek, Coldwater Creek, and Palo Duro Creek. There are three major surface water reservoirs within the Canadian River Basin in Texas. Two of these reservoirs are water-supply reservoirs. Lake Meredith supplies water within the basin to the cities of Borger and Pampa and Lake Palo Duro provides water to the Palo Duro River Authority's member cities. Rita Blanca Lake is operated by Dallum and Hartley counties for recreational purposes (TWDB, 1997). These three existing major reservoirs in the Canadian River Basin have capacities ranging from 12,100 to 1,407,600 ac-ft and are listed in Table 2. The Canadian River Basin's total permitted conservation storage is 573,000 ac-ft.

Table 2 Major Reservoirs in the Canadian River Basin

Reservoir	Drainage Area (square miles)	Stream	Impoundment Date	Original Conservation Storage (ac-ft)
Lake Rita Blanca	1,062	Rita Blanca Creek	9/1941	12,100
Lake Meredith	16,048	Canadian River	1/1965	500,000
Palo Duro	614	Palo Duro Creek	1991	60,900

Groundwater resources supply approximately 99% of the annual water use for the Canadian River Basin. Due to an anticipated reduction in irrigation water use requirements of about 45% below current levels, the total water use is projected to decline over the 1990-2050 planning period. A total water use of about 1.023 million acre-feet is projected in the year 2050. Estimated declines in groundwater availability resulting in insufficient quantities of groundwater to meet current and projected future levels of irrigation water requirements and increased irrigation technology associated with irrigation water use savings is primarily responsible for the anticipated reduction in irrigation water requirements. Since locally-developable surface water supplies are scarce in the Canadian River Basin, it is estimated that by 2050 over 21,000 ac-ft per year of the basin water use needs will be supplied by reuse (TWDB, 1997).

Canadian River Compact

The Canadian River Compact is an interstate compact between New Mexico, Texas and Oklahoma. The Canadian River includes the tributary of the Arkansas River that extends from northeastern New Mexico and flows eastward across the Texas Panhandle into Oklahoma in addition to the North Canadian River. The North Canadian River originates in northeastern New Mexico and flows eastward reaching into the Texas Panhandle as it crosses Oklahoma until it merges with the Canadian River in eastern Oklahoma. The major purposes of the Canadian River Compact are to promote interstate comity; to remove causes of present and future controversy; to make secure and protect present developments within the signatory states; and to provide for the construction of additional works for the conservation of the waters for Canadian River.

The Canadian River Compact states that New Mexico shall have free and unrestricted use of all waters originating in the drainage basin of the Canadian River above Conchas Dam in New Mexico. New Mexico is also allowed free and unrestricted use of all waters originating in the drainage basin of Canadian River in New Mexico below Conchas Dam, provided that the total amount of conservation storage in New Mexico available for impounding these waters below Conchas Dam is not greater than 200,000 ac-ft. New Mexico's right to provide conservation storage in the North Canadian River drainage basin is limited to the storage of such water that at the time is unappropriated under the laws of New Mexico and Oklahoma.

The Canadian River Compact states that the right of Texas to impound waters of the North Canadian River in Texas is limited to storage for municipal uses, for household uses, livestock watering, and the irrigation of lands which are cultivated solely for the purpose of providing food and feed for the householders and domestic livestock actually living or kept on the property. Exclusive of reservoirs in the drainage basin of North Canadian River, Texas can impound and retain 500,000 ac-ft of water in conservation storage until no more than 300,000 ac-ft of conservation storage is provided in Oklahoma, exclusive of the reservoirs in the drainage basin of the North Canadian River and exclusive of reservoirs east of the 97th Meridian. Once more than 300,000 ac-ft of conservation storage is provided in Oklahoma, exclusive of the reservoirs in the drainage basin of the North Canadian River and exclusive of the reservoirs east of the 97th Meridian, Texas can impound and retain 200,000 ac-ft plus whatever amount of water shall be at the same time in conservation storage in the previously described Oklahoma drainage basin of the Canadian River. For the purpose of determining the amount of water in conservation storage, the Canadian River Compact considers the maximum quantity of water in storage following each flood or series of floods. Oklahoma is allowed free and unrestricted use of all waters of the Canadian River in Oklahoma. Appendix T provides a detailed description of the modeling of the Canadian River Compact.

1.2 Study Objectives

The objective of this study is to meet the requirements placed on the Texas Natural Resource Conservation Commission (TNRCC) by Senate Bill 1. Senate Bill 1, passed by the 75th Texas Legislature, requires that the TNRCC develop or acquire new reservoir/river basin simulation models in order to determine water availability in 22 river basins within Texas. On December 20, 2000, the TNRCC authorized Espey Consultants, Inc. (EC) to estimate naturalized inflows and develop a water availability model for the Red and Canadian River Basins in Texas.

In order to meet the study objectives for the Red and Canadian River Basins Water Availability Study two tasks had to be performed:

- Calculation of naturalized flows.
- Development of a water availability model using Texas A&M's Water Rights Analysis Package (WRAP (DECEMBER, 2001)).

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

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

1.3 Study Approach

Procedures and criteria for undertaking the water availability analyses for all basins in Texas have been developed by the WAM Management team, consisting of representatives from the TNRCC, Texas Parks and Wildlife Department (TPWD), and the Texas Water Development Board (TWDB). These procedures include the development of naturalized streamflows from historical hydrological information, utilization of the WRAP program, and adhering to the Texas prior appropriation system, the Texas Water Code, and water management and regulatory policies set by the TNRCC.

The WRAP (DECEMBER, 2001) program, developed by Dr. Ralph A. Wurbs at Texas A & M University, simulates a basin using monthly time steps, historical hydrologic river basin characteristics, and the Texas prior appropriation system. The model performs a sequential monthly water volume accounting computation by determining if TNRCC permitted water diversions can be made at a particular location during a specified hydrologic period of analysis given historic hydrologic conditions. The model is set up to allow water rights that have seniority the first right of diversion ("first in time, first in right").

The steps taken to develop the Red and Canadian River Basins Water Availability Models were to collect, analyze, and compile data for a period from 1948 through 1998. Data required for input into the model include control points, naturalized flows, evaporation rates, water right data, reservoir area-capacity curves, return flows, and water use demand patterns. Once the data were obtained, nine model scenarios were analyzed using WRAP (DECEMBER, 2001) to determine the water availability for the 1948-1998 hydrologic period. Section 5.1 describes the WAM scenarios in more detail.

The principal results from the water availability analyses are:

1. *Reliability of existing water rights*

   The results of the water availability analysis under varied cancellation and reuse policies satisfy the requirements of SB1. Results presented in this draft report are only a partial summary of the complete output generated by WRAP (DECEMBER, 2001). The complete water availability output for existing water rights in the Red and Canadian River Basins are available from the TNRCC.

2. *Monthly estimates of unappropriated water that would be available for diversion and/or storage.*

Naturalized streamflows are the flows that would have occurred in the absence of human activities such as reservoir development, diversions, and return flows. Naturalized flows are used so that historical diversions, impoundments, and returns do not affect the water availability analysis. Naturalized flows at primary control points are based on historical hydrologic records, adjusted to remove the impact of human activities. They are used as input to the water availability model, which simulates the operation of existing water rights considering their location, characteristics, and priority under Texas water law. Naturalized flows at secondary control points are estimated from nearby primary control points.

Existing data on the Red and Canadian River Basins are limited prior to 1948; therefore, this study will use hydrologic data from January 1948 through December of 1998 as the period of record. This period of record was selected because sufficient data are available to make the modeling effort reliable and because it encompasses the droughts of 1951-1956, 1963-1964, 1965-1967, 1980, 1984, 1988, and 1996.

2.0 EXISTING WATER AVAILABILITY INFORMATION

Key data for water availability modeling include water rights, historical water use, historical return flows, historical streamflow, reservoir data, and evaporation rates. This section discusses available information for the key data as well as previous water availability and planning studies.

The initial intent of the naturalized flow procedure was to calculate the naturalized flow for 43 control points in the Red River Basin distributed in Texas, Oklahoma and Arkansas. However, while compiling the diversion, return flow and reservoir data for all three states, TNRCC determined that naturalizing the flow in Oklahoma and Arkansas would not be possible with the data that was available.

Data collected from Oklahoma consisted of hundreds of water rights with only one or two years of water use records. Of these records, the water use was reported in an annual value so estimates of monthly distribution would have to be determined. Likewise, the return flow data collected from Oklahoma was for a small period of record (1989 through 1998). The Environmental Protection Agency (EPA) provided additional data on several of the large wastewater discharge facilities in Oklahoma but only after 1982. No data could be obtained prior to 1982. Similar data problems were encountered in Arkansas. Since the period of record for this project is 1948 through 1998, most of the data that would be used to naturalize the streamflow would be estimated values. The decision was made by TNRCC to only naturalize the flow for the Texas portion of the Red River Basin. A detailed description of the naturalization process can be found in *Deliverable 2 – Final Naturalized Streamflows for the Red and Canadian River Basins.*

2.1 Water Rights

There are 271 water rights in the Red River Basin and 37 water rights in the Canadian River Basin.

Table 3 provides a summary of water rights by sub-watershed. Information regarding water rights was obtained from the TNRCC master water rights database and from hard copies of the water rights. Appendix A lists water rights in the Red and Canadian River Basins sorted by river order number and sequenced from downstream to upstream. Appendix B is the same database sorted by priority date from the most senior water right to the most junior water right. Current water rights documents (all Certificates of Adjudication and Permits issued by the TNRCC through February 1999) were reviewed and compared to the TNRCC database and the database was revised when appropriate. A revised database with suggested corrections was prepared and submitted to the TNRCC and is shown in Appendix C.

2.2 Historical Water Use

Surface water resources supply approximately 12% of the total water use in the Red River Basin while groundwater supplies the rest. Surface water is supplied by 24 reservoirs in the basin. Water used for irrigated agriculture is the major surface water use in the basin. In 1990, the total water use for the Red River Basin was approximately 1.224 million acre-feet. Between 1980 and 1990 total water use declined 296,000 ac-ft. A decline in water requirements for irrigated agriculture of more than 313,000 ac-ft is primarily responsible for the decline in water usage. Approximately 86% of the total water used in the Red River Basin is associated with agricultural irrigation. Between 1980 and 1990 municipal water use increased slightly in the basin. In terms of major basin imports and exports, water is imported to the City of Amarillo from the Canadian and water is exported to the North Texas Municipal Water District in the Trinity Basin (TWDB, 1997).

Table 3 Summary of Water Rights by Sub-Watershed (ac-ft/yr)

Sub-Watershed	Upstream Control Points	Downstream Control Points	Municipal	Industrial	Irrigation	Others	Total
Red River Basin							
PD_WA		Prairie Dog Town Fork, Red River near Wayside	2		2,285	5,400	7,687
PD_CH	Prairie Dog Town Fork, Red River near Wayside	Prairie Dog Town Fork, Red River near Childress	4,417	1,200	1,461		7,078
GC_QN		Groesbeck Creek at SH6 near Quanah			319		319
SF_WL		Salt Fork, Red River near Wellington	14,530	500	4,497	750	20,277
SW_KT		Sweetwater Creek near Kelton			531		531
PR_CS		Pease River near Childress	50		625		675
PR-VN	Pease River near Childress	Pease River near Vernon			45		45
RR_BB	Pease River near Vernon Groesbeck Creek at SH6 near Quanah Prairie Dog Town Fork, Red River near Childress	Red River near Burkburnett		7,137	522		7,659
NW_PD		North Wichita River near Paducah			36		36
NW_TS	North Wichita River near Paducah	North Wichita River near Truscott				3,050	3,050
SW_GR		South Wichita River at low flow dam near Guthrie					0
SW_BJ	South Wichita River at low flow dam near Guthrie	South Wichita River near Benjamin				8,780	8,780
WR_SM	North Wichita River near Truscott South Wichita River near Benjamin	Wichita River near Seymour			405		405
WR_MB	Wichita River near Seymour	Wichita River near Mabelle			2,153		2,153
SS_DD	Wichita River near Mabelle	South Side Canal near Dundee					0
BC_ET		Beaver Creek near Electra	1,515		4,200	30	5,745
WR_WF	South Side Canal near Dundee Beaver Creek near Electra	Wichita River at Wichita Falls	1,640		776	30	2,446
WR_CH	Wichita River at Wichita Falls	Wichita River near Charlie	32,439	40,000	121,362	10,202	204,003
LW_AC		Little Wichita River near Archer City	42,136		65		42,201

Table 3 Summary of Water Rights by Sub-Watershed (ac-ft/yr) (Continued)

Sub-Watershed	Upstream Control Points	Downstream Control Points	Municipal	Industrial	Irrigation	Others	Total
Red River Basin							
LW_HN	Little Wichita River near Archer City	Little Wichita River above Henrietta	45,100				45,100
EF_HN		East Fork Little Wichita River near Henrietta					0
RR_TR	Little Wichita River above Henrietta East Fork Little Wichita River near Henrietta Wichita River near Charlie Red River near Burkburnett	Red River near Terral	1,784	270	4,350	1	6,405
RR_GA	Red River near Terral Moss Lake near Red River	Red River near Gainesville	2,366		263	89	2,718
ML_RR		Moss Lake near Red River	4,500		23		4,523
RR_CB	Red River near Gainesville	Red River near Colbert	46,580	14,000	1,018	100	61,698
RR_AC	Red River near Colbert	Red River near Arthur City	114,360	46,750	20,109		181,219
RR_IN	Red River near Arthur City	Red River at Index	14,220	232	12,390		26,842
EF_CL		Elm Fork of the North Fork Red River near Carl			431		431
NF_CA		North Fork Red River near Carter			907		907
Canadian River Basin							
CR_AM		Canadian River near Amarillo			349	30	379
CR_CN	Canadian River near Amarillo	Canadian River near Canadian	100,000	51,490	902		152,392
WC_LP		Wolf Creek at Lipscomb					0
CC_GR		Coldwater Creek near Gruver			230		230
PD_SP		Palo Duro Creek near Spearman			806		806

Groundwater resources supply approximately 99% of the annual water use for the Canadian River Basin. There are three major surface water reservoirs within the Canadian River Basin in Texas. Two of these reservoirs are water-supply reservoirs. Lake Meredith supplies water within the basin to the cities of Borger and Pampa and Lake Palo Duro provides water to the Palo Duro River Authority's member cities. Water use for municipal, industrial, and agricultural purposes declined 151,122 acre-feet from 1980 to 1990. This reduction is primarily due to a decline of 149,505 acre-feet of water requirements for agricultural irrigation. Currently, 94% of the total water use in the basin is for agricultural irrigation. Municipal water use increased by 11% from 1980 to 1990. During 1990, exports from the Canadian River Basin included 37,030 acre-feet of water to the Brazos River Basin, 14,434 acre-feet of water to the Red River Basin, and 2,850 acre-feet of water to the Colorado River Basin for municipal and industrial use (TWDB, 1997).

Water use data were collected for the naturalization process. Surface water use records were obtained in a digital format for the study period from 1948 through 1998 from the TNRCC. The permit files were also reviewed to obtain water use data for water rights with large diversion amounts as well as to identify water rights with missing data. Holders of water rights with incomplete records were contacted to obtain additional information to fill in the missing data. If no data was available, water use data was estimated on a per capita basis for municipal water rights. Per capita water use estimations were determined by dividing the water use in a given year by the population of the community using the water in that same year. These per capita values were then multiplied by the population of the community during the period of missing data. Estimates for water use for industrial and irrigation water rights were based on historical use patterns of those water rights or rights with similar uses and diversion amounts. When a good estimate could not be formed, the historical use was estimated to be zero. This estimation provided a conservatively low estimate in the naturalized streamflow calculations.

In accordance with TNRCC requirements, surface water use for the Red and Canadian River Basins was summarized for the fourteen year period from 1984 through 1997 from the TNRCC permit files. This period of record was selected because data records were readily available and comprehensive. The water use data obtained from the TNRCC is actual water use for each water right as reported to the TNRCC by the water users in the basin. Surface water use data were reported in the county where the diversion point is located. The surface water data were also defined by county and use type, and summarized for each year between 1984 and 1997. Included in Appendix E are the water use summaries by counties for the Red and Canadian River Basins. Future water use demand projections were obtained from the TWDB from the Water Resource Planning Division. These projections were part of the regional water plans also developed for SB1. Future demand projections for each county in the Red and Canadian River Basins are shown in Appendix E.

Groundwater records for this time period were obtained from the Texas Water Development Board (TWDB). The groundwater data were presented by county, defined by use type, and summarized by year. Historical groundwater use records from 1984 to 1997 were obtained from the Texas Water Development Board (TWDB). The groundwater data are presented by county, defined by use type, and summarized by year in Appendix E.

2.3 Historical Return Flows and Treated Wastewater Effluent Discharge

Available records for return flows of treated municipal and industrial wastewater effluent discharges were obtained from TNRCC for the time period of 1978 through 1998. Prior to 1978, return flow records were generally not available. The following techniques were used to estimate return flows where records were not available:

- Return flows entity was contacted to determine whether any records or estimates of flows existed for the time frame not covered by the TNRCC database.
- For cities without such records, return flows were estimated on the basis of water use or a per capita value.
- For industries without such records, return flows were estimated on the basis of water use.
- Agricultural return flows were neglected.

Estimates of return flow were then calculated for all return flow locations from the date in which the discharge began up through 1978. All return flows in the Red and Canadian River Basins were utilized in the calculation of naturalized flows. Only those return flows over 1.0 MGD were modeled in the Red River Basin; however, all of the return flows in the Canadian River Basin were modeled due to a limited number of treatment facilities located in the Canadian River Basin. A detailed description of the modeling of return flow is included in Section 4.2.3.3. For the modeling process, return flows were located using latitude and longitude coordinates provided by the TNRCC. The modeled return flow locations are shown in the Red and Canadian River Basin maps located in Appendix K. The return flow points on the map are denoted by blue circles.

2.4 Previous Water Availability and Planning Studies

There are currently no known naturalized flow studies for the Red or Canadian River Basins. TNRCC Legacy WAM was not performed on either of these basins. Therefore, no comparison of naturalized flow will be performed after the naturalized flow estimates are completed.

2.5 Significant Considerations Affecting Water Availability in the Basins

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

- Modeling of the Red and Canadian River Compacts (curtailment of certain water rights depending on compact requirements).
- Input of historical inflows from Oklahoma into the Red River to allow those water rights on the Red River in Texas to have access to that flow.
- Modeling 404,000 ac-ft of dead and silt storage in Lake Meredith (Canadian River Basin) and the impact on water rights upstream.
- Filling of downstream reservoirs with senior water rights take precedence over diversion by upstream junior water rights. The firm yield analysis of this study maximizes the amount of diversions that could be made from the reservoir under their respective priority dates up to the authorized diversion amount. Watershed parameters used in this study to distribute naturalized flows between control points were received from the TNRCC are assumed to be correct.
- Reservoirs less than 5,000 ac-ft are modeled using a regression relationship to relate reservoir storage to surface area (described in Section 3.4.2).
- The model uses a monthly time step. Therefore, this type of analysis does not account for travel times between control points or flow requirements that depend on instantaneous flows, such as instream flow requirements.
- In general, the amounts of appropriated water covered by existing rights are determined by the permitted diversion for each water right and are not based on firm yields, geographical location, or other practical limits. Thus, the remaining unappropriated water at any point in the basin is based on the assumption that all rights are taking their full paper values of diversions whenever that much water is available.
- For water rights with off-channel storage, WRAP limits the streamflow depletions, which are made to meet diversions and refill storage on a monthly and annual basis.

3.0 HYDROLOGIC DATA REFINEMENT

3.1 Natural Streamflow at Gaged Locations

USGS Gage locations served as primary control points for the water availability model. Primary control points were developed using the following general criteria:

- Streamflow gages with over 20 years of record and drainage areas over 100 square miles;
- Spatial distribution of primary control points throughout the basin;
- Reservoir control points were avoided if possible due to the difficulty in obtaining accurate information on reservoir discharges; and
- Primary control points on the Red River were selected to account for intervening flows from smaller tributaries with no USGS gages.

Naturalized flows were estimated at primary control points in the Red and Canadian River Basins. The location of these control points corresponds to USGS streamflow gages with relatively extensive historic records as shown in Table 4. To estimate naturalized flows, the gage records were adjusted to account for upstream diversions, return flows, changes in reservoir content, and net reservoir evaporation.

One primary control point did not meet the above gage criteria. This primary control point was created and placed on Coldwater Creek near Gruver in the Canadian River Basin. Since there was no USGS gage at this location there is no flow record associated with this control point. Historical flows were estimated for this control point to allow naturalized flows to also be calculated at this point. A description of the historical and naturalized flow estimating procedure is defined in *Deliverable 2 – Final Naturalized Streamflows for the Red and Canadian River Basins.*

3.1.1 Streamflow Naturalization Methodology

Whenever possible, naturalized streamflows at the primary control points are based on available streamflow records using the methodology described herein. Naturalized flow data is based on historical flows, adjusted to remove the effects of human activity. A general equation for naturalized flow is as follows:

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

The elements of the equation are determined as follows:

- ***Historical Flow*** – Flows at primary control points were determined based on recorded USGS streamflow gage data. Five primary control points were assigned at USGS gaging stations and one primary control points was assigned downstream of Caddo Lake, as described above. Table 4 shows the control points assigned to the Red and Canadian River Basins and the historical period of record associated with each control point. Figure 1 shows the water rights and the 25 primary control points in the Texas Red River Basin and the five primary control points in the Red and Canadian River Basins.

Table 4 USGS Streamflow Gages in the Red and Canadian River Basins

ID	Gage	USGS Number	Drainage Area (Square Miles)	Period of Record
Red River Basin				
PD_WA	Prairie Dog Town Fork, Red River near Wayside	7297910	4,211	10/67-Present
PD_CH	Prairie Dog Town Fork, Red River near Childress	7299540	7,725	10/65-Present
GC_QN	Groesbeck Creek at SH6 near Quanah	7299670	303	12/61-Present
SF_WL	Salt Fork, Red River near Wellington	7300000	1,222	7/52-Present
SW_KT	Sweetwater Creek near Kelton	7301410	287	12/61-Present
PR_CS	Pease River near Childress	7307800	2,754	12/59-Present
PR-VN	Pease River near Vernon	7308200	3,488	12/59-Present
RR_BB	Red River near Burkburnett	7308500	20,570	1/60-Present
NW_PD	North Wichita River near Paducah	7311600	540	2/51-Present
NW_TS	North Wichita River near Truscott	7311700	937	12/59-Present
SW_GR	South Wichita River at low flow dam near Guthrie	7311782	223	10/84-Present
SW_BJ	South Wichita River near Benjamin	7311800	584	12/59-Present
WR_SM	Wichita River near Seymour	7311900	1,874	12/59-Present
WR_MB	Wichita River near Mabelle	7312100	2,086	10/59-Present
BC_ET	Beaver Creek near Electra	7312200	652	3/60-Present
WR_WF	Wichita River at Wichita Falls	7312500	3,140	4/38-Present
WR_CH	Wichita River near Charlie	7312700	3,439	10/67-Present
LW_AC	Little Wichita River near Archer City	7314500	481	10/45-Present
LW_HN	Little Wichita River above Henrietta	7314900	1,037	10/66-Present
EF_HN	East Fork Little Wichita River near Henrietta	7315200	178	12/63-Present
RR_TR	Red River near Terral	7315500	28,723	1/48-Present
RR_GA	Red River near Gainesville	7316000	30,782	10/36-Present
RR_CB	Red River near Colbert	7332000	39,777	10/24-9/59
RR_AC	Red River near Arthur City	7335500	44,531	10/05-9/11; 10/36-Present
RR_IN	Red River at Index	7337000	48,030	7/36-Present
Canadian River Basin				
CR_AM	Canadian River near Amarillo	7227500	19,445	4/38-Present
CR_CN	Canadian River near Canadian	7228000	22,866	4/38-Present
WC_LP	Wolf Creek at Lipscomb	7235000	697	10/40-Present
CC_GR	Coldwater Creek near Gruver	Created		n/a
PD_SP	Palo Duro Creek near Spearman	7233500	960	8/45-9/79

- ***Upstream Diversions*** – Upstream diversions as recorded in TNRCC records (or as estimated when records are missing) for all water right permits in the basin. A detailed description of the estimation procedure used to fill in missing data is given in the Final Naturalized Streamflow Report submitted to TNRCC.

- ***Upstream Return Flows*** – Upstream return flows are based on TNRCC wastewater discharge permit records, or as estimated when records are not available. A detailed description of the return flow estimating procedures is also given in the Final Naturalized Streamflow Report submitted to TNRCC in November 2001. All return flows were used in calculated naturalized flows, but only those return flows over 1.0 MGD were included in the model. Return flows greater than 1.0 MGD that were used for once-through cooling purposes, or stormwater flows, were also not included in the model.

- ***Changes in Upstream Reservoir Contents*** – Changes in contents for major upstream reservoirs are based on USGS records, records kept by others, or estimates of content changes if records were not available. The sources of data utilized for reservoir content changes are listed in Table 5. Content changes for reservoirs with less than 5,000 ac-ft of conservation storage were neglected. Summaries of all reservoirs with greater than 5,000 ac-ft of conservation storage in the Red and Canadian River Basins can be found in Table 1 and Table 2, respectively.

- ***Upstream Reservoir Evaporation*** – Monthly evaporation from upstream reservoirs is estimated by multiplying the net reservoir evaporation rate by the average reservoir surface area. Evaporation from reservoirs with less than 5,000 ac-ft of conservation storage is neglected. Section 3.3 includes a discussion of the development of net reservoir evaporation rates.

Table 5 Sources of Data Utilized for Reservoir Content Changes

Reservoir	Period	Method
Red River Basin		
Lake Nocona	Before 1961 1961-Present	No impact N. Montague County Water Supply
Hubert H Moss Lake	Before 4/66 4/66-Present	No impact City of Gainesville
Lake Texoma	Before 1/44 1/44-Present	No impact US Army Corps of Engineers, Tulsa District
Valley Lake	Before 12/60 12/60-Present	No impact Texas Power and Light Co.
Randall Lake	N/a	City of Denison
Coffee Mill Lake; Lake Fannin	Before 1938 1938-Present	No impact US Department of Agriculture
Lake Bonham	Before 11/69 11/69-Present	No impact Bonham Municipal Water Authority
Pat Mayse	Before 9/67 9/67-Present	No impact US Army Corps of Engineers, Tulsa District
Lake Crook	Before 1923 1923-Present	No Impact, City of Paris
Truscott Brine	Before 12/82 12/82-Present	No impact USACE
Lake Kemp	Before 1922 1922-Present	No impact City of Wichita Falls & Wichita County
Lake Diversion	Before 1924 1924-Present	No impact City of Wichita Falls & Wichita County Water Improvement District No.2
Santa Rosa Lake; Wharton Lake	Before 1929 1929-Present	No impact WT Waggoner Estate
Lake Electra	N/a	City of Electra
North Fork Buffalo Creek	Before 11/64 11/64-Present	No impact Wichita County Water Control & Improvement District No.3
Lake Kickapoo	Before 2/46 2/46-Present	No impact City of Wichita Falls
Lake Arrowhead	N/A	City of Wichita Falls
Bivins	Before 1926 1926-Present	No impact City of Amarillo

Table 5 Sources of Data Utilized for Reservoir Content Changes (Continued)

Reservoir	Period	Method
Red River Basin		
Buffalo Lake	Before 6/38 6/38-Present	No impact US Department of Interior
Mackenzie	Before 4/74 4/74-Present	No impact Makenzie Municipal Water Authority
Baylor Creek	Before 12/49 12/49-Present	No impact City of Childress
Greenbelt	Before 12/66 12/66-Present	No impact Greenbelt M&I WA
Cibola National Forest	N/A	US Forest Service
Lake Wichita	Before 1901 1901-Present	No impact City of Wichita Falls
Canadian River Basin		
Lake Rita Blanca	Before 9/41 9/41-Present	No impact Dallum & Hartley County
Lake Meredith	Before 1/65 1/65-Present	No impact Canadian River Municipal Authority
Palo Duro	N/A	Palo Duro River Authority

3.1.2 Streamflow Data Sources

Streamflow data in the Red and Canadian River Basins were obtained from USGS gage flows. The USGS maintains a network of streamflow gages throughout the United States. USGS gage measurements are the most reliable source of historical streamflow data. Table 4 lists USGS streamflow gages in the Red and Canadian River Basins. Figure 2 shows the length of record for each USGS streamflow gage in the basins. Reference Figure 1 for primary control points selected in this study.

3.1.3 Delivery Factors and Channel Loss Rates

Channel losses may occur because of infiltration, evapotranspiration, and diversions not reflected in the water right use database. Gage records reflect natural channel losses, but streamflow losses are expected to change as diversions, return flows, and other adjustments change the flow in the channel. Within WRAP, streamflow losses are modeled as a linear function of the adjustment (*D*). Thus naturalized streamflows at control points (Q_{nat}) are calculated using the following equation:

$$Q_{nat} = Q_{obs} + D - C_L \cdot D$$

C_L represents a channel loss factor from the location of the adjustment to the downstream control point. If the adjustment (*D*) increases flow in the channel, the loss factor decreases the net adjustment to account for increased channel losses. If the adjustment decreases flow, the loss factor will increase the net adjustment to account for smaller channel losses.

The existing WRAP code cannot account for seasonal or short-term variations in loss factors. As a result, only long-term consistent losses should be accounted for within a WRAP model.

Given that the channel loss factor applies only to diversions and returns which tend to be continuous as in wastewater flows, or in dry weather as in irrigation diversions, it appears reasonable to focus the analysis on the dry weather condition. During dry weather, channel losses will tend to be a high percentage of the flow adjustments.

Soil Conservation Service (SCS) Curve Numbers (CN) typical of a reach were considered in making the selection of a loss percentage. To a first approximation, channel losses should be inversely related to the CN—the lower the CN (more sandy the soil, etc.) the higher the channel losses and visa versa. However, it must be recognized that the CN is an approximation designed to apply to runoff from a watershed, not conditions in a streambed that may be very different from the watershed.

Another general point is that while putting a loss percentage in the model as a function of reach length is technically more rigorous than adopting a simple percentage, there will be cases where the rigor is not justified. For purposes of estimating naturalized flows, the channel loss percentage was used to modify flow adjustments without considering reach length. However, when applying the channel loss percentage to secondary control points (water rights) in the WRAP model, a loss per mile basis was required simply because many of the water rights are within close proximity of each other.

Another point is the need to retain flexibility. Accordingly, the values proposed should not be considered as fixed but rather as initial judgments that may need refinement for particular circumstances.

In addition to the curve number analysis, many wastewater discharge plants were contacted in the Canadian River Basin. All of the facilities contacted (even those discharging as high as 1.0 MGD) indicated that the discharge seldom reached the Canadian River. Due to the arid region and sandy soil environment, these wastewater discharges generally evaporate or percolate into the river channel of the tributaries that they are discharged into. Therefore, as an estimate of this tendency, a channel loss percentage of 70% was applied to all control points in the Canadian River Basin.

For the Red River, there are several processes at work. Within the western end in the panhandle, lighter colors (lower CN) are common. As the river flows towards the east, darker colors indicating higher CN values dominate. A second factor influencing the channel loss conditions in the watershed is the increase in annual average precipitation moving from west to east. This tends to make perennial streams more common and reduce the frequency of dry streambeds with high channel losses. A third factor is that towards the eastern end of the river, the amount of heavy crop irrigation tends to be less, thus reducing the likelihood of groundwater recharge. No attempt was made to quantify these factors, but they should be noted as qualitatively consistent with this level of estimation of channel loss factors. In the upper reaches of the river, west of the eastern panhandle boundary, a channel loss percentage of 70%, equal to that of the Canadian River, was employed. Again in these western areas of the Red River, wastewater discharge facilities were contacted to determine the amount of discharge that actually travels down the tributary and eventually discharges into the Red River. As in the Canadian, most of the discharges did not reach the Red River. At the other end, east of Lake Texoma, CN values approach 90. Given the other factors of more rain and lower irrigation pumping, a channel loss factor of 0% was employed. Between these two points, channel loss factors were determined by linear interpolation.

To calculate the delivery factor, the channel loss percentage was applied to the longest stream segment provided in the CRWR ArcView coverage of the two portions of Red River Basin in which channel losses were applied. This produced a percent loss per mile for each area, which was then applied to each incremental stream segment in the respective areas. The delivery factor for each stream segment was then subtracted from one to generate the channel loss factor for each incremental stream segment in the areas, as shown below.

$$\text{Channel Loss Factor}_{\text{Upper Red and Canadian}} = 1 - \left[1 - \frac{.70}{\text{Longest Length}}\right]^{\text{Incremental Length}}$$

$$\text{Channel Loss Factor}_{\text{Mid Red}} = 1 - \left[1 - \frac{.40}{\text{Longest Length}}\right]^{\text{Incremental Length}}$$

3.1.4 Completion of Streamflow Records and Quality Control

Most of the primary control points in the Red and Canadian River Basins do not have a complete flow record for 1948 through 1998. The length of record and periods of missing data for the primary control points are shown in Figure 2. Historical USGS gaged flow data was used as a basis for the flow at a given control point based on the drainage area ratio. Control points with missing data were filled by correlating the overlapping data period with nearby gages and using the gage with the highest correlation value. Appendix G gives a complete list of the options considered to fill in missing data. Appendix I shows the Red and Canadian River Basins naturalized flows for the primary control points.

Figure 2 Hydrology Records for Control Points in the Red and Canadian River Basins

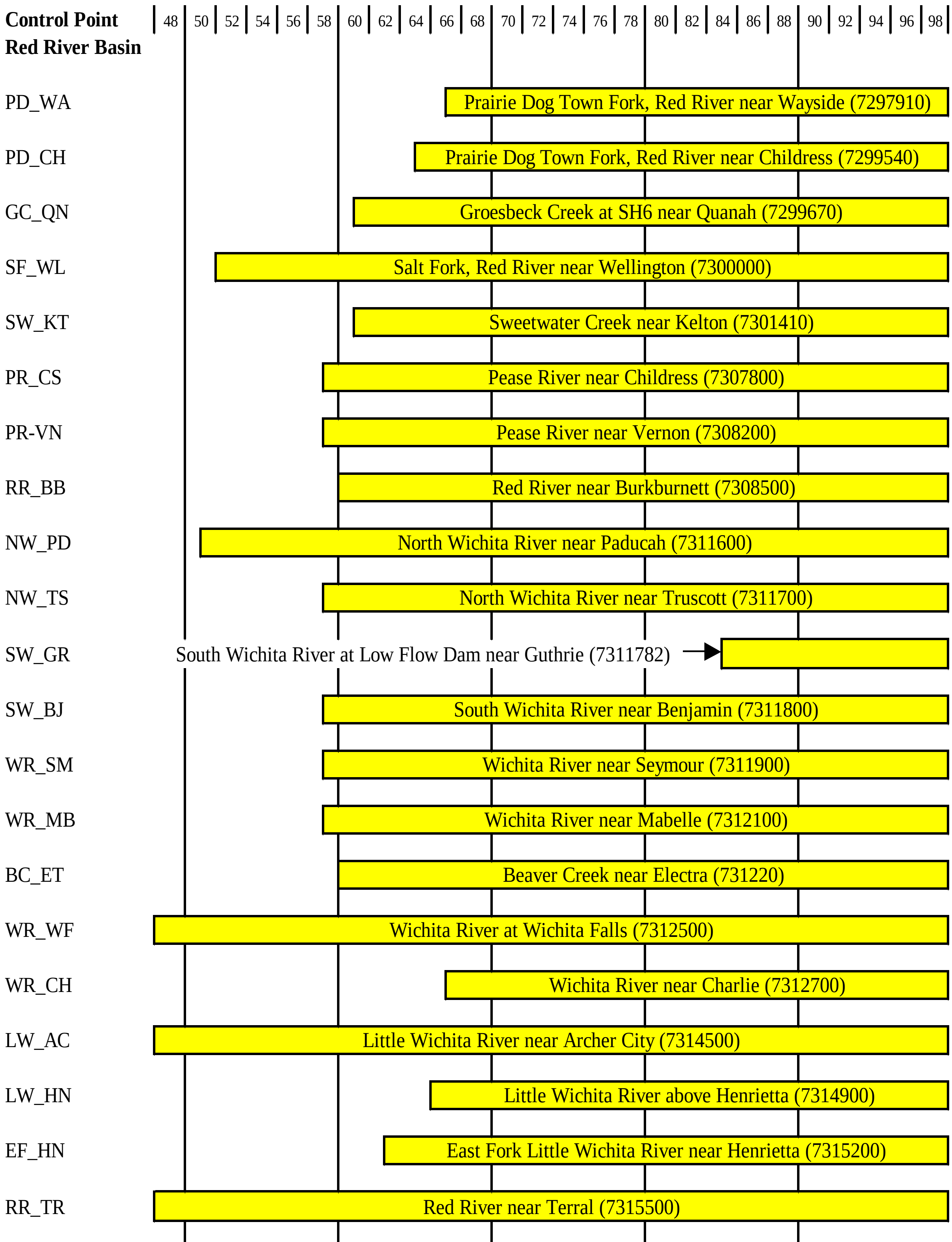
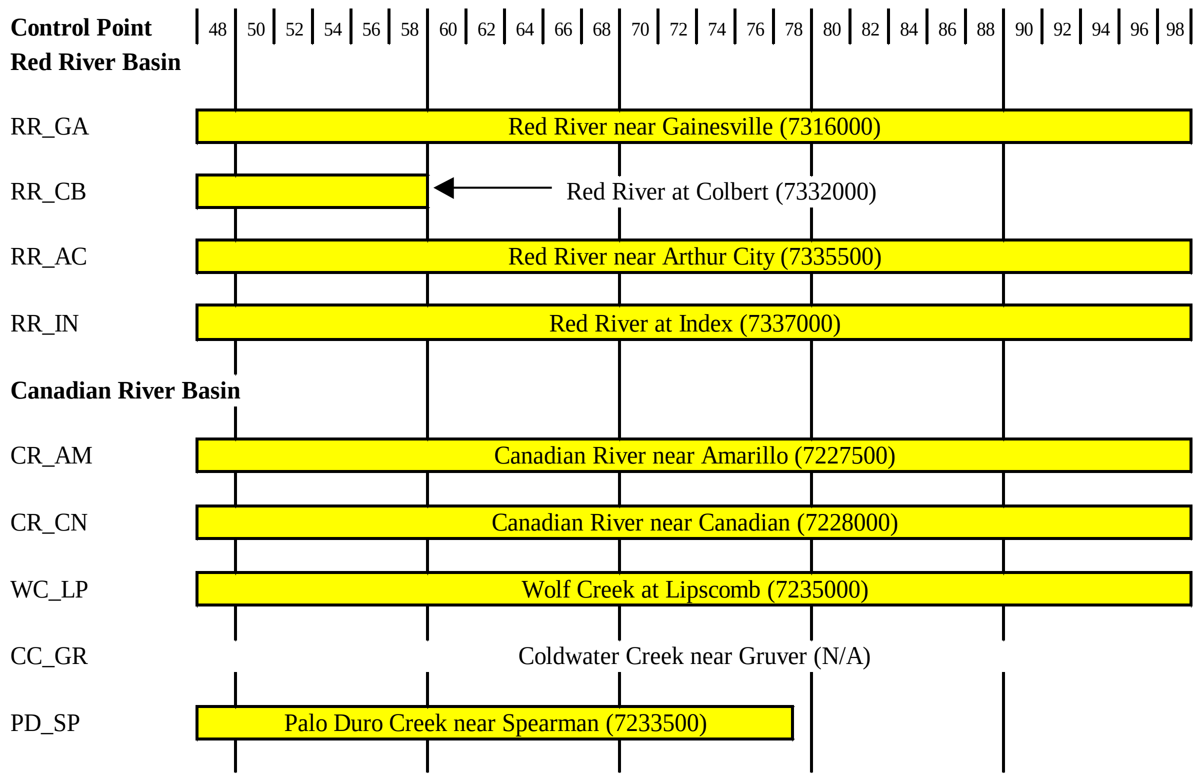


Figure 2 Hydrology Records for Control Points in the Red and Canadian River Basins



Negative incremental flows occur when the upstream naturalized flow is greater than the naturalized flow calculated for the downstream control point. In normal conditions, it is assumed that the flow from the incremental watershed area, when naturalized and added to the upstream naturalized flow, will be greater than the naturalized flow calculated upstream. However, during computation of naturalized flow for this study, negative incremental flows were calculated for some months at some of the primary control points. Negative incremental flows between control points are generally explained by the following reasons:

- Timing problems created by large flows, which pass different points during different month;
- Incorrect data;
- Errors in the estimation of hydrologic data; and/or
- Channel losses in the watershed

Negative incremental streamflow adjustments were made for those gages that had negative incremental flows. These adjustments were made to the data to eliminate the negative flows to minimize the affects of negative flows.

Negative incremental streamflow adjustments were made by setting the negative flow value to zero. Then the amount of flow that was added to the negative number to make it zero was subtracted from the surrounding months.

3.1.5 Comparison with Other Naturalized Streamflow

Comparison of Naturalized Flows to TNRCC Legacy WAM

A water availability model previously developed by the TNRCC is referred to as a Legacy WAM. There is no Legacy WAM for the Red and Canadian River Basins. Therefore, no comparison was performed with the results of this study.

3.1.6 Statistical Assessment of Trends in Streamflow

Trends in streamflow were analyzed by comparing historical to naturalized flows at control points that are also USGS gages. For these control points, the historical gaged flows were compared to the estimated natural flows for the corresponding years with actual gaged data. The minimum, 90% exceedance, 75% exceedance, median, 25% exceedance, 10% exceedance, maximum, and average flows were calculated for each month. Complete tables for each of these control points are in Appendix J, along with the double mass curve comparing the gage flow to the naturalized flow. Table 6 lists the control points along with the comparison periods, the median annual flows for both the gaged and naturalized flows, and the ratio of the cumulative naturalized flow to the cumulative gaged flow.

Table 6 Naturalized Streamflow Comparison Summary Red and Canadian Basin Control Points

No.	ID	Gage	USGS Number	Drainage Area (sq mi)	Comparison Period	Median Annual Gage Flow (ac-ft)	Median Annual Naturalized Flow (ac-ft)	Cumulative Naturalized Flow/Gage Flow Ratio
Red River Basin								
R-1	PD_WA	Prairie Dog Town Fork, Red River near Wayside	7297910	4,211	10/67-Present	14,840	16,408	1.106
R-2	PD_CH	Prairie Dog Town Fork, Red River near Childress	7299540	7,725	10/65-Present	70,617	73,750	1.044
R-3	GC_QN	Groesbeck Creek at SH6 near Quanah	7299670	303	12/61-Present	14,934	14,675	0.983
R-4	SF_WL	Salt Fork, Red River near Wellington	7300000	1,222	7/52-Present	41,354	44,858	1.085
R-5	SW_KT	Sweetwater Creek near Kelton	7301410	287	12/61-Present	9,184	9,204	1.002
R-6	PR_CS	Pease River near Childress	7307800	2,754	12/59-Present	40,524	40,552	1.001
R-7	PR-VN	Pease River near Vernon	7308200	3,488	12/59-Present	80,916	80,898	1.000
R-8	RR_BB	Red River near Burkburnett	7308500	20,570	1/60-Present	691,246	697,136	1.009
R-9	NW_PD	North Wichita River near Paducah	7311600	540	2/51-Present	15,093	15,096	1.000
R-10	NW_TS	North Wichita River near Truscott	7311700	937	12/59-Present	45,158	45,165	1.000
R-11	SW_GR	South Wichita River at low flow dam near Guthrie	7311782	223	07/1900-Present	4,177	4,491	1.075
R-12	SW_BJ	South Wichita River near Benjamin	7311800	584	12/59-Present	27,799	28,113	1.011
R-13	WR_SM	Wichita River near Seymour	7311900	1,874	12/59-Present	110,369	118,906	1.077
R-14	WR_MB	Wichita River near Mabelle	7312100	2,086	10/59-Present	107,363	187,704	1.748
R-16	BC_ET	Beaver Creek near Electra	7312200	652	3/60-Present	59,303	66,250	1.117
R-17	WR_WF	Wichita River at Wichita Falls	7312500	3,140	4/38-Present	194,156	318,297	1.639
R-18	WR_CH	Wichita River near Charlie	7312700	3,439	10/67-Present	268,878	688,730	2.561
R-19	LW_AC	Little Wichita River near Archer City	7314500	481	10/45-Present	33,308	58,888	1.768
R-20	LW_HN	Little Wichita River above Henrietta	7314900	1,037	10/66-Present	38,439	94,048	2.447
R-21	EF_HN	East Fork Little Wichita River near Henrietta	7315200	178	12/63-Present	17,124	17,124	1.000
R-22	RR_TR	Red River near Terral	7315500	28,723	N/A	1,353,901	1,534,948	1.134
R-23	RR_GA	Red River near Gainesville	7316000	30,782	10/36-Present	1,708,102	1,891,956	1.108
R-25	RR_CB	Red River near Colbert	7332000	39,777	24-59	1,960,304	2,278,963	1.163
R-26	RR_AC	Red River near Arthur City	7335500	44,531	10/05-9/11; 10/36-Present	3,601,328	3,995,678	1.110
R-27	RR_IN	Red River at Index	7337000	48,030	7/36-Present	3,668,879	5,358,220	1.460
Canadian River Basin								
C-1	CR_AM	Canadian River near Amarillo	7227500	19,445	4/38-Present	152,874	153,761	1.006
C-2	CR_CN	Canadian River near Canadian	7228000	22,866	4/38-Present	130,454	189,221	1.450
C-3	WC_LP	Wolf Creek at Lipscomb	7235000	697	10/40-Present	7,202	7,202	1.000
C-4	CC_GR	Coldwater Creek near Gruver	Created		n/a	15,067	15,125	1.004
C-5	PD_SP	Palo Duro Creek near Spearman	7233500	960	8/45-9/79	10,443	10,856	1.040

Examination of the Red River cumulative naturalized flow results found in Appendix J, in upstream to downstream order, indicates the most distinct departure from gaged flow is found below reservoirs. Little to no difference from gaged flow is observed in the control points in the smaller watersheds in the upstream, western region of the Red River Basin. The effects of reservoirs are less distinct on the mainstem control points, particularly as the naturalized flow accumulates downstream. Diversions and return flows created little noticeable difference in the flow naturalization process for the Red River. Each control point is described below, starting in the upper basin in the Panhandle of Texas and continuing downstream into Arkansas.

Naturalized and gaged flows for the smaller, upper basin control points are very similar, specifically for SW_KT, SF_WL, GC_QN, PR_CS, and PR_VN. Naturalized flows for PD_WA and PD_CH are slightly higher than gaged flow, which can be attributed to reservoir effects in these watersheds. These effects on river flow are carried downstream to the mainstem control point at RR_BB, where the naturalized flow is greater than gaged flow, but continues to closely track the gaged flow values.

The same trends are observed in the control points on the Wichita River, just south of the control points listed above. NW_PD, NW_TS, SW_GR, SW_BJ, and WR_SM all show nearly identical naturalized and gaged flows. The most marked difference from gaged flows is observed at WR_MB, the control point directly downstream of Lakes Kemp and Truscott Brine. Naturalized flow at this control point is distinctly higher than gaged flow, and the increase can be attributed to the two reservoirs just upstream. The effects of these reservoirs are carried downstream to WR_WF, with the effects of Lake Diversion also increasing naturalized flows at this control point. Naturalized flows at WR_CH just downstream continue to be greater than gaged flows, with the additional effects of Lake Wichita increasing the naturalized flows. This control point also shows slight effects of return flows, with the net effect of decreasing the flows. BC_ET drains to WR_WF. This control point accumulates flows downstream of Santa Rosa Lake and shows a slightly higher naturalized flow.

The Little Wichita River, just south and east of the Wichita River, shows similar trends. LW_AC and LW_HN exhibit effects from Lakes Kickapoo and Arrowhead, with naturalized flows markedly higher than gaged flows. EF_HN naturalized and gaged flows are the same, as there are no return flows, diversions, or reservoirs in this watershed.

The next mainstem control point downstream is RR_TR, collecting all of the above control points. The naturalized flow here tracks gaged flow, but is slightly greater than gaged flow. Continuing downstream, RR_GA continues showing the effects of the upstream reservoirs. RR_CB, just downstream of Lake Texoma, shows a slightly more distinct increase in naturalized flows compared to RR_GA, as would be expected from the effects of this large reservoir. RR_AC and RR_IN continue to have greater naturalized flows than gaged flows.

Canadian River Basin

The flow naturalization process for the Canadian River Basin did not produce a distinct departure from the gaged flow values. As shown in Attachment D, naturalized flows and gaged flows did not vary for the small, upstream watersheds at control points WC_LP, PD_SP and CC_GR. These control points have few diversions, return flows, or reservoir effects. CR_AM displayed very similar values for naturalized and gaged flows on the cumulative flows chart; however, the percentile comparison shows slightly higher values for naturalized flow than gaged flow, indicating the slight effects of diversions and reservoirs at this location.

Naturalized flows at CR_CN were higher except in the months of January, February, and March, indicating the effects of irrigation diversions, as the diversion amounts are lower during these months. The major effect at this control point is attributed to Lake Meredith. As shown on the cumulative flow chart, after impounding and filling Lake Meredith in the mid to late 60s, the naturalized flow increases above gaged flows markedly. This increase is primarily due to correcting for evaporative losses from the lake. As discussed in a previous section miscellaneous adjustments were made to account for apparent losses due to Lake Meredith that had not been accounted for with the evaporative losses or content changes. These miscellaneous adjustments appear to have provided the expected outcome, as naturalized flows continue to accumulate at a regular pace over time (CR_CN in Attachment J).

The annual statistics are shown in Figure 3, Figure 4 and Figure 5 for RR_AC, WR_MB, and SW_GR, respectively. The 90% exceedance, median and 10% exceedance flows for control points RR_AC, WR_MB, and SW_GR are displayed graphically in Figure 6, Figure 7, and Figure 8, respectively. The figures for WR_MB are generally representative of control points affected by the combination of upstream reservoirs and diversion. The figure for SW_GR is generally representative of areas minimally affected by changes to flow.

Figure 3 RR_AC Statistical Comparison of Annual Historical and Naturalized Flows

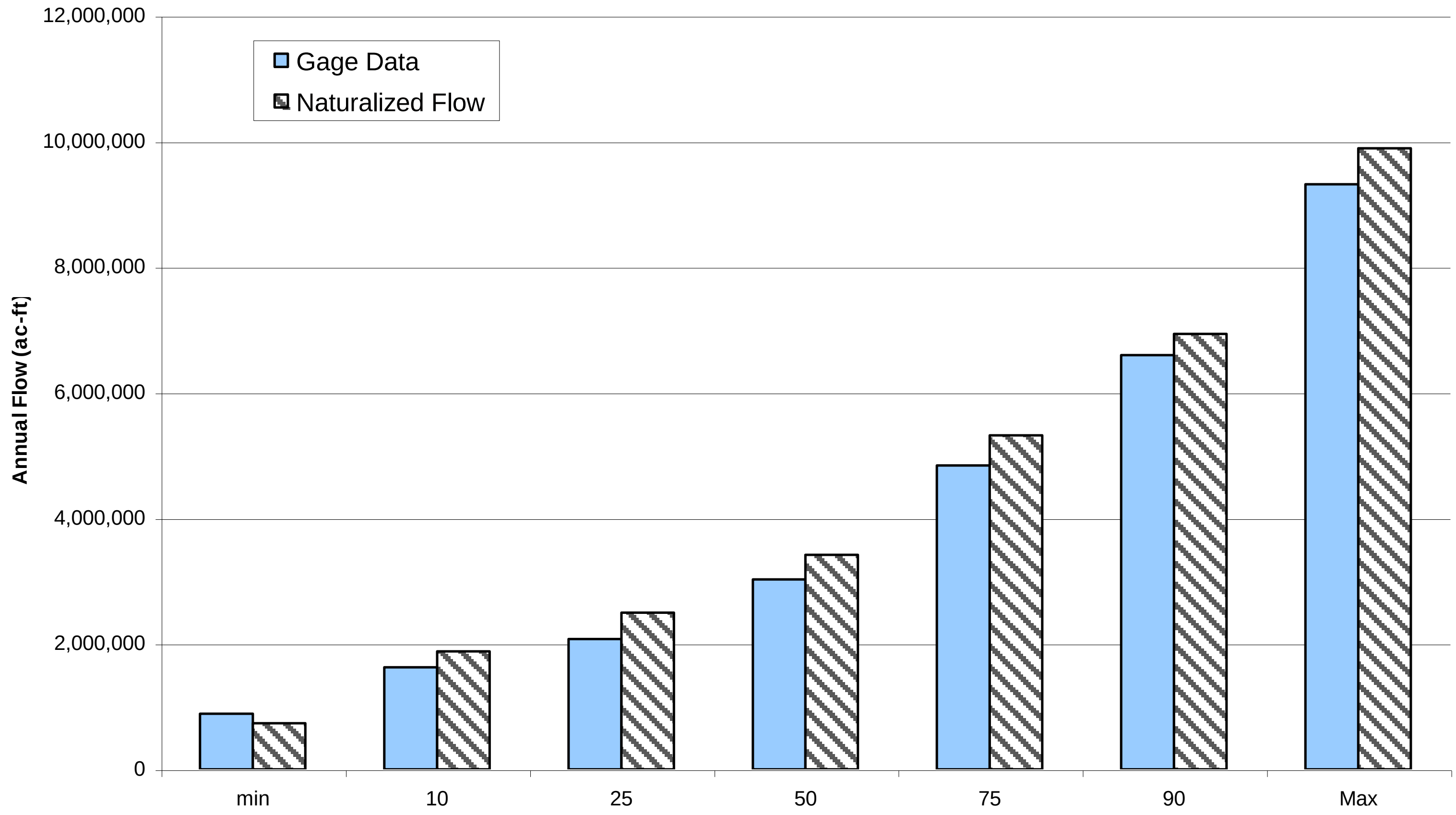


Figure 4 WR_MB Statistical Comparison of Annual Historical and Naturalized Flows

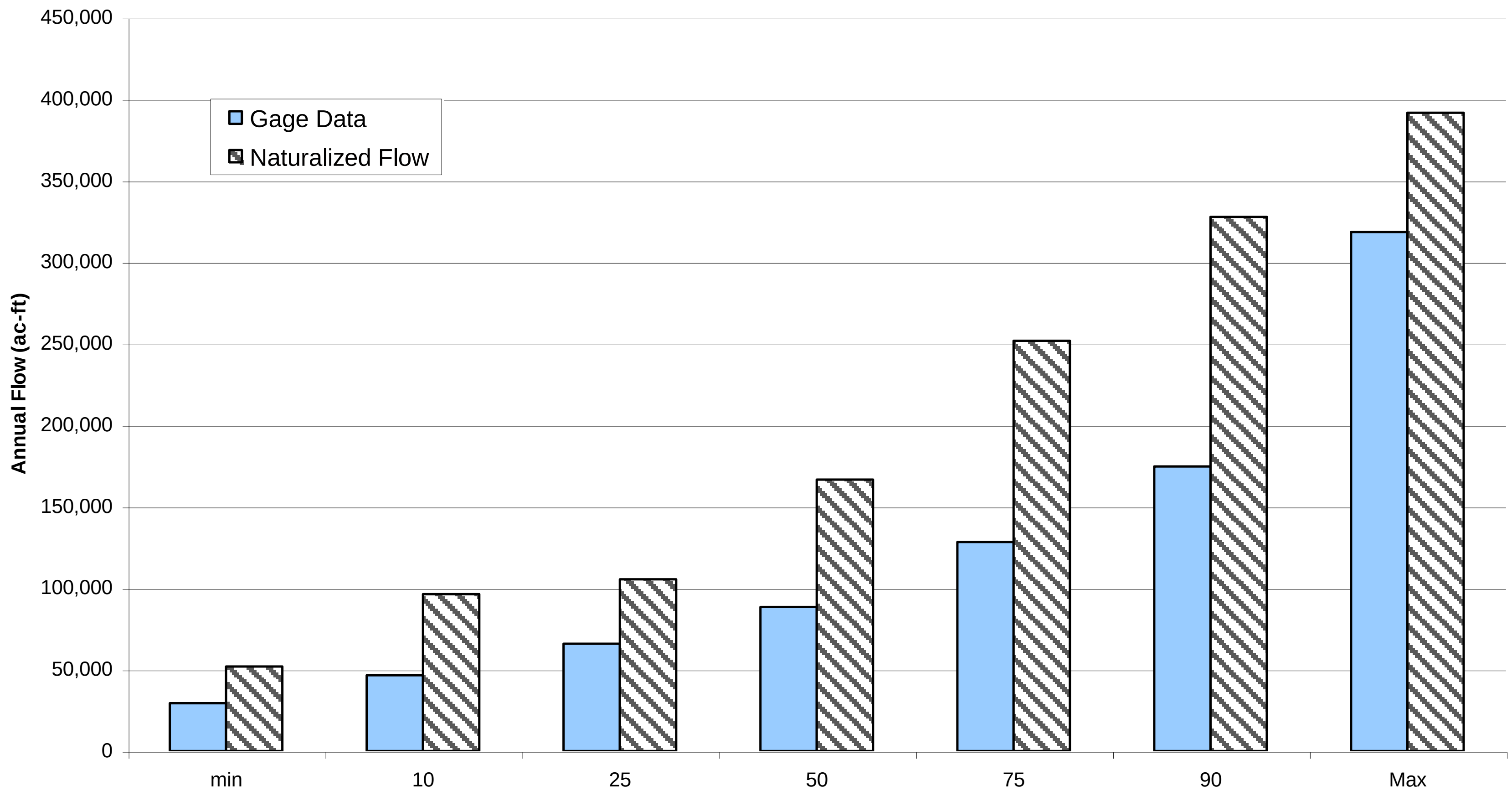


Figure 5 SW_GR Statistical Comparison of Annual Historical and Naturalized Flows

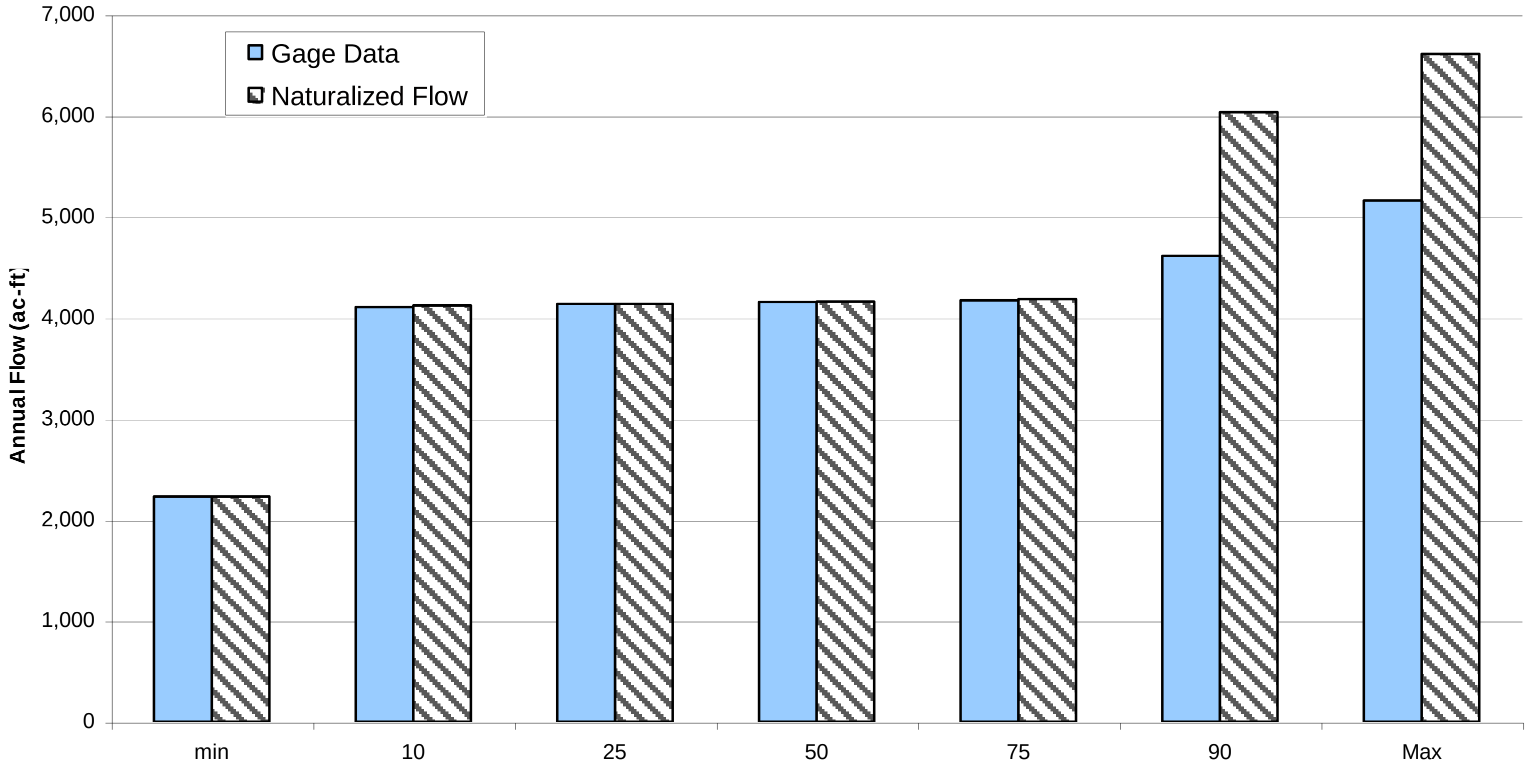


Figure 6 Monthly Statistics for RR_AC

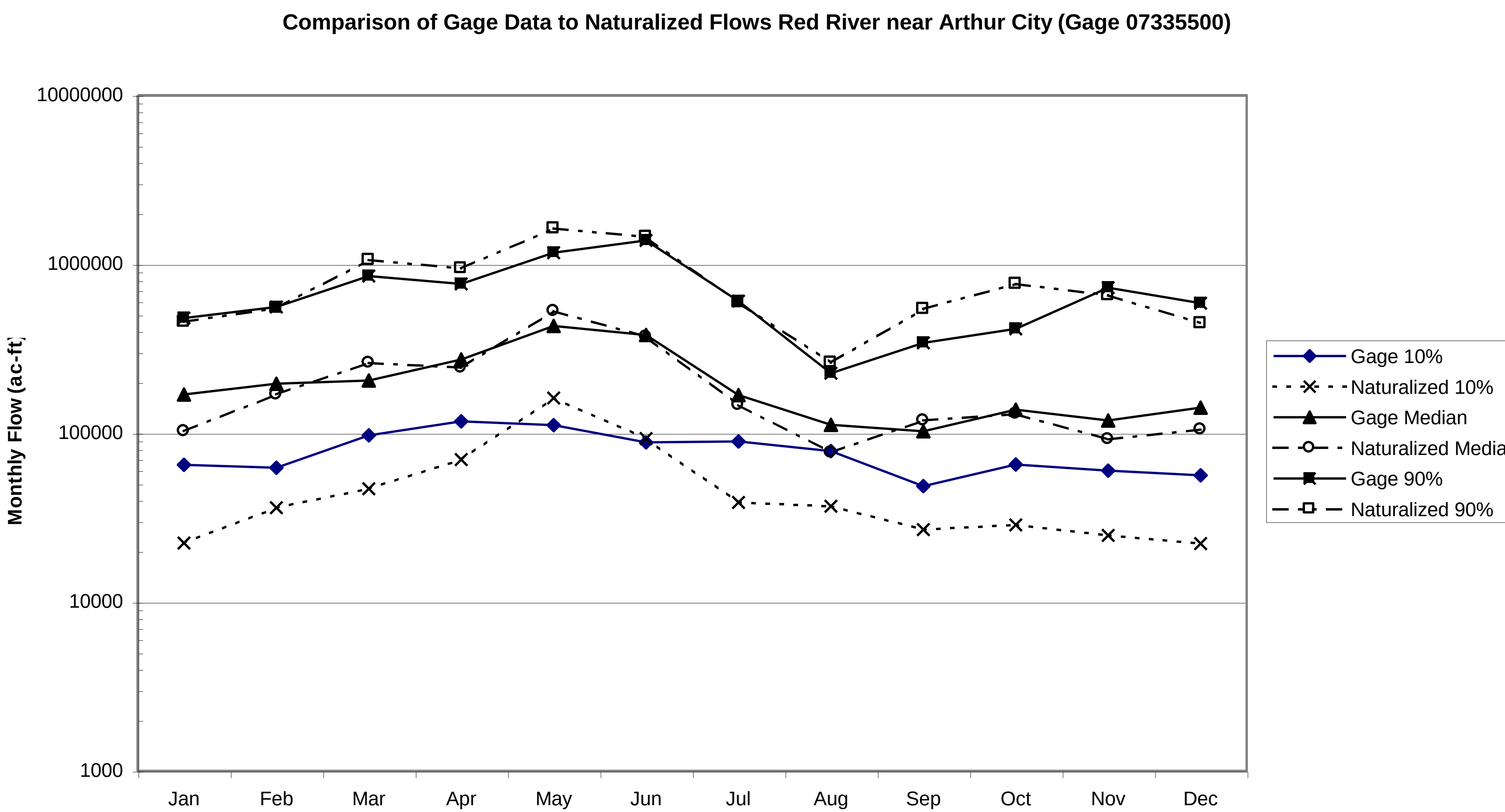


Figure 7 Monthly Statistics for WR_MB

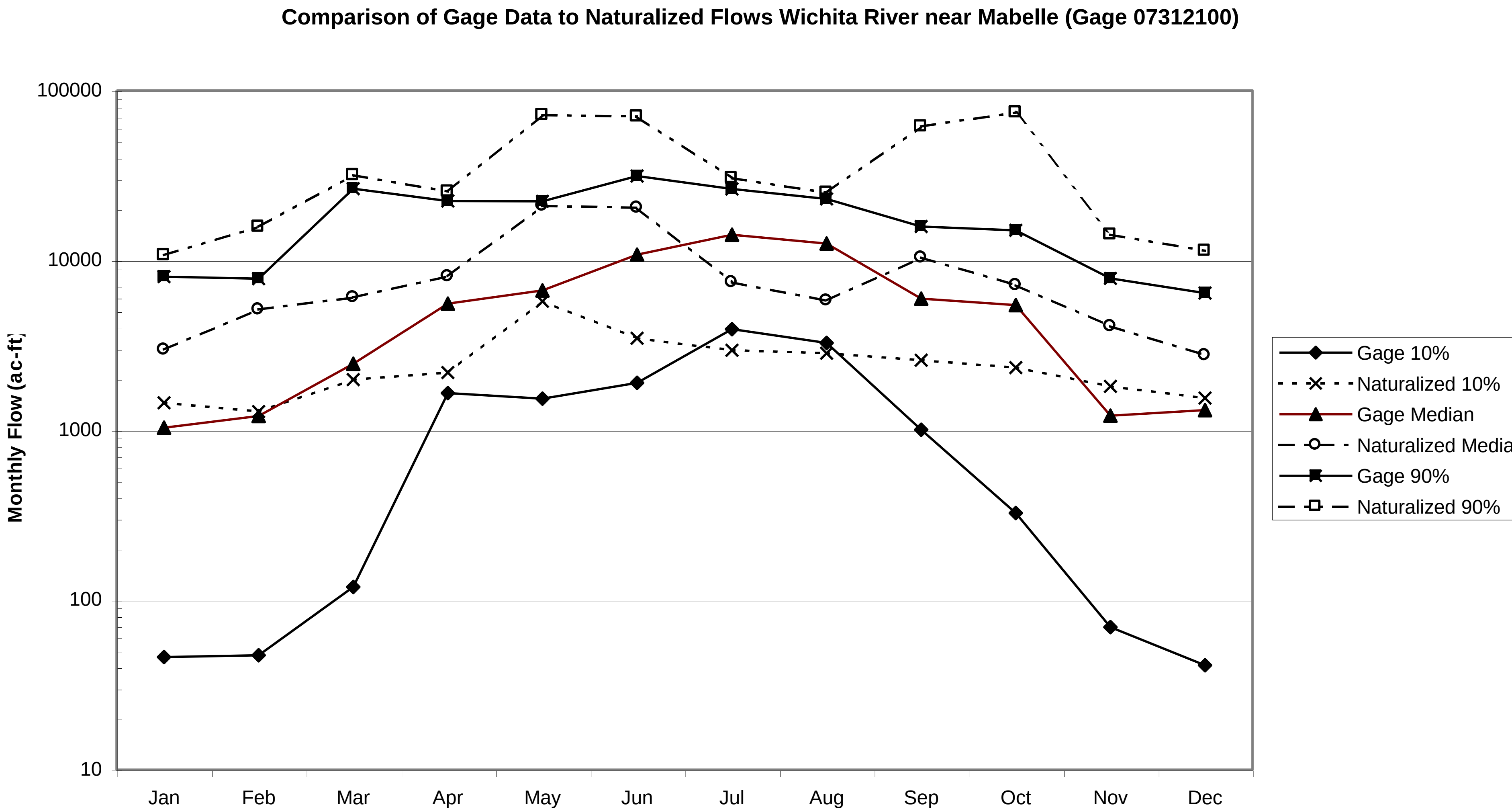
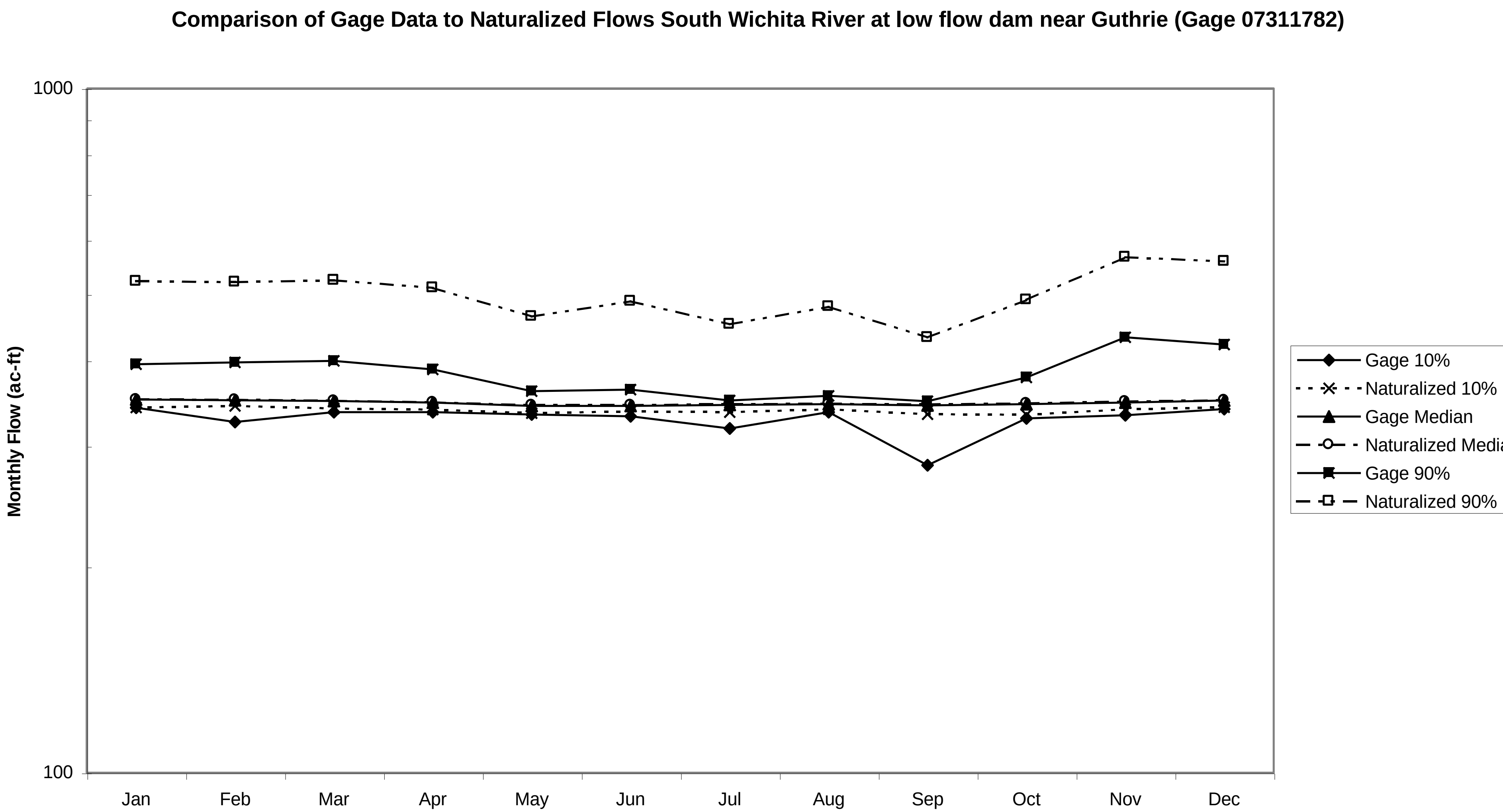


Figure 8 Monthly Statistics for SW_GR



3.2 Natural Streamflow at Ungaged Locations

Naturalized streamflow was derived at ungaged locations in the Red and Canadian River Basins utilizing data from gaged sites and watershed parameters at ungaged sites within the WRAP (DECEMBER, 2001) program. Ungaged sites, or secondary control points, include any ungaged locations within the basin where water availability calculations need to be performed including diversion locations for water rights, the ends of classified stream segments, and return flow or groundwater inflow locations. The map attached in Appendix K provides the locations of all primary (gaged) and secondary (ungaged) control points.

WRAP (DECEMBER, 2001), developed by Dr. Ralph A. Wurbs at Texas A & M University, has the capability to compute naturalized flows at ungaged sites by utilizing the drainage area method. Specifically, naturalized flows or inflows at gaged sites are input into the program along with total drainage areas of gaged and ungaged points. Watershed parameters were obtained from CRWR. The specific methods used in this program are described in the WRAP (DECEMBER, 2001) user's manual. Table 7 provides the watershed parameters at all control points. Watershed parameters were provided by the CRWR to TNRCC and then to EC. After review of the watershed parameters, additional estimations were made by EC to more accurately represent the drainage areas and stream lengths associated with the Red River. Additional watershed parameters will be provided by the TNRCC to replace the estimated values and allow the simulations to be performed again.

The drainage area method distributes flow from a gaged to an ungaged location utilizing the following equation:

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

WRAP also allows the naturalized flow do be distributed to the secondary control points by utilizing the Natural Resource Conservation Service (NRCS) curve number and annual precipitation. The NRCS Curve Number method adds an adjustment for watershed characteristics is as follows:

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

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

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

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

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

WRAP (DECEMBER, 2001) utilizes the following algorithm to calculate flows at ungaged sites:

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

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

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

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

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

In this study, the watershed parameters (the CN, mean precipitation, and drainage areas at gaged and ungaged sites) were derived by the CRWR using a geographic information system (GIS) grid basis. The CRWR used USGS digital elevation models (DEMs), EPA river reach segments, USGS gauging locations, U.S. Department of Agriculture-Parameter-elevation Regressions on Independent Slopes Model (PRISM) for mean annual precipitation, TNRCC water right diversion locations, and curve numbers derived by the NRCS at the Blackland Research Center at Texas A & M to create a geospatial database and model of the basin. From this geospatial model, the CRWR delineated drainage areas, curve numbers and mean annual precipitation for each water right diversion location within the basin. Although WRAP allows for distribution of the naturalized streamflow using the curve number and annual precipitation, the decision was made by the TNRCC to only use the drainage area ration to distribute the flows to the secondary control points.

Table 7 Control Points and Corresponding Watershed Parameters

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
10010	60205265301	W10070	34.08	56.87	22.68
10020	60205264301	W10070	48.00	68.61	21.88
10030	60205263301	W10070	32.77	65.65	21.73
10040	60205254001	H10080	371.04	59.75	22.25
10050	10203885201	H10080	3.65	79.81	22.40
10060	60205250002	10050	3.62	79.76	22.40
10070	212	H10080	847.97	62.00	21.67
10080	60205249301	10070	1.18	50.66	22.13
10090	60205248301	10070	5.47	81.92	22.09
10100	60205247301	10070	4.25	70.70	22.82
10110	211	10070	2.03	66.11	21.01
10120	60205246301	10070	4.82	49.59	23.08
10130	60205245301	10070	0.41	68.43	21.40
10140	60205244301	10070	245.11	68.61	20.71
10150	60205243301	10140	142.76	69.14	20.39
10160	60205242301	10150	134.61	68.99	20.37
10170	60205241301	10160	126.59	68.82	20.35
10180	60205240301	10170	117.80	68.57	20.33
10190	60205239301	10180	114.83	68.53	20.32
10200	60205262101	H10080	17.22	57.21	22.66
10210	10203877301	10200	7.16	60.06	22.63
10220	60205261102	H10080	30.56	80.88	22.46
10230	60205260002	10220	11.42	78.14	22.39
10240	60205259001	10220	3.40	80.58	22.71
10250	60205259301	10240	3.35	80.62	22.71
10260	60205258001	H10080	215.94	71.72	22.64
10270	60205257101	10260	18.94	72.16	22.30
10280	60205256001	10260	177.46	72.65	22.70
10290	10203901001	10280	137.22	72.99	22.86
10300	60205255301	10280	22.94	71.71	23.07
10310	206	H10100	1171.05	67.21	22.00
10320	60205237301	10310	22.52	78.49	21.88
10330	60205236002	10310	6.07	64.97	22.49
10340	10203859301	10330	5.32	67.50	22.50
10350	60205236001	10310	1025.15	67.20	21.94
10360	60205236301	10350	3.56	67.83	22.35

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
10370	214	OUT	80.64	74.33	47.64
10380	60204961301	10370	5.64	73.88	47.64
10390	10203976001	10370	64.51	73.27	47.83
10400	60204962001	10390	64.44	73.32	47.83
10410	213	10400	61.79	70.74	47.74
10420	60204960301	10410	0.20	78.00	47.64
10430	123	10410	2.98	70.00	48.03
10450	10205078601	OUT	0.00	73.25	27.48
A10000	7301410	10040	297.28	62.39	22.13
A10010	60205253002	A10000	292.91	62.45	22.12
A10020	60205253303	A10010	0.85	52.07	22.42
A10030	60205253302	A10010	1.46	75.07	22.35
A10040	60205253301	A10030	1.42	75.49	22.35
A10050	60205252301	A10030	15.50	58.59	22.45
A10060	10203891001	A10030	63.46	66.15	21.97
A10070	60205251301	A10060	0.47	69.30	21.97
B10000	7300000	10350	1012.49	67.27	21.94
B10010	60205235001	B10000	989.54	67.14	21.94
B10020	10203889001	B10010	28.05	74.89	21.86
B10030	10204265301	B10010	14.02	62.96	23.08
B10040	60205234001	B10010	103.49	72.31	21.74
B10050	60205233003	B10040	76.78	74.59	21.77
B10060	60205233301	B10010	263.56	64.98	21.23
B10070	60205232001	B10060	18.58	62.37	22.09
B10080	210	B10060	201.05	63.51	21.07
C10000	7297910	D10000	920.84	69.85	17.90
C10010	149	C10000	895.72	70.01	17.84
C10020	60205195301	C10010	15.38	66.87	18.82
C10025	302	C10010	678.00	70.99	17.45
C10030	221	C10025	677.25	70.99	17.45
C10040	60205194301	C10030	676.11	71.01	17.45
C10050	10205022301	C10040	670.02	71.06	17.43
C10060	60205193301	C10050	667.53	71.10	17.43
C10070	60205189301	C10060	542.62	72.35	17.30
C10075	262	C10070	100.00	75.00	40.00
C10080	60205188301	C10070	474.85	72.36	17.14

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
C10090	60205187401	C10080	313.94	74.23	17.06
C10100	60205196301	C10090	2.01	70.00	17.75
C10110	60205186301	C10090	299.91	74.66	17.05
C10120	60205185301	C10080	87.24	70.73	17.12
C10130	60205184101	C10120	76.59	70.83	17.11
C10140	60205184301	C10130	76.40	70.84	17.11
C10150	60205183101	C10140	74.53	70.89	17.11
C10160	60205183301	C10150	74.41	70.90	17.11
C10170	60205182101	C10160	73.84	70.92	17.11
C10180	60205182301	C10170	73.77	70.92	17.11
C10190	60205181301	C10060	112.21	65.04	18.05
C10200	10205312301	C10190	102.74	64.77	18.01
C10210	60205180301	C10200	71.82	63.91	17.89
C10220	60205179001	C10210	11.17	64.49	17.57
D10000	7299540	H10150	2949.79	68.32	19.61
D10010	60205222301	D10000	3.14	47.45	20.84
D10020	60205221302	D10000	14.67	76.45	20.68
D10030	60205221301	D10000	35.57	69.52	20.67
D10040	10203958301	D10000	0.44	90.00	20.75
D10050	60205220301	D10000	6.59	73.52	21.05
D10060	60205219301	D10050	4.35	72.74	21.07
D10070	60205217301	D10000	1.54	72.88	20.99
D10080	60205216301	D10000	3.15	69.97	21.02
D10090	60205215301	D10000	2.89	74.62	20.92
D10100	60205214301	D10000	13.91	63.47	21.42
D10110	60205213301	D10000	4.28	62.42	21.52
D10120	60205212301	D10000	5.94	64.17	20.62
D10130	60205211301	D10000	319.35	66.47	18.92
D10140	219	D10130	280.82	66.58	18.75
D10150	60205207301	D10140	199.13	66.40	18.59
D10160	60205206301	D10150	191.28	66.33	18.56
D10170	60205198302	D10160	96.95	65.41	18.32
D10180	60205198301	D10170	96.47	65.37	18.31
D10190	60205197302	D10180	95.45	65.27	18.30
D10200	60205205301	D10160	68.38	66.70	18.64
D10210	60205204301	D10200	66.30	66.53	18.61

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
D10220	60205203301	D10210	62.67	66.64	18.57
D10230	60205202301	D10220	59.44	66.24	18.53
D10240	60205200301	D10230	37.00	65.83	18.30
D10250	60205199302	D10240	21.85	66.26	18.14
D10260	60205199301	D10250	20.23	66.52	18.13
D10270	60205210301	D10120	53.46	67.94	18.97
D10280	60205209301	D10270	39.15	66.97	18.84
D10290	60205208301	D10280	31.13	66.18	18.73
E10000	7299670	H10130	319.99	79.93	22.90
E10010	60205227001	E10000	317.45	80.03	22.89
E10020	60205228001	E10010	314.54	80.10	22.88
E10025	86	E10020	200.00	80.10	22.88
E10030	60205226001	E10020	167.41	80.37	22.40
E10040	60205225001	E10030	156.85	80.51	22.28
E10050	60205224301	E10040	0.69	81.68	20.87
F10000	7307800	G10000	2187.77	61.58	21.07
F10010	202	F10000	1088.56	60.30	21.35
F10020	60205111001	F10010	1000.57	59.85	21.30
F10030	218	F10020	951.78	59.75	21.28
F10040	201	F10030	36.65	60.52	21.16
F10050	60205110301	F10030	0.85	76.25	21.42
F10060	60205266301	F10030	0.78	73.28	21.30
F10070	10204127301	F10060	0.15	61.00	21.30
F10080	10204127001	F10070	0.35	63.26	21.30
F10090	217	F10080	19.15	61.84	21.11
F10100	10205316301	F10000	1.98	81.79	20.86
F10110	60205107301	F10000	13.72	71.56	20.23
F10120	60205108301	F10000	6.03	77.32	20.07
F10130	60205106301	F10000	1.32	76.63	20.97
F10140	60205105301	F10000	5.88	75.31	20.98
F10150	60205103301	F10140	1.48	74.39	21.06
F10160	60205104301	F10140	0.91	69.76	21.03
F10170	60205102301	F10000	2.97	63.75	21.04
F10180	197	F10000	1.71	57.79	21.06
F10190	60205101301	F10000	5.35	59.15	21.09
F10200	60205100301	F10000	2.42	75.39	21.05

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
F10210	60205267301	F10000	8.93	69.28	21.13
F10220	60205099301	F10210	8.32	69.43	21.14
G10000	7308200	H10060	611.21	85.00	25.59
G10010	60205112302	G10000	6.57	47.00	24.41
G10020	60205112301	G10010	0.54	47.00	24.41
H10000	7308500	U10180	8252.67	77.00	29.13
H10010	256	H10000	28.57	77.00	29.53
H10020	145	H10000	8005.01	39.00	26.77
H10030	198	H10020	788.79	39.00	26.77
H10040	60205113302	H10030	2.04	84.00	26.38
H10050	60205113301	H10040	0.34	84.00	26.38
H10060	299	H10030	617.96	39.00	25.98
H10070	148	H10020	7216.22	39.00	26.77
H10080	9991	H10070	7147.14	77.00	26.77
H10090	60205238301	H10080	6.05	77.53	26.46
H10100	9990	H10080	5403.54	69.94	20.90
H10110	60205230301	H10100	41.25	81.16	24.55
H10120	60205231001	H10100	346.06	79.67	23.03
H10130	60205230001	H10120	332.45	79.82	22.96
H10140	60205229301	H10130	4.68	80.49	24.50
H10150	147	H10100	3122.22	68.05	19.73
H10160	60205223001	H10100	198.71	67.09	21.53
I10000	7311600	J10000	485.03	71.70	22.49
I10010	60205114301	I10000	4.00	82.88	22.32
I10020	189	I10000	3.07	41.89	21.91
J10000	7311700	M10030	949.40	68.72	23.21
J10010	60205116301	J10000	26.02	63.03	24.74
J10020	60205115001	J10000	60.43	60.21	23.71
K10000	7311782	L10010	219.80	67.22	23.16
K10010	60205117001	K10000	219.79	67.22	23.16
K10020	215	K10010	0.37	74.75	22.27
L10000	7311800	M10030	556.40	59.35	23.76
L10010	60205118001	L10000	429.88	61.63	23.49
M10000	7311900	N10050	1834.99	63.88	23.76
M10010	60205120301	M10000	0.69	80.52	26.81
M10020	60205119301	M10000	1.00	80.76	25.95

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
M10030	216	M10000	1788.99	63.97	23.70
N10000	7312100	P10120	2048.40	63.85	24.07
N10010	181	N10000	2047.65	63.85	24.07
N10020	60205123301	N10010	2047.65	63.85	24.07
N10030	185	N10020	1909.11	63.74	23.87
N10040	190	N10030	1909.04	63.74	23.87
N10050	60205121101	N10040	1906.01	63.74	23.86
N10060	60205121301	N10050	0.03	61.00	26.61
O10000	7312200	P10090	647.91	74.18	26.03
O10010	10205393301	O10000	606.57	74.52	25.97
O10020	60205128301	O10010	14.52	75.86	27.85
O10030	60205128001	O10010	476.64	76.08	25.58
O10040	60205127301	O10010	398.97	76.05	25.37
O10050	60205126301	O10040	333.17	76.06	25.24
O10060	60205127001	O10050	331.83	76.08	25.23
O10070	60205125002	O10060	331.72	76.08	25.23
O10080	60205125301	O10070	324.52	76.14	25.21
O10090	60205124301	O10080	322.51	76.25	25.20
P10000	7312500	Q10040	3166.05	66.20	24.98
P10010	10204290001	P10000	3142.10	66.17	24.95
P10020	10204290301	P10010	0.78	61.10	29.01
P10030	60205133301	P10010	1.78	78.40	28.58
P10040	10205530001	P10010	3104.08	66.12	24.90
P10045	333	P10040	2.50	63.87	28.59
P10050	60205132301	P10040	8.46	63.87	28.59
P10060	60205131301	P10040	33.18	63.22	28.50
P10070	60205130002	P10040	2970.36	66.03	24.75
P10080	60205123001	P10070	2966.08	66.01	24.74
P10090	60205129001	P10080	675.80	73.73	26.08
P10100	10204099101	P10080	2208.48	63.71	24.24
P10110	60205123302	P10100	2176.36	63.66	24.22
P10120	177	P10110	2114.54	63.54	24.15
Q10000	7312700	U10170	3431.27	66.73	25.27
Q10010	60205136002	Q10000	3386.81	66.75	25.20
Q10015	316	Q10010	5.00	66.75	25.20
Q10020	60205135003	Q10010	3348.96	66.67	25.16

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
Q10025	315	Q10020	3258.00	66.22	24.98
Q10030	10205152501	Q10025	3168.77	66.22	24.98
Q10040	10205152001	Q10030	3168.77	66.22	24.98
Q10050	10204283301	Q10020	4.92	86.92	29.05
Q10060	60205122002	Q10020	135.16	74.25	27.95
Q10070	192	Q10060	127.44	73.83	27.89
Q10080	60205122301	Q10070	127.44	73.83	27.89
Q10090	191	Q10080	95.10	72.59	27.57
Q10100	60205134102	Q10090	90.86	72.67	27.53
R10000	7314500	S10040	468.11	67.16	28.03
R10010	60205144301	R10000	262.31	70.20	27.58
R10020	169	R10010	142.76	69.25	27.29
R10030	60205148301	R10000	1.76	59.31	29.13
R10040	60205148001	R10000	90.10	64.62	28.66
R10050	60205147301	R10040	0.59	74.04	28.82
R10060	60205145301	R10040	0.47	75.18	28.46
R10070	60205146302	R10040	12.16	64.45	28.48
R10080	60205146301	R10070	7.14	59.48	28.48
S10000	7314900	U10060	999.13	64.07	28.96
S10010	60205151301	S10000	0.46	47.33	29.85
S10020	161	S10000	826.60	66.13	28.75
S10030	60205150301	S10020	826.59	66.13	28.75
S10040	165	S10030	732.31	66.50	28.54
S10050	60205149301	S10040	8.27	75.79	30.13
T10000	7315200	U10020	193.68	68.67	31.34
U10000	7315500	V10060	13383.86	67.40	24.69
U10010	162	U10000	13379.86	64.18	29.69
U10020	10204268101	U10010	1475.37	64.16	29.69
U10030	60205109301	U10020	2.55	62.86	31.37
U10040	60205153301	U10020	0.29	54.68	31.73
U10050	60205154301	U10020	4.22	58.51	31.61
U10060	60205152301	U10020	1007.08	64.07	28.98
U10070	60205143001	U10010	11865.96	71.77	31.31
U10080	60205142303	U10070	0.53	78.18	31.30
U10090	60205142302	U10070	0.85	78.10	31.29
U10100	60205142301	U10070	2.62	72.15	31.20

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
U10110	143	U10070	11839.00	67.15	23.91
U10120	60205141301	U10110	0.35	70.81	31.22
U10130	60205140001	U10110	3465.55	66.70	25.32
U10140	60205139003	U10130	3460.05	66.71	25.31
U10150	60205137302	U10140	1.37	72.03	30.70
U10160	60205137301	U10140	0.95	69.97	30.59
U10170	60205138401	U10140	3433.51	66.73	25.27
U10180	9992	U10110	8338.89	67.23	23.60
V10000	7316000	W10380	14119.80	67.00	35.83
V10010	60204882301	V10000	0.29	67.90	36.39
V10020	60204881301	V10000	68.53	62.35	36.13
V10030	10205434301	V10020	0.45	73.15	35.59
V10040	10205434302	V10020	0.45	73.17	35.59
V10050	60204880301	V10000	2.25	77.72	35.14
V10060	9993	V10000	14036.30	96.31	3.42
V10070	60204879301	V10060	91.05	76.91	33.80
V10080	60204878301	V10070	5.07	80.85	33.44
V10090	10205605001	V10070	6.10	76.94	34.26
V10100	10205605301	V10090	4.84	78.92	34.30
V10110	10203834301	V10060	1.95	61.49	31.14
V10120	60204876301	V10060	11.32	68.56	32.16
V10130	60204875301	V10060	0.13	61.00	31.10
V10140	60204875302	V10060	0.22	61.00	31.49
V10150	60204874301	V10060	0.32	62.30	31.69
W10000	7332000	X10630	15051.87	68.73	28.38
W10010	60204903001	W10000	1.79	78.00	38.98
W10020	60204901301	W10000	10.24	59.00	38.98
W10030	60204902301	W10020	3.22	59.00	39.37
W10040	139	W10000	15034.87	95.00	38.98
W10050	142	W10040	15034.86	95.00	38.98
W10060	60204901302	W10050	15034.85	95.00	38.98
W10070	9995	W10060	14992.69	95.00	39.37
W10080	60204897301	W10070	0.21	79.13	38.98
W10090	60204896301	W10070	0.32	84.60	38.19
W10100	60204895303	W10070	3.75	69.10	39.50
W10110	60204895304	W10070	0.14	66.24	39.49

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
W10120	60204895305	W10110	0.12	66.98	39.49
W10130	10205113301	W10070	0.69	80.30	40.00
W10140	60204895309	W10070	103.78	71.37	38.95
W10150	60204895308	W10140	102.85	71.31	38.95
W10160	60204895310	W10150	3.21	69.07	39.47
W10170	60204895307	W10160	3.15	69.05	39.48
W10180	60204895306	W10170	2.59	69.55	39.52
W10190	60204895302	W10150	2.75	69.23	39.32
W10200	60204894301	W10150	0.78	72.15	40.04
W10210	60204895301	W10150	0.04	65.71	39.21
W10220	60204893302	W10150	0.14	70.00	38.67
W10230	60204893301	W10150	0.03	70.00	38.92
W10240	60204892301	W10230	0.90	70.45	38.54
W10250	60204891301	W10150	1.60	71.53	38.54
W10260	60204890301	W10250	0.30	70.00	38.54
W10270	60204889301	W10150	4.73	71.97	38.54
W10280	60204887301	W10070	0.25	74.45	38.62
W10290	60204886301	W10070	0.16	84.97	38.62
W10300	60204885302	W10070	0.02	74.00	38.19
W10310	60204885301	W10070	0.17	74.00	38.19
W10320	60204883301	W10070	0.62	76.51	38.09
W10330	60204884301	W10070	0.09	77.73	38.19
W10340	60204884302	W10070	0.16	81.76	38.19
W10350	60204884303	W10340	0.13	81.21	38.19
W10360	60204884304	W10070	0.16	84.57	38.19
W10370	9994	W10070	14217.45	91.87	6.01
W10380	141	W10370	14210.45	67.52	25.50
X10000	7335500	Y10370	16767.56	78.00	44.88
X10010	60204940301	X10000	177.90	95.00	45.28
X10020	153	X10010	136.73	55.00	45.28
X10030	60204939302	X10020	0.16	70.00	44.09
X10040	60204939301	X10030	0.14	59.00	44.09
X10050	60204937301	X10020	0.00	70.00	43.70
X10060	60204936301	X10020	0.77	70.00	43.31
X10070	60204938301	X10020	1.33	70.00	43.70
X10080	10205129301	X10070	0.04	70.00	43.70

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
X10090	60204935301	X10020	0.23	70.00	43.70
X10100	60204934302	X10020	0.39	70.00	43.70
X10110	60204934301	X10020	0.02	70.00	43.70
X10120	10204294301	X10020	0.01	70.00	43.70
X10130	60204933301	X10020	0.12	70.00	43.70
X10140	10205276001	X10000	16558.91	95.00	44.88
X10150	9997	X10140	16554.91	69.04	29.02
X10160	60204930001	X10150	16474.91	84.00	43.70
X10170	10203888001	X10160	15.53	78.00	42.91
X10175	60204931301	X10170	0.17	70.00	43.70
X10180	10203888002	X10160	16458.91	84.00	42.91
X10190	10203924002	X10180	424.88	95.00	42.91
X10200	60204920001	X10190	424.74	78.00	42.91
X10210	60204929301	X10200	0.81	78.00	43.31
X10220	60204915303	X10200	11.23	84.00	43.31
X10230	60204915302	X10200	39.83	90.00	42.91
X10240	60204928301	X10230	0.58	78.00	42.91
X10250	60204927301	X10200	0.52	92.00	43.70
X10260	60204926101	X10200	277.16	85.00	42.91
X10270	60204925301	X10260	25.66	70.00	42.52
X10280	260	X10260	3.14	85.00	42.91
X10290	60204923301	X10260	0.38	70.00	42.91
X10300	60204924301	X10260	0.58	70.00	42.91
X10310	60204922001	X10260	9.73	70.00	42.52
X10320	60204922301	X10310	1.08	70.00	42.91
X10330	60204921002	X10260	6.76	85.00	42.52
X10340	60204921001	X10260	109.31	85.00	42.52
X10350	10204044101	X10180	16017.26	95.00	42.91
X10360	10204044001	X10350	16016.75	95.00	43.31
X10370	9996	X10360	16015.45	68.68	28.36
X10380	10204033004	X10370	16015.33	78.00	42.91
X10390	10204033003	X10380	16015.22	95.00	42.91
X10400	60204919001	X10390	16006.40	70.00	42.91
X10410	60204918101	X10400	15992.90	95.00	42.91
X10420	10204059002	X10410	15988.39	95.00	42.91
X10430	60204917003	X10420	15986.49	92.00	42.91

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Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
X10440	60204917001	X10430	15985.96	95.00	42.52
X10450	60204916001	X10440	13.11	95.00	42.52
X10460	60204915301	X10440	0.62	55.00	42.13
X10470	60204914301	X10440	5.77	70.00	42.13
X10480	60204913002	X10440	5.00	55.00	41.34
X10490	60204900301	X10440	8.50	92.00	42.13
X10500	60204912301	X10440	0.12	78.00	40.94
X10510	60204912401	X10440	260.28	84.00	41.34
X10520	60204908001	X10510	193.63	78.00	40.16
X10530	60204907001	X10520	112.65	78.00	40.16
X10540	60204906301	X10530	0.24	70.00	40.55
X10550	60204905301	X10530	0.69	70.00	40.16
X10560	292	X10530	40.73	78.00	40.16
X10570	60204911302	X10510	0.05	90.00	39.76
X10580	60204911301	X10510	0.12	90.00	39.76
X10590	60204910301	X10510	2.38	70.00	39.76
X10600	60204909301	X10510	2.42	70.00	40.16
X10610	10205630001	X10440	15065.96	95.00	40.16
X10620	265	X10610	2.02	70.00	39.76
X10630	60204904003	X10610	15052.34	90.00	39.37
Y10000	7337000	Z10030	18563.36	78.00	47.64
Y10010	138	Y10000	18562.86	78.00	48.03
Y10020	60204959002	Y10010	18529.86	78.00	47.64
Y10030	60204958301	Y10020	0.21	78.00	47.64
Y10040	10205632001	Y10020	18499.98	84.00	47.64
Y10050	60204957003	Y10040	18499.29	78.00	47.64
Y10060	60204956001	Y10050	18497.53	84.00	48.03
Y10070	60204955301	Y10060	4.83	55.00	48.43
Y10080	60204954002	Y10060	18344.33	84.00	48.03
Y10090	137	Y10080	18341.77	78.00	48.03
Y10100	9999	Y10090	18341.52	68.97	30.36
Y10110	60204953002	Y10100	18335.02	95.00	48.03
Y10120	10204058002	Y10110	17445.95	84.00	48.03
Y10130	10204058001	Y10120	17445.45	95.00	47.64
Y10140	60204952002	Y10130	38.45	78.00	47.24
Y10150	60204951301	Y10130	1.56	70.00	45.67

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Red River Basin					
Y10160	60204950301	Y10130	0.18	70.00	46.85
Y10170	60204949002	Y10130	176.36	78.00	46.46
Y10180	60204946003	Y10170	127.86	78.00	46.46
Y10190	60204946004	Y10170	44.07	70.00	46.06
Y10200	60204948301	Y10190	0.25	70.00	46.85
Y10210	60204947301	Y10190	0.69	70.00	46.85
Y10220	60204946002	Y10130	17007.53	61.00	46.46
Y10230	9998	Y10220	16982.06	67.97	29.30
Y10240	10205233005	Y10230	184.51	78.00	45.67
Y10250	10205233004	Y10240	180.74	78.00	45.67
Y10260	10205233002	Y10250	178.66	78.00	45.67
Y10270	10205149301	Y10260	0.74	59.00	45.28
Y10280	60204945001	Y10260	145.02	70.00	45.28
Y10290	10205558401	Y10280	0.33	92.00	45.67
Y10300	312	Y10280	6.85	70.00	45.28
Y10305	15	Y10280	3.00	70.00	45.28
Y10310	10205119001	Y10300	4.76	70.00	45.28
Y10320	60204944301	Y10310	1.24	70.00	45.28
Y10330	60204943301	Y10280	55.25	59.00	45.67
Y10340	60204942301	Y10330	1.54	70.00	45.67
Y10350	151	Y10330	29.01	95.00	45.67
Y10360	60204941301	Y10230	1.49	84.00	45.67
Y10370	60204941002	Y10230	16776.56	95.00	45.67
Z10000	None	OUT	27574.00	74.00	48.00
Z10010	10002	Z10000	27476.00	74.00	48.00
Z10020	10001	Z10010	26677.00	74.00	48.00
Z10030	10000	Z10020	22913.00	74.00	48.00
Canadian River Basin					
F10025	10103968301	F10020	86.8702	73.38	18.63
A10060	10104106301	A10000	8.2029	70.89	19.22
A10080	10104184301	A10060	0.0539	61	19.17
A10030	10105049301	A10000	3.8847	77.54	19.33
A10040	10105057301	A10030	1.72	80.71	19.33
A10050	10105057302	A10040	1.0619	83.47	19.33
A10070	10105627301	A10060	0.1759	63.75	19.23
A10020	10105638301	A10000	2.3111	65.87	19.27

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Canadian River Basin					
A10160	60103776301	A10000	938	66.15	16
A10140	60103777301	A10000	40	63	17
A10150	60103777302	A10000	2	63	17
A10130	60103778301	A10110	2	63	17
A10110	60103779301	A10000	100	63	17
A10120	60103779302	A10110	1	63	17
A10100	60103779303	A10000	20	63	17
A10090	60103779304	A10000	30	63	17
B10140	60103780301	B10130	4	61	17
B10150	60103781301	B10130	2.0891	61.28	17.4
B10130	60103782301	B10120	15956.624	63.49	16.86
B10100	60103783301	B10000	0.3172	78.51	19.74
B10090	60103784301	B10000	0.338	82.66	19.74
B10070	60103784501	B10000	143.8726	62.92	20.32
B10080	60103785301	B10070	0.425	84.88	19.8
B10050	60103786301	B10000	10.4785	49.31	19.1
B10030	60103787101	B10000	108.7236	70.91	21.16
B10020	60103788301	B10000	0.3841	68.92	21.73
F10130	60103789301	F10120	41.7521	41.43	21.82
F10120	60103790301	F10150	44.4081	41.26	21.79
C10020	60103791301	C10000	20	70	66
C10010	60103792301	C10000	5.8012	69.97	17.66
D10050	60103793301	D10040	95	73.8	17.29
D10040	60103794301	D10030	190.0188	73.8	17.29
D10020	60103795001	D10010	193.3565	73.71	17.29
D10030	60103795301	D10020	193.1206	73.71	17.29
D10100	60103796301	D10090	22.9228	70.39	17.39
D10080	60103797301	D10010	247.2188	73.16	17.3
D10090	60103797302	D10080	212.4132	73.29	17.27
D10070	60103798301	D10010	8.2689	70.06	17.6
D10060	60103799302	D10010	20.4277	66.1	18.42
D10010	60103800001	D10000	1039.1558	69.59	17.65
F10070	60103801301	F10060	23.4439	68.04	18.32
F10060	60103801302	F10050	23.4623	68.03	18.32
F10040	60103802301	F10030	19.2661	71.77	18.53
F10020	60103803301	OUT	1413.3659	69.92	17.92

Table 7 Control Points and Corresponding Watershed Parameters (Continued)

Control Point Name	CRWR Number	Downstream Control Point	Drainage Area (sq mi)	CN	Avg Precip (in)
Canadian River Basin					
F10010	60103804301	OUT	6.3311	70.18	18.36
F10080	60103805001	OUT	419.6927	79.5	20.66
E10010	60103806301	E10000	405.863	78.77	19.7
F10110	60103807001	F10160	14.6744	60.6	21.24
F10140	10072.001	F10150	18121.261	62.87	17.26
A10180	10099.001	A10170	936.9006	66.15	16
B10060	10283.001	B10000	0.942	58.79	20.6
B10040	10358.002	B10030	20.7075	79.41	20.92
A10010	10392.001	A10000	26.747	71.94	19.4
F10090	10508.001	OUT	1.42	79.12	22.56
B10110	10535.001	B10000	19.2	64.36	20.29
F10100	10572.001	OUT	4.4203	59.51	22.67
F10050	10751.001	F10020	86.2819	69.36	18.34
F10030	10977.001	F10025	86.0848	73.34	18.63
B10010	11027.001	B10000	3.8185	64.21	21.75
A10000	CR_AM	B10160	15297.574	63.6	16.78
B10000	CR_CN	F10140	18112.047	62.88	17.26
D10000	PD_SP	F10020	1150	69.75	17.75
E10000	WC_LP	F10160	732.08	72	20
C10000	CC_GR	OUT	1000	70	17.65
A10200	681	A10000	10649.72	64.4	16.8
A10190	689	A10180	882.4458	66.11	15.92
A10170	690	A10160	937.1465	66.15	16
B10160	677	B10130	15451.332	63.54	16.81
B10120	675	B10000	15956.645	63.49	16.86
B10145	678	B10130	15.8923	54.89	18.96
F10150	676	OUT	18399.195	62.65	17.32
E10020	685	E10010	28.9478	84.28	19.61
F10160	686	OUT	1059.1689	66.93	20.67

3.2.1 Distribution of Natural Flows Considering Channel Losses

Channel losses were analyzed in the Red and Canadian River Basins. Refer to the discussion in Section 3.1.3.

3.2.2 Impacts on Instream Flows

A detailed analysis of reservoir storage, unappropriated, and regulated flows has not been made due to the estimation of watershed parameters for the basins. After watershed parameters have been generated, a detailed analysis of the basin will be made and presented in a final version of this report.

3.3 Adjusted Net Reservoir Evaporation

Adjusted net evaporation data are utilized in water availability modeling in two ways:

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

Adjusted net evaporation data for the reservoirs within the Canadian and Red River Basins were calculated by a computer program discussed in Section 3.3.2.

3.3.1 Evaporation Data Sources

The evaporation and precipitation data were developed based on data obtained from the TWDB and National Climatic Data Center (NCDC) daily records. Runoff data were developed based on USGS gaged flows.

3.3.2 Procedures for Estimation of Adjusted Net Reservoir Evaporation

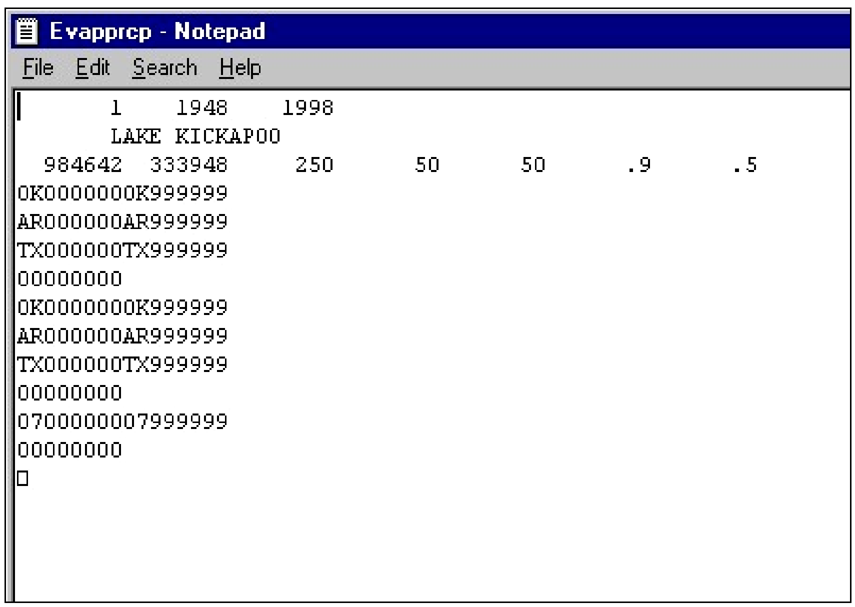
Adjusted net reservoir evaporation is the rate at which water is lost to evaporation from the surface of a reservoir. It represents the net impact of evaporation and rainfall directly on the reservoir surface. The equation for adjusted net reservoir evaporation used in this study is:

$$ANE = GE - R + xR,$$

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

A computer program was written to compute the *ANE*. The input records used for this program consist of the name of the reservoir, the reservoir's longitude and latitude coordinates, and several program parameters that can be adjusted to achieve the desired results. These adjustable program parameters include beginning year, ending year, evaporation gage search radius, precipitation gage search radius, stream gage search radius, and two parameters used for a rainfall-runoff correlation. The coordinates for each reservoir's dam were published in the U.S. Army Corps of Engineers *National Inventory of Dams*. An example of the input record is shown in Figure 9.

Figure 9 Sample Input Record for the Adjusted Net Evaporation Program




```
       1    1948    1998
       LAKE KICKAPOO
  984642  333948     250      50      50      .9      .5
OK0000000K999999
AR000000AR999999
TX000000TX999999
00000000
OK0000000K999999
AR000000AR999999
TX000000TX999999
00000000
0700000007999999
00000000
```

The program begins by searching the NCDC database for both evaporation and precipitation gages that are located within the specified search radii. The pan evaporation data measured at the NCDC stations are adjusted using pan coefficients from Plates 1 & 3 of the *Weather Bureau Technical Paper No. 37*. The program then takes these daily records of evaporation and precipitation and uses them to estimate monthly evaporation (*GE*) and monthly precipitation (*R*) at the site of interest using weighted averages.

The next function of the program is to estimate monthly runoff at the site. The program begins by searching the USGS streamflow records for stations within the prescribed radius. The program then selects the station with the smallest drainage area that also has a period of record of at least ten years. In an effort to make the most accurate estimation of runoff, an Antecedent Precipitation Index (API) rainfall-runoff correlation was applied to the estimated precipitation at the site. Three different API curves were used for this study. The selection of the appropriate curve was based on the site's geographical location. The program adjusts the streamflow monthly volumes from the selected USGS station to reflect the results of the API rainfall-runoff correlation by carrying out an iterative process. The result of this function is the estimated monthly runoff (xR) at the site.

The last function performed by the program is to calculate the monthly values of adjusted net evaporation rate (*ANE*) at the site.

The sources of the data required to determine reservoir evaporation rate, shown in Table 8, are as follows:

- *Gross Reservoir Evaporation* – The NCDC database of meteorological parameters. For this particular study the ranges of pan evaporation gages that were considered were AR000000 through AR999999, OK000000 through OK999999, and TX000000 through TX999999. The Weather Bureau *Technical Paper No. 37* was used for pan coefficients to adjust pan evaporation data.

- *Precipitation* - The NCDC database of meteorological parameters. For this particular study the ranges of precipitation gages that were considered were AR000000 through AR999999, OK000000 through OK999999, and TX000000 through TX999999.

- *The Portion of Rainfall That Would Have Run Off in the Absence of a Reservoir* – Runoff was obtained from USGS database of streamflow data. The National Weather Service – River Forecast Center in Tulsa, Oklahoma, developed the API curves used in this study.

3.3.3 Comparison of Evaporation Data Sets

Monthly values of adjusted net evaporation for each of the major reservoirs were used as input to the 51-year period WRAP (DECEMBER, 2001) model of the Red and Canadian River Basins. In addition, adjusted net evaporation for each 1-degree quadrangle was input for simulation of the minor reservoirs. Methods for estimating quadrangle runoff are shown in Table 9.

Table 8 Sources of Data for Deriving Net Evaporation Rates

Reservoir	Quadrangle Factors (**)
Red River Basin	
Lake Nocona	0.177 (309) + 0.210 (409) + 0.449 (410) + 0.164 (411)
Hubert H Moss Lake	0.127 (309) + 0.150 (409) + 0.485 (410) + 0.238 (411)
Lake Texoma	0.120 (309) + 0.244 (410) + 0.450 (411) + 0.186 (412)
Valley Lake	0.058 (309) + 0.120 (410) + 0.673 (411) + 0.149 (412)
Randall Lake	0.096 (309) + 0.200 (410) + 0.529 (411) + 0.175 (412)
Coffee Mill Lake; Lake Fannin	0.161 (410) + 0.422 (411) + 0.417 (412)
Lake Bonham	0.156 (410) + 0.531 (411) + 0.313 (412)
Pat Mayse	0.233 (411) + 0.573 (412) + 0.194 (413)
Lake Crook	0.191 (411) + 0.648 (412) + 0.161 (413)
Truscott Brine	
Lake Kemp	0.199 (308) + 0.139 (407) + 0.433 (408) + 0.229 (409)
Lake Diversion	0.214 (309) + 0.307 (408) + 0.344 (409) + 0.135 (410)
Santa Rosa Lake; Wharton Lake	0.283 (308) + 0.151 (407) + 0.350 (408) + 0.216 (409)
Lake Electra	0.250 (308) + 0.239 (309) + 0.261 (408) + 0.250 (409)
North Fork Buffalo Creek	0.198 (308) + 0.294 (309) + 0.198 (408) + 0.310 (409)
Lake Kickapoo	0.140 (308) + 0.160 (309) + 0.237 (408) + 0.463 (409)
Lake Arrowhead	0.159 (309) + 0.133 (408) + 0.544 (409) + 0.164 (410)
Bivins	0.275 (205) + 0.246 (206) + 0.249 (305) + 0.230 (306)
Buffalo Lake	0.237 (205) + 0.200 (206) + 0.319 (305) + 0.244 (306)
Mackenzie	0.053 (206) + 0.058 (305) + 0.827 (306) + 0.062 (307)
Baylor Creek	0.072 (207) + 0.750 (307) + 0.101 (308) + 0.077 (407)
Greenbelt	0.242 (206) + 0.275 (207) + 0.226 (306) + 0.257 (307)
Cibola National Forest	
Lake Wichita	0.232 (309) + 0.175 (408) + 0.430 (409) + 0.163 (410)
Canadian River Basin	
Lake Rita Blanca	0.426 (105) + 0.207 (106) + 0.367 (205)
Lake Meredith	0.139 (106) + 0.159 (205) + 0.577 (206) + 0.125 (207)
PaloDuro	0.127 (105) + 0.484 (106) + 0.236 (107) + 0.153 (206)

(**) Numbers in parentheses indicate evaporation quadrangles.

Table 9 Methods for Estimating Quadrangle Runoff

Quadrangle	Gage	Basin	USGS Number	Drainage Area (square miles)	Period
Red River Basin					
205	Canadian River near Amarillo (CR_AM)	Canadian	7227500	19,445	1/48-Present
206	Canadian River near Canadian (CR_CN)	Canadian	7228000	22,866	1/48-Present
207	Canadian River near Canadian (CR_CN)	Canadian	7228000	22,866	1/48-11/61
	Sweetwater Creek near Kelton (SW_KT)	Red	7301410	287	12/61-Present
305	Prairie Dog Town Fork, Red River near Wayside (PD_WA)	Red	7297910	4,211	10/67-Present
306	Prairie Dog Town Fork, Red River near Wayside (PD_WA)	Red	7297910	4,211	10/67-Present
307	Pease River near Childress (PR_CS)	Red	7307800	2,754	12/59-9/65
	Prairie Dog Town Fork, Red River near Childress (PD_CH)	Red	7299540	7,725	10/65-Present
308	Pease River near Vernon (PR_VN)		7308200	3,488	12/59-Present
309	Deep Red Run near Randlett (DR_RD)	Red	7311500	617	10/49-12/60
	East Cache Creek near Walters (EC_WA)	Red	7311000	675	1/48-9/49; 10/69-Present
	Red River near Burkburnett (RR_BB)	Red	7308500	20,570	1/61-9/69
406	DMF Brazos River at Justiceburg	Brazos	8079600	1,466	12/61-Present
407	Salt Fork Brazos River near Aspermont	Brazos	8082000	5,130	1/48-Present
408	Brazos River at Seymour	Brazos	8082500	15,538	1/48-9/59
	Wichita River near Mabelle (WR_MB)	Red	7312100	2,086	10/59-Present
409	Big Sandy Creek near Bridgeport	Trinity	8044000	333	1/48 - 2/56
	West Fork Trinity River near Jacksboro	Trinity	8042800	683	3/56-Present
410	Big Sandy Creek near Bridgeport	Trinity	8044000	333	1/48 - 9/49
	Denton Creek near Justin	Trinity	8053500	400	10/49-Present
411	East Fork Trinity River near Rockwall	Trinity	8061500	840	1/48 - 8/49
	Sister Grove Creek near Princeton	Trinity	8059500	113	9/49-1/75
	Little Elm Creek near Aubrey	Trinity	8052700	75.5	2/75 - 6/75
	Sister Grove Creek near Blue Ridge	Trinity	8059400	83.1	7/75-Present
412	White Oak Creek below Talco	Red	7343800	494	1/48 - 9/49
	North Sulphur River near Cooper	Red	7343000	276	10/49-Present
	Or				
	South Sulphur River near Cooper	Red	7342500	527	10/49-Present
413	Red River at Index (RR_IN)	Red	7337000	48,030	1/48-Present
414	Red River near Spring Bank (RR_SB)	Red	7344350	56,909	1/48-Present
508	Clear Fork Brazos River at Nugent	Brazos	8084000	2,199	1/48-Present

Table 9 Methods for Estimating Quadrangle Runoff (Continued)

Quadrangle	Gage	Basin	USGS Number	Drainage Area (square miles)	Period
Red River Basin					
509	TNRCC Naturalized Flow for Leon Reservoir	Brazos	8099000	259	1/48 - 4/51
	Palo Pinto Creek near Santo	Brazos	8090500	573	5/51-3/58
	North Bosque River at Stephenville	Brazos	8093700	95.9	3/58-9/79
	North Bosque River at Hico	Brazos	8094800	359	10/79-Present
510	Clear Fork Trinity River near Aledo	Trinity	8046000	251	8/48 - 2/57
	Denton Creek near Justin	Trinity	8053500	400	3/57 - 9/60
	Walnut Creek near Mansfield	Trinity	8049700	62.8	10/60-Present
511	Cedar Creek near Mabank	Trinity	8063000	733	1/48 - 12/62
	Kings Creek near Kaufman	Trinity	8062900	233	1/63-9/87
	Walnut Creek near Mansfield	Trinity	8049700	62.8	10/87-Present
512	Neches Naturalized Flows for Kickapoo Creek near Brownsboro (KI_BR)	Neches	8031200	232	1/48 - Present
513	Little Cypress near Jefferson	Cypress	7346070	675	1/48-Present
514	Twelvemile Bayou near Dixie	Red	7348000	3,137	1/48-9/95
	Red Chute Bayou at Sligo	Red	7349860	980	10/95-9/97
Canadian River Basin					
105	Beaver River near Felt	Canadian	7232250	879	10/95-10/99
106	Palo Duro Creek near Spearman (PD_SP)	Canadian	7233500	960	8/45-9/79
107	Wolf Creek at Lipscomb (WC_LP)	Canadian	7235000	697	1/48-Present
205	Canadian River near Amarillo (CR_AM)	Canadian	7227500	19,445	1/48-Present
206	Canadian River near Canadian (CR_CN)	Canadian	7228000	22,866	1/48-Present
207	Canadian River near Canadian (CR_CN)	Canadian	7228000	22,866	1/48-11/61
	Sweetwater Creek near Kelton (SW_KT)	Red	7301410	287	12/61-Present

3.4 Reservoir Elevation-Area-Capacity Relationships

Area-capacity relationships in this study were derived from two primary sources; original area-capacities were used for reservoirs with capacities over 5,000 ac-ft and a standard area-capacity relationship was developed for reservoirs with capacities less than 5,000 ac-ft. Table 10 is a list of major reservoirs in the Red and Canadian River Basins (over 5,000 ac-ft of conservation storage). Data sources for these reservoirs can be found in Table 11.

The elevation-area-capacity relationship for a reservoir is necessary to describe the storage capacities of the reservoir along with the evaporation potential. This relationship, which is also referred as the area-capacity curve, is typically developed during the reservoir design phase from the topography of the inundated area of the reservoir. The original capacity at the normal operating pool of a reservoir generally complies with the authorized capacity of the water use permit. Once impoundment of a reservoir begins, the reservoir accumulates sediment carried by the upstream inflow. The sediment successively deposited within the reservoir reduces the capacity and water surface area of the reservoir at various storage stages, thereby reducing the yield and changing evaporative characteristics of the reservoir.

Table 10 Major Reservoirs in the Red and Canadian River Basins Data

Reservoir	Drainage Area (square miles)	Stream	Date of Impoundment	Sources	Conservation Storage (Ac-Ft)			Sediment Survey Date
					Permitted	Original	Surveyed	
Red River Basin								
Lake Nocona	94	Farmers Creek	1961	N. Montague County Water Supply	25,389	26,400	22,398	1986
Hubert H Moss Lake	65	Fish Creek	Apr-66	City of Gainesville	23,210	23,210	24,155	1999
Lake Texoma	33,783	Red River	Jan-44	Flood Control	2,722,000	2,722,000	2,126,450	N/A
Valley Lake	8	Sand Creek	Dec-60	Texas Porer and Light Co.	15,000	16,400	N/A	N/A
Randall Lake	10.3	Shawnee Creek	N/A	City of Denison	5,400	4,250	N/A	N/A
Coffee Mill Lake	39	Coffee Mill Creek	1938	US Department of Agriculture	8,000	8,000	N/A	N/A
Lake Bonham	29	Timber Creek	Nov-69	Bonham Municipal Water Authority	13,000	12,000	N/A	N/A
Pat Mayse	175	Sanders Creek	Sep-67	Flood Control	124,500	124,500	115,657	1994
Lake Crook	52	Pine Creek	1923	City of Paris	12,000	9,964	N/A	N/A
Truscott Brine	26.2	Bluff Creek	Dec-82	USACE	107,000	111,147	N/A	N/A

Table 10 Major Reservoirs in the Red and Canadian River Basins Data (Continued)

Reservoir	Drainage Area (square miles)	Stream	Date of Impoundment	Sources	Conservation Storage (Ac-Ft)			Sediment Survey Date
					Permitted	Original	Surveyed	
Red River Basin								
Lake Kemp	2,086	Wichita River	1922	City of Wichita Falls & Wichita County	318,000	318,020	268,600	1985
Lake Diversion	N/A	Wichita River	1924	City of Wichita Falls & Wichita County Water Improvement District No.2	45,000	40,000	34,430	1972
Santa Rosa Lake; Wharton Lake	336	Beaver Creek	1929	WT Waggoner Estate	9,556	11,570	9,556	1972
Lake Electra	14.7	Camp Creek		City of Electra	8,730	8,050	No Data	No Data
North Fork Buffalo Creek	33	North Fork Buffalo	Nov-64	Wichita County Water Control & Improvement District No.3	15,400	15,400	N/A	N/A
Lake Kickapoo	275	North Fork Little Wichita River	Feb-46	City of Wichita Falls	105,000	106,000	N/A	N/A
Lake Arrowhead	832	Little Wichita River		City of Wichita Falls	228,000	262,000	N/A	N/A

Bivins	62	Palo Duro Creek	1926	City of Amarillo	5,122	5,120	N/A	N/A

Table 10 Major Reservoirs in the Red and Canadian River Basins Data (Continued)

Reservoir	Drainage Area (square miles)	Stream	Date of Impoundment	Sources	Conservation Storage (Ac-Ft)			Sediment Survey Date
					Permitted	Original	Surveyed	
Red River Basin								
Buffalo Lake	575	Tierra Blanco	Jun-38	US Department of Interior	18,120	18,150	N/A	N/A
Mackenzie	188	Tule Creek	Apr-74	Makenzie Municipal Water Authority	46,450	47,151	N/A	N/A
Baylor Creek	40	Baylor	Dec-49	City of Childress	9,200	9,220	N/A	N/A
Greenbelt	356	Salt Fork Red River	Dec-66	Greenbelt M&I WA	59,800	60,400	N/A	N/A
Cibola National Forest		McClellan		US Forest Service	5,005	5,005	No Data	No Data
Lake Wichita	143	Holiday Creek	1901	City of Wichita Falls	23,000	1,400	13,680	1980
Canadian River Basin								
Lake Rita Blanca	1,062	Rita Blanca Creek	Sep-41	Dallum & Hartley County	12,100	12,100	N/A	N/A
Lake Meredith	16,048	Canadian River	Jan-65	Canadian River Municipal Authority	151,200	1,407,600	1,358,594	1995

Palo Duro	614	Palo Duro Creek		Palo Duro River Authority	60,900	N/A	N/A

Table 11 Major Reservoirs in the Red and Canadian River Basins Area Capacity Source Information

Reservoir	Date of Impoundment	Conservation Storage Original (Ac-Ft)	Original Area-Capacity Source	Conservation Storage Surveyed (Ac-Ft)	Date of Survey	Surveyed Area-Capacity Source
Red River Basin						
Lake Nocona	1961	25,400	North Montague Co. Water Supply District	22,398	1986	Freese & Nichols, 1986 Report for North Montague Co. Water Supply District
Hubert H Moss Lake	Apr-66	23,210	City of Gainesville	24,155	1999	Volumetric Survey – TWDB
Lake Texoma	Jan-44	2,722,000	USACOE, Tulsa District	2,126,450	1985	USACOE, Tulsa
Valley Lake	Dec-60	16,400	Texas Power & Light	N/A	N/A	N/A
Randall Lake	1909	4,250	City of Denison	N/A	N/A	N/A
Coffee Mill Lake	1938	8,000 (1967)	U.S. Dept. of Ag, Forest Service	N/A	N/A	N/A
Lake Bonham	Nov-69	12,000	Bonham Municipal Water Authority	N/A	N/A	N/A

Table 11 Major Reservoirs in the Red and Canadian River Basins Area Capacity Source Information (Continued)

Reservoir	Date of Impoundment	Conservation Storage Original (Ac-Ft)	Original Area-Capacity Source	Conservation Storage Surveyed (Ac-Ft)	Date of Survey	Surveyed Area-Capacity Source
Red River Basin						
Pat Mayse	Sep-67	123,345	USACOE, Tulsa	115,657	1994	USACOE, Tulsa
Lake Crook	1923	9,964 (1956)	City of Paris	N/A	N/A	N/A
Truscott Brine	Dec-82	50,569	USACOE, Tulsa	N/A	N/A	N/A
Lake Kemp	1922	319,600 (1971)	USACOE, Tulsa	268,600	1985	USACOE, Tulsa
Lake Diversion	1924	40,000	Wichita Co. Water Improvement District #2	34,430	1972	TNRCC Dam Safety Report
Santa Rosa Lake	1929	11,570	W.T. Waggoner Estate	9,556	1972	TNRCC Dam Safety Report
Lake Electra	1950	No Data	No Data	No Data	No Data	No Data
North Fork Buffalo Creek	Nov-64	15,400	Wichita Co. Water Improvement District #3 & City of Iowa Park	N/A	N/A	N/A

Table 11 Major Reservoirs in the Red and Canadian River Basins Area Capacity Source Information (Continued)

Reservoir	Date of Impoundment	Conservation Storage Original (Ac-Ft)	Original Area-Capacity Source	Conservation Storage Surveyed (Ac-Ft)	Date of Survey	Surveyed Area-Capacity Source
Red River Basin						
Lake Kickapoo	Feb-46	106,000	City of Wichita Falls	N/A	N/A	N/A
Lake Arrowhead	1966	262,000	City of Wichita Falls	N/A	N/A	N/A
Bivins	1926	5,120 (1946)	City of Amarillo	N/A	N/A	N/A
Buffalo Lake	Jun-38	18,150	U.S. Dept. of Interior, Fish & Wildlife	N/A	N/A	N/A
Mackenzie	Apr-74	46,077	Mackenzie Municipal Water Authority	N/A	N/A	N/A
Baylor Creek	Dec-49	9,220	City of Childress	N/A	N/A	N/A
Greenbelt	Dec-66	60,400	Greenbelt Municipal & Industrial Water Authority	N/A	N/A	N/A
Cibola National Forest	1938	No Data	No Data	No Data	No Data	No Data

Table 11 Major Reservoirs in the Red and Canadian River Basins Area Capacity Source Information (Continued)

Reservoir	Date of Impoundment	Conservation Storage Original (Ac-Ft)	Original Area-Capacity Source	Conservation Storage Surveyed (Ac-Ft)	Date of Survey	Surveyed Area-Capacity Source
Red River Basin						
Lake Wichita	1901	15,720 (1958)	City of Wichita Falls	13,680	1980	City of Wichita Falls
Canadian River Basin						
Lake Rita Blanca	Sep-41	12,100	U.S. Dept. of Ag, SCS	N/A	N/A	N/A
Lake Meredith	Jan-65	1,407,600	USBR Original Data	1,358,594	1995	Volumetric Survey - TWDB
Palo Duro	1991	60,900	Palo Duro River Authority	N/A	N/A	N/A

3.4.1 Large Reservoirs

The Red River Basin has 24 major reservoirs. The area-capacity curves of the original design and the recent survey were published by the TWDB, as shown in Table 11.

The storage capacity data for the above-mentioned reservoirs were further reviewed for consistency with other available information, such as the "water resource" data published by USGS. All the area-capacity data, including those of year 2000 condition, were plotted and fitted to power-type equations. A number of 12 or less data points (depending on data availability) were selected as input to the WRAP model to define the area-capacity curve.

The method for developing the year 2000 area-capacity curve or relationship for each of the major reservoirs can be described as follows:

- The conservation storage capacity of each reservoir for year 2000 is to be reduced by the accumulated amount of sediment entering the reservoir between the date of the latest survey and year 2000. The amount of accumulated sediments is equal to the product of annual sedimentation rate, drainage area of the reservoir, and number of years between the latest survey and year 2000. The sedimentation rate can be obtained from data of the latest survey and the original design (see Table 12).

- It is assumed that the sediment accumulated within a reservoir is distributed at all elevations of the reservoir. The surface area of the reservoir at each elevation is then reduced due to sediment accumulation. The reductions of surface area at all elevations are assumed to be equal. This assumption constitutes the basis of the "area increment" method.

- This "area increment" method is an empirical procedure that reduces the water surface area from the area-capacity curve of the latest survey by a constant area until the new calculated storage capacity is reduced by the total volume of accumulated sediment.

Table 12 Sedimentation Rates for Major Reservoirs in the Red and Canadian River Basins

Reservoir	Original Capacity (Ac-Ft)	Date of Impoundment	Surveyed Capacity (Ac-Ft)	Date of Survey	Period (Years)	Drainage Area (Square Miles)	Sedimentation Rate (Ac-Ft per S.M. per Year)
Red River Basin							
Lake Nocona	25,400	1961	22398	1986	25	94	1.2774
Hubert H Moss Lake	23,210	Apr-66	24155	1999	33	65	Increase in Capacity
Lake Texoma	2,722,000	Jan-44	2126450	1985	41	33,783	0.43
Valley Lake	16,400	Dec-60	16141	2000	40	8	0.8094
Randall Lake	4,250	1909	4069	2000	91	10.3	0.1931
Coffee Mill Lake	8,000 (1967)	1938	7035	2000	33	39	0.7498
Lake Bonham	12,000	Nov-69	11238	2000	31	29	0.8476
Pat Mayse	123,345	Sep-67	115657	1994	27	175	1.6271
Lake Crook	9,964 (1956)	1923	7774	2000	44	52	0.9572
Truscott Brine	50,569	Dec-82	49518	2000	18	26.2	2.2286
Lake Kemp	319,600 (1971)	1922	268600	1985	14	2086	1.7463
Lake Diversion	40,000	1924	34430	1972	48		N/A
Santa Rosa Lake	11,570	1929	9556	1972	43	336	0.1394
Lake Electra	No Data	1950	No Data	No Data	No Data	14.7	No Data
North Fork Buffalo Creek	15,400	Nov-64	14413	2000	36	33	0.8308
Lake Kickapoo	106,000	Feb-46	103036	2000	54	275	0.1996
Lake Arrowhead	262,000	1966	260112	2000	34	832	0.0667

Table 12 Sedimentation Rates for Major Reservoirs in the Red and Canadian River Basins (Continued)

Reservoir	Original Capacity (Ac-Ft)	Date of Impoundment	Surveyed Capacity (Ac-Ft)	Date of Survey	Period (Years)	Drainage Area (Square Miles)	Sedimentation Rate (Ac-Ft per S.M. per Year)
Red River Basin							
Bivins	5,120 (1946)	1926	3923	2000	54	62	0.3575
Buffalo Lake	18,150	Jun-38	14593	2000	62	575	0.0998
Mackenzie	46,077	Apr-74	42330	2000	26	188	0.7666
Baylor Creek	9,220	Dec-49	6504	2000	51	40	1.3314
Greenbelt	60,400	Dec-66	51210	2000	34	356	0.7593
Cibola National Forest	No Data	1938	No Data	No Data	No Data		No Data
Lake Wichita	15,720 (1958)	1901	13680	1980	22	143	0.6484
Canadian River Basin							
Lake Rita Blanca	12,100	Sep-41	10770	2000	59	1,062	0.0212
Lake Meredith	1,407,600	Jan-65	1358594	1995	30	16,048	0.1018
Palo Duro	60,900	1991	60094	2000	9	614	0.1459

Note: Surveyed capacities are from TWDB surveys

3.4.2 Small Reservoirs

Standard elevation-area-capacity relationships have been used in the water availability analyses for small reservoirs with less than 5,000 ac-ft of storage. The TNRCC Dam Safety files and water rights files were examined to locate additional area-capacity curves for small impoundments within the Red and Canadian River Basins.

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

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

This form of equation, known as a power function, is the only equation form available to represent area-capacity relationships in WRAP (DECEMBER, 2001). To obtain the coefficients a, b, and c, regression analyses of available area-capacity data for existing small reservoirs have been performed. All available area-capacity curves for the small reservoirs in the Red and Canadian River Basins were plotted, and power function regression analyses were performed to obtain the best-fit equation. The data for the Canadian and Upper-Red River Basin were analyzed separately from the lower Red River Basin data.

For the upper portion of the Red River Basin, the R^2 for the best-fit line is also shown below.

$$a = 1.0706 \quad b = .6265 \quad c = 0 \quad R^2 = 0.9265$$

The graphs for the equation shown above and the original data points are shown in Figure 10. The area capacity relationship developed for small reservoirs in the Canadian and upper-portion of the Red River Basin with capacities less than 5,000 ac-ft is:

$$Area = 1.0706\left(Capacity\right)^{0.6265} + 0.00$$

For the lower Red, the R^2 for the best-fit line is also shown below.

$$a = 0.9477 \quad b = .665 \quad c = 0 \quad R^2 = 0.9587$$

The graphs for the equation shown above and the original data points are shown in Figure 11. The area capacity relationship developed for small reservoirs in the lower portion of the Red River Basin with capacities less than 5,000 ac-ft is:

$$Area = 0.9477\left(Capacity\right)^{0.665} + 0.00$$

The reservoir coefficients that were calculated were then input into WRAP to allow the surface area to be determined based on the storage in the reservoir during each month of the simulation. Therefore, allowing WRAP to remove the correct amount of evaporation from each of the minor reservoirs each month. The evaporation amount is determined by WRAP by multiplying the surface area by the amount of evaporative loss for the quadrangle that the minor reservoir is located. The net adjusted evaporation losses for each quadrangle are input in the evaporation records card.

3.5 Aquifer Recharge

The Red River crosses over several major aquifers in Texas. The aquifers include the Ogallala Aquifer in the west and the Trinity Aquifer in the north and east. The Canadian River is above the Ogallala Aquifer in the northern part of the Texas panhandle. There are several outcrops in the north and mid basin where varying amounts of aquifer recharge occur

(Water for Texas, 1997). These amounts were not investigated as part of this project. Aquifer recharge was not analyzed in this study.

3.5.1 Historical Recharge

The historical recharge rates in the western Red River Basin (above the Ogallala Aquifer) and the Canadian River Basin vary drastically. There have been numerous studies documenting the historical recharge into the Ogallala Aquifer through stream loss and playa lake infiltration. Recharge rates in various studies range from 0.01 to 0.833 inches per year (Peckham and Ashworth, 1993). Likewise, throughout the Red River Basin the estimates of historical recharge vary significantly. Historical recharge generally decreases from east to west. A detailed review of these studies and analysis of recharge was not performed as part of this report.

3.5.2 Enhanced Recharge

There are no known enhanced recharge structures in the Red or Canadian River Basins

Figure 10 Upper-Red and Canadian River Basins Standard Area-Capacity Curve Reservoirs Less Than 5,000 acre-feet

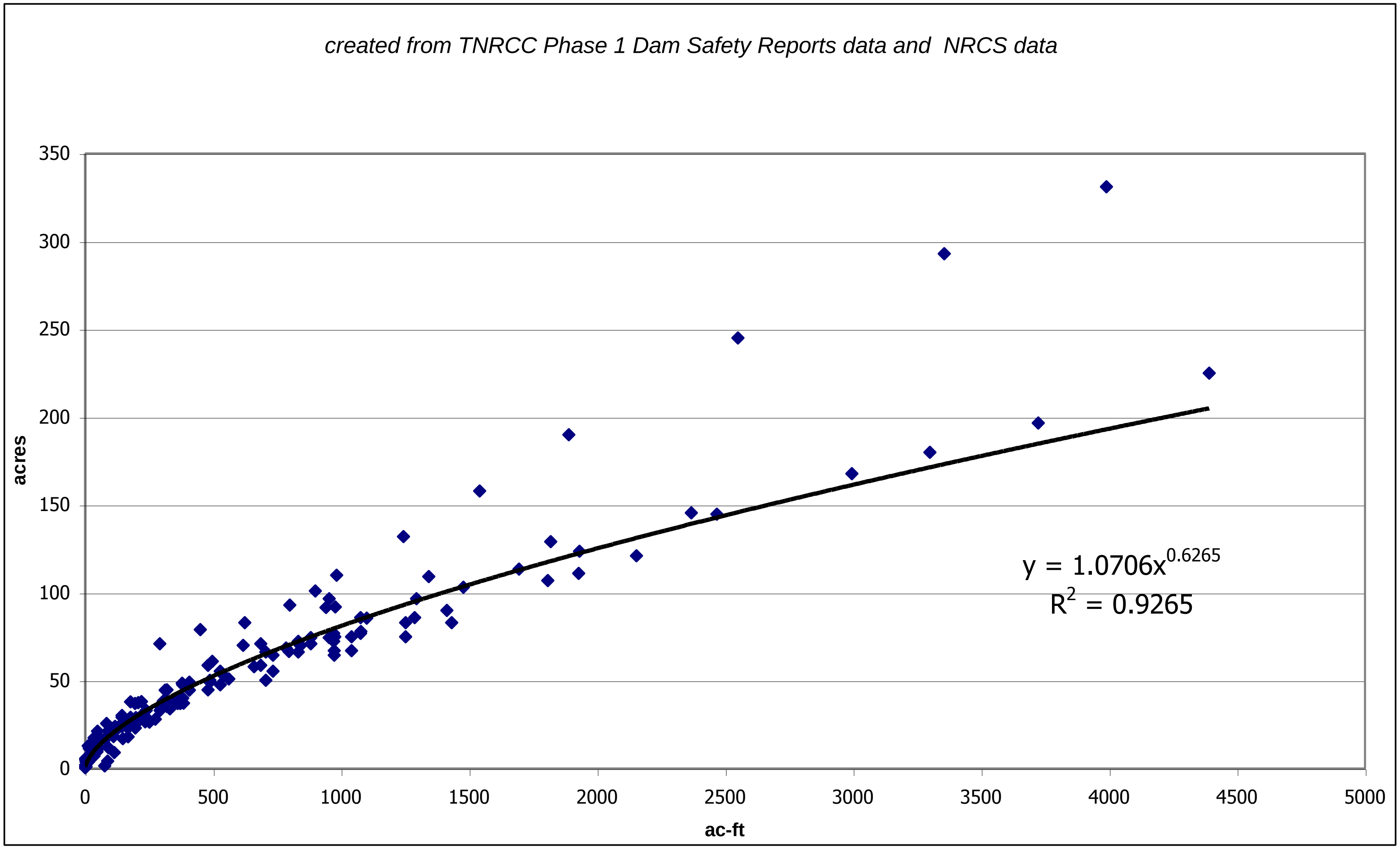
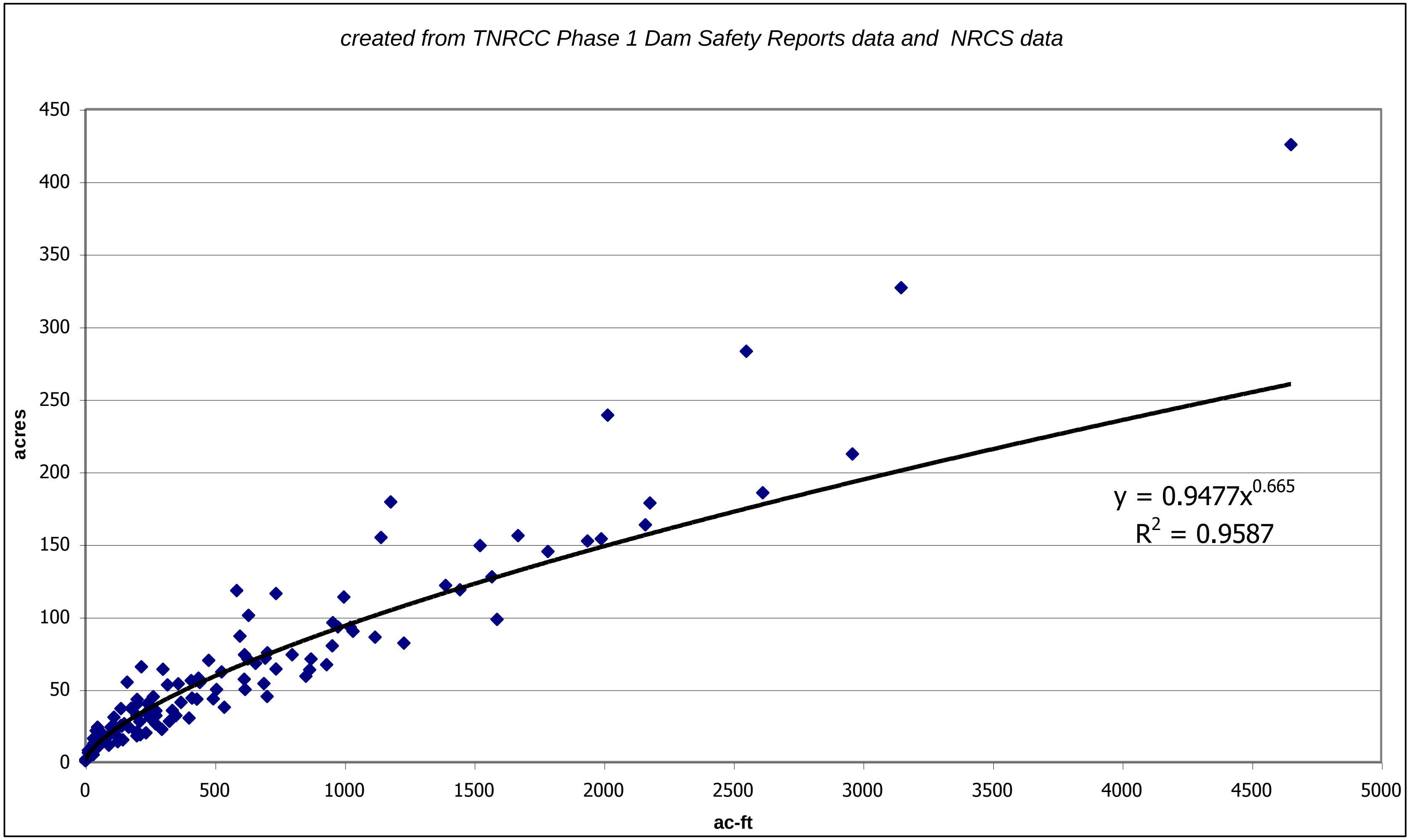


Figure 11 Lower Red River Basin Standard Area-Capacity Curve Reservoirs Less Than 5,000 acre-feet



4.0 WATER AVAILABILITY MODEL OF THE BASIN

WRAP (DECEMBER, 2001) was used to model the water availability of the Red and Canadian River Basins, utilizing input data specific to the Red and Canadian River Basins including water rights, reservoir information, and naturalized streamflows. The WRAP (DECEMBER, 2001) program was originally developed by Dr. Ralph Wurbs at the Texas A & M University in March 1986. Throughout the evolution of the WAM process and completion of numerous river basins, WRAP has undergone numerous improvements and upgrades. WRAP was selected by the WAM Management Team as the best model available to model the Texas prior appropriation system as well as meet the requirements set forth by SB1. Specific parameters utilized in WRAP will be described in the following sections.

4.1 Description of WRAP Model

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

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

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

Characteristics of specific water rights are incorporated as assumptions in the input data, such as in the WR record, WS record, and the OR record. These input cards describe how a water right will be simulated (from run of river, reservoir storage, or both), how the water rights will be divided (into use types and priority), and how multiple-reservoir operations will be defined.

4.1.1 Base WRAP Model

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

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

4.1.2 Basin Specific WRAP Model

No basin specific changes were made to the WRAP (DECEMBER, 2001) program for modeling the Red and Canadian River Basins.

4.2 Development of WRAP Water Rights Input File

Water rights, input files, and river basin control point schematic were created using the revised TNRCC master water rights list, the written certificates of adjudication and water rights permits, TNRCC adjudication maps, and geo-referenced data from the TNRCC (obtained from the CRWR). The basic steps included in creating the water right input card include:

- Identifying primary and secondary control points.
- Obtaining all water right diversion locations from TNRCC.
- Determining diversion amounts, use types, and priority dates for all water rights within the basin.
- Determining impoundment amounts for water rights, storage, and reservoir information (input in the WS record).
- Compiling and computing return flows for all industrial and municipal water right diversions including interbasin transfers.

- Computing monthly distribution factors to distribute annual diversion amounts.
- Creating a control point schematic.
- Input naturalized streamflow and evaporation data.

Each task methodology is described in the following sections.

4.2.1 Control Points

Control points are used in the WRAP program as a means of spatially referencing the position of all inflows and outflows in a river basin. The actual formulation of the basin schematic used for the WRAP program is done in the CP record. The CP record lists control points from upstream to downstream. The river layout is reproduced in the CP record by listing each control point and following it with the next downstream control point. In the Red and Canadian River Basins Water Availability Model, control points were segregated into two distinct types:

- Primary control points – For the Red River Basin, 25 points are located at USGS streamflow gage locations. For the Canadian River Basin, four points are located at USGS streamflow gage locations and one control point is located at Coldwater Creek near Gruver.
- Secondary control points – points located at water right diversions or impoundments, water import locations, groundwater return flow sites, return flow sites, and classified stream segments that are not primary control points. Naturalized streamflow is distributed by WRAP to these secondary control points based on drainage area ratio.

Table 4 lists the suggested primary control points for the basins. Figure 1 shows the primary control point locations and their relationship to the secondary control points. Figure 2 shows the period of record for the suggested primary control points. These primary control points were developed using the following general criteria:

- Streamflow gages with over 20 years of record and drainage areas over 100 square miles.
- Spatial distribution of primary control points throughout the basins.
- Reservoir control points were avoided if possible due to the difficulty in obtaining accurate information on reservoir discharges.

There was one exception to the above criteria. One primary control point was developed to define the watershed of Coldwater Creek near Gruver. This control point was created at a location where there was no USGS gage. Therefore, historical records were defined using a drainage area ratio with nearby gages.

The control points with calculated flows (Primary) are discernable from control points with estimated flows at ungaged sites (Secondary). Also, the two types of control points were labeled in different manners in the model. Primary control points were labeled using an alphanumeric six-digit code that represents the name of the USGS gage (Ex. SW_KT – Sweetwater Creek near Kelton was labeled as A10000). All primary control points were labeled as a letter of the alphabet with the number 10000. Secondary control points were also labeled using an alphanumeric six-digit code. Their code corresponds to which primary control point they fall under. The secondary control points were coded downstream to upstream. For example, the first point upstream of the primary control point was labeled A10010.

The six-digit code is in the form: AXXXXX, and is defined below:
- A identifies the primary control point.
- XXXXX represents the relative location to the primary control point.

The water quality stream segment control points were identified as part of the CRWR dataset and used as secondary control points with no diversions at the points. The water quality stream segments were also numbered with the six-digit code. Again, the letter in the first character of the name identifies which primary control point the water quality stream segment is associated with.

4.2.2 Monthly Demand Distribution Factors

Diversion amounts associated with each water right were input into the WR record in WRAP (DECEMBER, 2001) as an annual amount in acre-feet per year (ac-ft/yr). The annual values are then distributed by the monthly distribution factors for each use type as specified in the UC record in WRAP. Seasonal use (demand) patterns were determined for municipal, industrial, irrigation, mining, and other water uses. Historical water consumption data was used to derive the seasonal pattern for each type of water use. The historical consumption data were derived from water use records submitted annually to the TNRCC by the water right holders. Table 13 shows the corresponding distributions for the different categories of water use.

For each individual water right corresponding to a specific type of water use, averages were computed for water consumption for each of the 12 months per primary control point. The monthly average was then divided by the annual average to produce a percent value to represent monthly consumption for the entire basin.

No significant trend of water demand pattern was indicated from one region to another in the Red and Canadian Basins. Therefore, only one set of use data for each type of water use for the entire basin was used.

Table 13 Seasonal Distribution Factors for the Red and Canadian River Basins

	Jan	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***	**Annual Average**
Red River Basin													
IRR	0.023	0.021	0.036	0.072	0.100	0.131	0.202	0.186	0.118	0.066	0.024	0.021	1.000
MUN	0.071	0.066	0.071	0.074	0.083	0.089	0.112	0.110	0.091	0.087	0.073	0.073	1.000
MIN	0.041	0.030	0.041	0.071	0.088	0.108	0.189	0.173	0.123	0.082	0.027	0.028	1.000
IND	0.052	0.046	0.048	0.070	0.090	0.110	0.169	0.138	0.106	0.074	0.049	0.047	1.000
OTHER	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	12.000
REC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	12.000
IFCON	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	12.000
IFCONA	4.500	4.500	4.500	10.000	10.000	10.000	10.000	10.000	10.000	4.500	4.500	4.500	87.000
IFCONB	5.000	5.000	13.000	13.000	13.000	13.000	13.000	13.000	13.000	5.000	5.000	5.000	116.000
IFCONC	27.000	27.000	40.000	40.000	69.000	69.000	69.000	69.000	69.000	27.000	27.000	27.000	560.000
IFCOND	1157.000	1157.000	1157.000	1866.000	1866.000	1866.000	1866.000	1866.000	1157.000	1157.000	1157.000	1157.000	17429.000
IFCONE	2767.000	2767.000	8780.000	8780.000	8780.000	9615.000	2767.000	2767.000	2767.000	2767.000	2767.000	2767.000	58091.000
Canadian River Basin													
IRR	0.002	0.003	0.043	0.117	0.138	0.150	0.156	0.171	0.124	0.077	0.014	0.004	1.000
MUN	0.064	0.063	0.070	0.085	0.094	0.097	0.112	0.107	0.092	0.080	0.068	0.069	1.000
MIN	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	12.000
IND	0.043	0.045	0.065	0.058	0.093	0.118	0.142	0.118	0.118	0.063	0.063	0.073	1.000
OTHER	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	12.000
REC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	12.000

4.2.3 Water Rights

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

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

- XX represents the Basin Number.
- Y represents the type of water right, where:
    - 6 is for Certificate of Adjudication.
    - 1 is for an Application.
- AAAAA represents the Water Right Number
- BBB represents the control point feature, where:
    - 001-100 water right location (regular diversion point)
    - 101-200 downstream boundary of diversion area
    - 201-300 upstream boundary of diversion area
    - 301-400 on-channel reservoir
    - 401-500 off-channel reservoir
    - 501-600 return flow points
    - 601-700 off-channel diversion point
    - 901-999 other

Water rights in the Red and Canadian River Basins for Scenario 1 are listed in Table 14. This table gives each water right location, permitted diversion amount, use type, priority date, and how each water right permit was segregated into multiple parts. The specific locations of the water right control points can be referenced on the maps of the Red and Canadian River Basins attached as Appendix K.

4.2.3.1 Priority Dates

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

Some water rights were characterized by multiple entries based on priority dates for storage, use types, as well as diversion locations. The priority date for each water right, as well as the instream flow requirements and the synthetic water rights utilized to distribute the return flows, is listed in Table 14.

The format of the priority dates is YYYYMMDD, defined as:

- YYYY represents the four-digit year for Y2K compliance.
- MM represents the month by the two-digit code
- DD represents the day of the month in a two–digit code.

4.2.3.2 Treatment of Reservoir Storage

The maximum storage for a reservoir is specified in the TNRCC water right permit or certificate of adjudication. For reservoirs having multiple priority dates for storage, WRAP requires multiple WR and WS records to represent the different priority dates assigned to reservoir storage. Storage in a reservoir is filled only after meeting the needs of senior water rights. Incorporating these different reservoir storage levels by priority date allows the WRAP (DECEMBER, 2001) model to fill a reservoir only when flow is available based on the specific priority date.

Table 14 Water Right Information

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	10203834301	V10110	0	Mun	19810129
WR	10203859301	10340	60	Irr	19820201
WR	10203877301	10210	90	Irr	19820308
WR	10203885201	10050	90	Irr	19820308
WR	10203888001	X10170	200	Irr	19820503
WR	10203888002	X10180	Backup	Irr	19820503
WR	10203889001	B10020	75	Irr	19820426
WR	10203891001	A10060	132	Irr	19810518
WR	10203901001	10290	25	Irr	19820322
WR	10203924002	X10190	320	Irr	19820705
WR	10203958301	D10040	0	Mun	19821129
WR	10203965101	U10020	3,600	Irr	19821122
WR	10203976001	10390	18	Irr	19830131
WR	10204033003	X10390	3,537	Irr	19830516
WR	10204033004	X10380	3,699	Irr	19890914
WR	10204044001	X10360	500	Irr	19831118
WR	10204044101	X10350	3728.28	Irr	19890529
WR	10204058002	Y10120	500	Irr	19830829
WR	10204059002	X10420	360	Irr	19830919
WR	10204099101	P10100	300	Irr	19840207
WR	10204127301	F10070	0	Rec	19830822
WR	10204265301	B10030	80	Irr	19850604
WR	10204283301	Q10050	0	Rec	19850806
WR	10204290301	P10020	0	Rec	19850903
WR	10204294301	X10120	103	Irr	19850618
WR	10205022301	C10050	2	Mun	19851015
WR	10205078601	10450	7.95	Irr	19860724
WR	10205113301	W10130	125	Irr	19861202
WR	10205119001	Y10310	300	Irr	19870130

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	10205129301	X10080	300	Irr	19870424
WR	10205149301	Y10270	0	Rec	19870724
WR	10205152001	Q10040	2352	Other	19870731
WR	10205233002	Y10260	2700	Irr	19890508
WR	10205233004	Y10250	250	Irr	19890508
WR	10205233005	Y10240	650	Irr	19890508
WR	10205276001	X10140	2535	Irr	19900126
WR	10205312301	C10200	0	Rec	19900824
WR	10205316301	F10100	0	Rec	19900919
WR	10205393301	O10010	300	Irr	19911211
WR	10205434301	V10030	0	Rec	19921103
WR	10205434302	V10040	10	Irr	19921103
WR	10205530001	P10040	32	Irr	19950524
WR	10205558401	Y10290	85	Irr	19960904
WR	10205605001	V10090	100	Irr	19980205
WR	10205605301	V10100	0	Irr	19980205
WR	10205630001	X10610	797.4	Irr	19990518
WR	10205632001	Y10040	800	Irr	19990601
WR	60204874301	V10150	30	Irr	19720522
WR	60204875301	V10130	133	Irr	19381231
WR	60204875302	V10140	0	Irr	19381231
WR	60204876301	V10120	1286	Mun	19350921
WR	60204878301	V10080	0	Rec	19711026
WR	60204879301	V10070	644.96	Mun	19581009
WR	60204880301	V10050	0	Rec	19730813
WR	60204881301	V10020	4500	Mun	19620820
WR	60204882301	V10010	0	Rec	19731105
WR	60204883301	W10320	80	Irr	19671231
WR	60204884301	W10330	16	Irr	19720515

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60204884302	W10340	56	Irr	19670731
WR	60204884303	W10350	0	Irr	19670731
WR	60204884304	W10360	0	Irr	19670731
WR	60204885301	W10310	0	Rec	19721211
WR	60204885302	W10300	0	Rec	19721211
WR	60204886301	W10290	33.3	Irr	19670731
WR	60204887301	W10280	0	Ind	19720320
WR	60204889301	W10270	30	Irr	19711012
WR	60204890301	W10260	20	Irr	19720424
WR	60204891301	W10250	130	Irr	19720424
WR	60204892301	W10240	20	Irr	19720424
WR	60204893301	W10230	24	Irr	19720424
WR	60204893302	W10220	0	Irr	19720424
WR	60204894301	W10200	0	Rec	19720222
WR	60204895301	W10210	0	Rec	19481231
WR	60204895302	W10190	0	Rec	19531221
WR	60204895303	W10100	0	Rec	19551231
WR	60204895304	W10110	0	Rec	19601231
WR	60204895305	W10120	0	Rec	19601231
WR	60204895306	W10180	0	Rec	19481231
WR	60204895307	W10170	0	Rec	19481231
WR	60204895308	W10150	0	Rec	19581231
WR	60204895309	W10140	0	Rec	19581231
WR	60204895310	W10160	0	Rec	19651231
WR	60204896301	W10090	21.25	Irr	19591231
WR	60204897301	W10080	10	Irr	19661231
WR	60204900301	X10490	10000	Ind	19590720
WR	60204901301	W10020	5280	Mun	19520319
WR	60204901302	W10060	0	Mun	19520319

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60204902301	W10030	120	Irr	19740930
WR	60204903001	W10010	4000	Ind	19560709
WR	60204904003	X10630	482	Irr	19551231
WR	60204905301	X10550	0	Rec	19710628
WR	60204906301	X10540	0	Rec	19730425
WR	60204907001	X10530	200	Irr	19521007
WR	60204908001	X10520	135	Irr	19650831
WR	60204909301	X10600	0	Rec	19751208
WR	60204910301	X10590	0	Rec	19730129
WR	60204911301	X10580	0	Irr	19751110
WR	60204911302	X10570	30	Irr	19751110
WR	60204912301	X10500	987	Irr	19700105
WR	60204912401	X10510	140	Min	19841016
WR	60204913002	X10480	30	Irr	19661231
WR	60204914301	X10470	30	Irr	19650731
WR	60204915301	X10460	0	Rec	19631216
WR	60204915302	X10230	0	Rec	19680226
WR	60204915303	X10220	0	Rec	19630702
WR	60204916001	X10450	160	Irr	19651231
WR	60204917003	X10430	219	Irr	19551231
WR	60204918101	X10410	360	Irr	19551231
WR	60204919001	X10400	20	Irr	19631231
WR	60204920001	X10200	640	Irr	19790221
WR	60204921001	X10340	109	Irr	19371231
WR	60204921002	X10330	0	Irr	19371231
WR	60204922001	X10310	0	Irr	19651217
WR	60204922301	X10320	362	Irr	19651217
WR	60204923301	X10290	20	Mun	19741104
WR	60204924301	X10300	0	Rec	19691208

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60204925301	X10270	5340	Mun	19661203
WR	60204926101	X10260	520	Irr	19660817
WR	60204927301	X10250	0	Rec	19720207
WR	60204928301	X10240	0	Rec	19830205
WR	60204929301	X10210	0	Rec	19720807
WR	60204930001	X10160	48	Irr	19590519
WR	60204931301	X10175	10	Irr	19680226
WR	60204933301	X10130	110	Irr	19790402
WR	60204934301	X10110	50	Irr	19800331
WR	60204934302	X10100	0	Irr	19800331
WR	60204935301	X10090	40	Irr	19680701
WR	60204936301	X10060	20	Irr	19680129
WR	60204937301	X10050	30	Irr	19690825
WR	60204938301	X10070	220	Irr	19810120
WR	60204939301	X10040	78	Irr	19810120
WR	60204939302	X10030	0	Irr	19810120
WR	60204940301	X10010	23885	Mun	19641105
WR	60204941002	Y10370	885	Irr	19700917
WR	60204941301	Y10360	298	Irr	19700917
WR	60204942301	Y10340	0	Rec	19161117
WR	60204943301	Y10330	12000	Mun	19220531
WR	60204944301	Y10320	0	Rec	19760614
WR	60204945001	Y10280	110	Irr	19530525
WR	60204946002	Y10220	1000	Irr	19790611
WR	60204946003	Y10180	350	Irr	19890815
WR	60204946004	Y10190	250	Irr	19890815
WR	60204947301	Y10210	225	Irr	19730618
WR	60204948301	Y10200	150	Irr	19730618
WR	60204949002	Y10170	550	Irr	19531026

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60204950301	Y10160	102	Irr	19730618
WR	60204951301	Y10150	0	Rec	19760712
WR	60204952002	Y10140	100	Irr	19530731
WR	60204953002	Y10110	750	Irr	19530630
WR	60204954002	Y10080	1875	Irr	19520731
WR	60204955301	Y10070	380.74	Irr	19511231
WR	60204956001	Y10060	81	Irr	19590715
WR	60204957003	Y10050	66.7	Irr	19541231
WR	60204958301	Y10030	7	Ind	19691231
WR	60204959002	Y10020	2556	Irr	19780306
WR	60204960301	10420	160	Irr	19500731
WR	60204961301	10380	1920	Mun	19280204
WR	60204962001	10400	80	Irr	19531231
WR	60205099301	F10220	116.8	Irr	19620625
WR	60205100301	F10200	19	Irr	19640916
WR	60205101301	F10190	37	Irr	19640525
WR	60205102301	F10170	33	Irr	19570311
WR	60205103301	F10150	28	Irr	19640512
WR	60205104301	F10160	17	Irr	19640629
WR	60205105301	F10140	30	Irr	19640622
WR	60205106301	F10130	80	Irr	19640504
WR	60205107301	F10110	101	Irr	19720501
WR	60205108301	F10120	0	Rec	19650802
WR	60205109301	U10030	200	Irr	19800303
WR	60205110301	F10050	0	Rec	19550101
WR	60205111001	F10020	22.7	Irr	19640430
WR	60205112301	G10020	0	Rec	19750630
WR	60205112302	G10010	0	Rec	19730806
WR	60205113301	H10050	125	Irr	19640413

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60205113302	H10040	0	Rec	19640413
WR	60205114301	I10010	35	Irr	19680205
WR	60205115001	J10020	3050	Other	19760920
WR	60205116301	J10010	0	Other	19760920
WR	60205117001	K10010	1240	Other	19760920
WR	60205118001	L10010	3770	Other	19760920
WR	60205119301	M10020	20	Irr	19690908
WR	60205120301	M10010	85	Irr	19570415
WR	60205121101	N10050	2153	Irr	19491231
WR	60205121301	N10060	0	Irr	19491231
WR	60205122002	Q10060	7289	Mun	19140622
WR	60205122301	Q10080	0	Mun	19140622
WR	60205123001	P10080	16660	Irr	19780410
WR	60205123301	N10020	0	Rec	19201002
WR	60205123302	P10110	0	Mun	19201002
WR	60205124301	O10090	3000	Irr	19290401
WR	60205125002	O10070	675	Irr	19541122
WR	60205125301	O10080	0	Irr	19830502
WR	60205126301	O10050	60.48	Mun	19260630
WR	60205127001	O10060	30	Min	19241222
WR	60205127301	O10040	0	Other	19241222
WR	60205128001	O10030	0	Mun	19740225
WR	60205128301	O10020	600	Mun	19490329
WR	60205129001	P10090	256	Irr	19690929
WR	60205130002	P10070	40	Irr	19631231
WR	60205131301	P10060	840	Mun	19620919
WR	60205132301	P10050	500	Mun	19490803
WR	60205133301	P10030	300	Mun	19381122
WR	60205134102	Q10100	125	Irr	19640701

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60205135003	Q10020	357	Irr	19540315
WR	60205136002	Q10010	200	Irr	19630304
WR	60205137301	U10160	125	Mun	19381129
WR	60205137302	U10150	100	Mun	19600404
WR	60205138401	U10170	55	Irr	19660314
WR	60205139003	U10140	30	Irr	19670718
WR	60205140001	U10130	270	Ind	19670626
WR	60205141301	U10120	0	Rec	19780925
WR	60205142301	U10100	200	Irr	19721218
WR	60205142302	U10090	0	Irr	19721218
WR	60205142303	U10080	0	Irr	19721218
WR	60205143001	U10070	200	Irr	19730226
WR	60205144301	R10010	38880	Mun	19440621
WR	60205145301	R10060	70	Mun	19620703
WR	60205146301	R10080	450	Mun	19350326
WR	60205146302	R10070	810	Mun	19530310
WR	60205147301	R10050	30	Irr	19700309
WR	60205148001	R10040	506	Mun	19570429
WR	60205148301	R10030	300	Mun	19500626
WR	60205149301	S10050	0	Rec	19630214
WR	60205150301	S10030	25000	Mun	19620620
WR	60205151301	S10010	0	Rec	19781030
WR	60205152301	U10060	100	Mun	19180316
WR	60205153301	U10040	50	Irr	19680701
WR	60205154301	U10050	15	Irr	19670531
WR	60205179001	C10220	796	Irr	19660731
WR	60205180301	C10210	0	Other	19611120
WR	60205181301	C10190	80	Irr	19491231
WR	60205182101	C10170	37	Irr	19640731

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60205182301	C10180	0	Irr	19640731
WR	60205183101	C10150	13	Irr	19640731
WR	60205183301	C10160	0	Irr	19640731
WR	60205184101	C10130	54	Irr	19640731
WR	60205184301	C10140	0	Irr	19640731
WR	60205185301	C10120	125	Irr	19650530
WR	60205186301	C10110	200	Irr	19620108
WR	60205187401	C10090	40	Irr	19670731
WR	60205188301	C10080	0	Rec	19371220
WR	60205189301	C10070	164	Irr	19770725
WR	60205193301	C10060	0	Rec	19400526
WR	60205194301	C10040	0	Rec	19560522
WR	60205195301	C10020	400	Irr	19740304
WR	60205196301	C10100	124	Irr	19610531
WR	60205197302	D10190	60	Irr	19630218
WR	60205198301	D10180	57	Irr	19691201
WR	60205198302	D10170	0	Irr	19691201
WR	60205199301	D10260	173	Irr	19710809
WR	60205199302	D10250	90	Irr	19710301
WR	60205200301	D10240	12	Irr	19691201
WR	60205202301	D10230	61	Irr	19691201
WR	60205203301	D10220	26	Irr	19691201
WR	60205204301	D10210	34	Irr	19700720
WR	60205205301	D10200	0	Rec	19380822
WR	60205206301	D10160	24	Irr	19691201
WR	60205207301	D10150	8	Irr	19691201
WR	60205208301	D10290	55	Irr	19700616
WR	60205209301	D10280	284	Irr	19680304
WR	60205210301	D10270	60	Irr	19691201

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60205211301	D10130	2000	Mun	19670626
WR	60205212301	D10120	107	Irr	19670515
WR	60205213301	D10110	0	Rec	19741021
WR	60205214301	D10100	0	Rec	19730904
WR	60205215301	D10090	0	Rec	19730904
WR	60205216301	D10080	0	Rec	19770117
WR	60205217301	D10070	0	Rec	19741021
WR	60205219301	D10060	0	Rec	19640316
WR	60205220301	D10050	20	Mun	19810504
WR	60205221301	D10030	397	Mun	19490202
WR	60205221302	D10020	0	Rec	19980130
WR	60205222301	D10010	0	Rec	19770620
WR	60205223001	H10160	38.5	Irr	19540415
WR	60205224301	E10050	0	Rec	19140630
WR	60205225001	E10040	96	Irr	19520916
WR	60205226001	E10030	60	Irr	19490221
WR	60205227001	E10010	100	Irr	19490221
WR	60205228001	E10020	63	Irr	19480601
WR	60205229301	H10140	30	Irr	19500531
WR	60205230001	H10130	0	Ind	19450305
WR	60205230301	H10110	16	Irr	19140627
WR	60205231001	H10120	41	Irr	19570831
WR	60205232001	B10070	200	Irr	19481027
WR	60205233003	B10050	3711	Mun	19580811
WR	60205233301	B10060	250	Irr	19580811
WR	60205234001	B10040	184	Irr	19530121
WR	60205235001	B10010	108	Irr	19530512
WR	60205236001	10350	130	Irr	19520107
WR	60205236002	10330	0	Irr	19520107

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60205236301	10360	1	Irr	19520108
WR	60205237301	10320	300	Irr	19620904
WR	60205238301	H10090	160	Irr	19640224
WR	60205239301	10190	5	Irr	19761025
WR	60205240301	10180	100	Irr	19680701
WR	60205241301	10170	4	Irr	19760322
WR	60205242301	10160	9	Irr	19730312
WR	60205243301	10150	217	Irr	19631231
WR	60205244301	10140	0	Rec	19380328
WR	60205245301	10130	129	Irr	19661231
WR	60205246301	10120	70	Irr	19760621
WR	60205247301	10100	100	Irr	19751215
WR	60205248301	10090	30	Irr	19670911
WR	60205249301	10080	10	Irr	19700401
WR	60205250002	10060	33	Irr	19550404
WR	60205251301	A10070	60	Irr	19671121
WR	60205252301	A10050	20	Irr	19720515
WR	60205253002	A10010	319	Irr	19551107
WR	60205253301	A10040	0	Irr	19551231
WR	60205253302	A10030	0	Irr	19551231
WR	60205253303	A10020	0	Irr	19551231
WR	60205254001	10040	125	Irr	19620630
WR	60205255301	10300	0	Rec	19530326
WR	60205256001	10280	50	Irr	19560402
WR	60205257101	10270	70	Irr	19530211
WR	60205258001	10260	140	Irr	19520708
WR	60205259001	10240	34	Irr	19511231
WR	60205259301	10250	0	Irr	19511231
WR	60205260002	10230	100	Irr	19531116

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Red River Basin					
WR	60205261102	10220	59	Irr	19550627
WR	60205262101	10200	29	Irr	19650731
WR	60205263301	10030	0	Rec	19620123
WR	60205264301	10020	70	Irr	19610520
WR	60205265301	10010	0	Rec	19630415
WR	60205266301	F10060	0	Rec	19710419
WR	60205267301	F10210	100	Irr	19631125
Canadian River Basin					
WR	10103968301	F10025	240	Irr	19830103
WR	10104106301	A10060	169	Irr	19840110
WR	10104184301	A10080	0	Other	19840904
WR	10105049301	A10030	0	Other	19860324
WR	10105057301	A10040	0	Rec	19860512
WR	10105057302	A10050	0	Rec	19860512
WR	10105627301	A10070	0	Rec	19990521
WR	10105638301	A10020	0	Rec	19990628
WR	60103776301	A10160	0	Rec	19380822
WR	60103777301	A10140	0	Min	19571231
WR	60103777302	A10150	30	Min	19571231
WR	60103778301	A10130	0	Ind	19680422
WR	60103779301	A10110	180	Irr	19650303
WR	60103779302	A10120	0	Irr	19770829
WR	60103779303	A10100	0	Irr	19770829
WR	60103779304	A10090	0	Rec	19770829
WR	60103780301	B10140	10	Irr	19680520
WR	60103781301	B10150	0	Other	19770613
WR	60103782301	B10130	100000	Mun	19560130
WR	60103782302	B10130	51200	Ind	19560130
WR	60103783301	B10100	0	Ind	19780306

Table 14 Water Right Information (Continued)

Record (WR/IF)	CRWR Number	Control Point Name	Annual Diversion/ Instream Flow	Use Type	Priority Date
Canadian River Basin					
WR	60103784301	B10090	230	Other	19761025
WR	60103785301	B10080	60	Other	19770103
WR	60103786301	B10050	250	Irr	19831231
WR	60103787101	B10030	640	Irr	19770124
WR	60103788301	B10020	4	Irr	19700720
WR	60103789301	F10130	0	Rec	19480505
WR	60103790301	F10120	0	Rec	19380304
WR	60103791301	C10020	190	Irr	9651231
WR	60103792301	C10010	40	Irr	19670411
WR	60103793301	D10050	90	Irr	19730604
WR	60103794301	D10040	150	Irr	19700601
WR	60103795001	D10020	125	Irr	19711116
WR	60103795301	D10030	0	Irr	19711116
WR	60103796301	D10100	195	Irr	19690602
WR	60103797301	D10080	0	Rec	19780123
WR	60103797302	D10090	0	Rec	19780123
WR	60103798301	D10070	50	Irr	19680722
WR	60103799302	D10060	106	Irr	19370630
WR	60103800001	D10010	90	Irr	19271221
WR	60103801301	F10070	0	Rec	19760120
WR	60103801302	F10060	0	Rec	19760120
WR	60103802301	F10040	120	Irr	19670531
WR	60103803301	F10020	10460	Mun	19740423
WR	60103804301	F10010	40	Irr	19690505
WR	60103805001	F10080	102	Irr	19580430
WR	60103806301	E10010	0	Rec	19380822
WR	60103807001	F10110	20	Irr	19800519

4.2.3.3 Return Flows

Return flow in the Red and Canadian Basins associated with water right diversions and groundwater use were input into WRAP as a constant monthly amount or as a percentage of the diversion amount of each water right. All groundwater return flows were modeled using the constant inflow (CI) record to provide continuous return flows throughout the simulation period. Constant inflow records are shown in Appendix O for each control point, and include:

- Return flow for individual facilities,
- Summary of all groundwater in each control point,
- Distribution of annual groundwater amount to monthly amounts for each return flow facility.

For this study, the CI records are used for wastewater discharge facilities that discharge groundwater only or with facilities that have combined surface and groundwater discharge. In the combined case, the CI record only represents the groundwater portion of the return flow. Groundwater return flow input into the CI record is the minimum return flow amount for each facility over the last five years of the period of record (1994 to 1998). The underlying assumption used for the CI record is that municipal use will be continuous throughout the period of record and this water will always be returned. The amount returned is only a function of the return flow percentage (100%, 50%, 0%), depending on the individual modeling scenarios amount of groundwater. A brief description of some of the return flow locations is given below.

Red River Basin

Wastewater Discharge Permit 2206.001

Wastewater permit 2206.001 is owned by the United States Army. This facility had return flow until 1996. There is no longer discharge from this facility and therefore it was not included in the model.

Wastewater Discharge Permit 1610.001

Wastewater permit 1610.001 is owned by G-P Gypsum Corporation and is a return flow from groundwater used for dewatering and operation of gypsum process. This return flow was included in the model through the CI record.

Wastewater Discharge Permit 10002.001

Wastewater permit 10002.001 is owned by the City of Burkburnett. Groundwater accounts for 60% of the flow to the WWTP. Therefore, the minimum amount of return flow from the last five years was calculated and 60% of that amount was input into the WWTP control point for Burkburnett (H10010).

Wastewater Discharge Permit 10073.001

Wastewater permit 10073.001 is owned by the City of Canyon. This permit had return flow until 1995 and then began using the effluent for irrigation use. Therefore, the WWTP control point (C10075) is left in the model but no return flow is associated at this point.

Wastewater Discharge Permit 10392.003

Wastewater permit 10392.003 is owned by the City of Amarillo. This permit discharges effluent for irrigation purposes. Therefore, the WWTP control point (C10025) is in the model but no return flow is associated at this point.

Wastewater Discharge Permit 10329.001

Wastewater permit 10329.001 is owned by the City of Sherman. This permit allows the owner to discharge 50% groundwater and 50% surface water. The minimum amount of return flow from the last five years was calculated and 50% of that amount was input into the WWTP control point for Sherman (X10560).

Wastewater Discharge Permit 10377.001

Wastewater permit 10377.001 is owned by the City of Vernon. This permit discharges only surface water and therefore is not included in the CI record.

As stated in an earlier section, return flow from irrigation water rights was not modeled. Large industrial and municipal water rights were assigned return flow percentages as described in the following discussion. The return flows described below are for larger rights and are for Scenario 1. These return flows were not included as return flow in Scenario 3.

Permit 4301 – Texoma Utility Authority

In this water right, 15,000 ac-ft municipal diversion is returned as a 60% return flow and 10,000 ac-ft industrial diversion is returned as a 70% return flow to the next downstream control point.

CA 4876 – City of Bowie

In this water right, 1,286 ac-ft municipal diversion is returned as a 60% return flow to the next downstream control point.

CA 4879 – North Montague County

In this water right, 1,080 ac-ft municipal diversion is returned as a 60% return flow to the next downstream control point.

CA 4901 – City of Denison

In this water right, 29,680 ac-ft municipal diversion is returned as a 60% return flow to their wastewater treatment plant (X10620).

CA 4903 – J-M Manufacturing

In this water right, 4,000 ac-ft industrial diversion is returned as a 70% return flow to the next downstream control point.

CA 4925 – City of Bonham

In this water right, 5,340 ac-ft municipal diversion is returned as a 60% return flow to their wastewater treatment plant (X10280).

CA 4940 – City of Paris

In this water right, 23,885 ac-ft municipal diversion is returned as a 60% return flow to their wastewater treatment plant (Y10300) and 1,115 ac-ft 100% to Sulphur Basin. This right also has 16,610 ac-ft municipal diversion is returned as a 60% return flow to their wastewater treatment plant (Y10300) and 20,000 ac-ft 100% to Sulphur Basin. The IBT stays in as a transfer in Scenario 3.

CA 4943 – City of Paris

In this water right, 12,000 ac-ft municipal diversion is returned as a 60% return flow to their wastewater treatment plant (Y10300)

CA 4961 – City of Texarkana

In this water right, 1,920 ac-ft industrial diversion is returned as a 60% return flow to the next downstream control point. There is no return flow for the irrigation part of this right.

CA 4961 – City of Texarkana

In this water right, 4,000 ac-ft industrial diversion is returned as a 70% return flow to the next downstream control point.

Permit 5003 – North Texas MWD

The authorized diversion amount of 84,000 ac-ft is diverted and returned as an interbasin transfer (100%) to the Trinity River Basin.

CA 5122 and CA 5150 – City of Wichita Falls

In this water right, has multiple diversions and return flows. Part of the return flows are returned to the City's wastewater treatment plant (Q10025) and the remainder is returned to the next downstream control point.

CA 5144 – City of Wichita Falls

In this water right, has multiple diversions and return flows. Part of the return flows are returned to the City's wastewater treatment plant (Q10025) and 1,120 ac-ft is transferred to the Brazos River Basin.

CA 5152 – City of Henrietta

In this water right, 2,350 ac-ft municipal diversion is returned as a 60% return flow to the City's wastewater treatment plant (Q10030).

CA 5233 – Greenbelt M&I

In this water right, 10,819 ac-ft municipal diversion is returned as a 60% return flow to the next downstream control point.

Canadian River Basin

CA 3782 – Canadian River Municipal Water Authority

This water right has an interbasin transfer of 151,200 ac-ft/yr to the Brazos River Basin.

CA 3803 – Palo Duro River Authority

In this water right, 10,460 ac-ft municipal diversion is returned as a 60% return flow to the next downstream control point.

4.2.3.4 Multiple Diversion Locations

A large number of water rights contained in the Red and Canadian River Basins have multiple diversion points and/or multiple use types. In general, these water rights were modeled with their authorized amount at the most downstream diversion location. Water rights with multiple diversion points include:

Red River Basin

CA 02-4875 two points of div. on two different reservoirs located on an unnamed tributary of West Belknap Creek w/max. combined rate of 0.83 cfs.

CA 02-4884 four points of div. on the perimeter of four different reservoirs on an unnamed tributary of Rick Creek with a max. combined rate of 6.0 cfs.

CA 02-4893 two points of div. on two different reservoirs on an unnamed tributary of Mustang Creek with a max. combined rate of 0.44 cfs.

CA 02-4895 two points of div. on Martin Branch and one point of div. on an unnamed tributary of Big Mineral Arm of Lake Texoma with a max. combined rate of 5.0 cfs.

CA 02-4900 one point of div. on Brushy Creek and one point of div. on Red River with a max. combined rate of 45.0 cfs, one point of div. on the dam of Lake Texoma with a max. rate of 16.0 cfs, and one point of div. on the perimeter of Valley Lake with a max. rate of 1384.0 cfs.

CA 02-4901 one point of div. on Lake Texoma and one point of div. on Randall Lake with a max. combined rate of 25.24 cfs.

CA 02-4904 three points of div. on Red River with a max. combined rate of 2.22 cfs.

CA 02-4911 two points of div. on the perimeter of two reservoirs on Iron Ore Creek with a max. combined rate of 0.75 cfs.

CA 02-4913 two points of div. on Murphy Creek with a max. combined rate of 2.0 cfs.

CA 02-4916 two points of div. on Narvaugh Creek with a max. combined rate of 2.67 cfs.

CA 02-4917 three points of div. on the Red River with a max. combined rate of 4.33 cfs.

CA 02-4921 one point of div. on Bois d'Arc Creek and one point of div. on Cooper Creek with a max. combined rate of 6.67 cfs.

CA 02-4922 two points of div. on Davis Creek with a max. combined rate of 9.0 cfs.

CA 02-4933 two points of div. on the perimeter of two reservoirs on an unnamed tributary of Sanders Creek with a max. combined rate of 3.56 cfs.

CA 02-4934 two points of div. on the perimeter of two reservoirs on an unnamed tributary of Sanders Creek with a max. combined rate of 1.33 cfs.

CA 02-4935 two points of div. on the perimeter of two reservoirs on an unnamed tributary of Sanders Creek with a max. combined rate of 2.22 cfs.

CA 02-4939 two points of div. on the perimeter of two reservoirs on an unnamed tributary of Shooter Creek with a max. combined rate of 2.22 cfs.

CA 02-4941 two points of div. on Red River with a max. combined rate of 16.0 cfs and two points of div. on the perimeter of Womack Lake with a max. combined rate of 5.33 cfs.

CA 02-4946 two points of div. on Red River with a max. combined rate of 17.33 cfs, and two points of div. one on Big Pine Creek and one on Little Pine Creek with a max. combined rate of 5.0 cfs.

CA 02-4948 one point of div. on Little Pine Creek, one point of div. on the perimeter of a reservoir on and unnamed tributary of Little Pine Creek, and one point of div. on Little Pine Creek with a max. combined rate of 2.0 cfs.

CA 02-4949 two points of div. on Big Pine Creek with a max. combined rate of 4.0 cfs.

CA 02-4952 two points of div. on Mill Creek with a max. combined rate of 4.44 cfs.

CA 02-4953 two points of div. on Red River with a max. combined rate of 11.11 cfs.

CA 02-4954 two points of div. on Red River with a max. combined rate of 19.44 cfs.

CA 02-4955 one point of div. on Daniel Creek and one point of div. on the perimeter of a reservoir on Daniel Creek with a max. combined rate of 13.33 cfs.

CA 02-4957 two points of div. on Red River with a max. combined rate of 3.33 cfs.

CA 02-4959 two points of div. on Red River with a max. combined rate of 35.56 cfs.

CA 02-5113 two points of div. from the perimeter of two reservoirs on Pease River with a max. combined rate of 1.11 cfs.

CA 02-5122 on point of div. on the dam of Lake Wichita and two points of div. on Holiday Creek with a max. combined rate of 12.22 cfs.

CA 02-5123 two points of div. on Wichita River with a max. combined rate of 40.0 cfs and one point of div. on the perimeter of Lake Diversion with an unspecified rate.

CA 02-5124 one point of div. on the perimeter of Santa Rosa Lake with a rate of 0.44 cfs, one point of div. on the dam of Santa Rosa with a rate of 10.0 cfs, and one div. point on Beaver Creek with a rate of 7.0 cfs.

CA 02-5125 two points of div. on Beaver Creek and one point of div. on the perimeter of a reservoir on Beaver Creek with a max. combined rate of 5.0 cfs.

CA 02-5127 one point of div. on Beaver Creek and one point of div. on the perimeter of Midway Lake with a max. combined rate of 0.89 cfs.

CA 02-5128 one point of div. on Beaver Creek with a rate of 1.33 cfs and one point of div. on the perimeter of Lake Electra with a rate of 1.25 cfs.

CA 02-5130 two points of div. on Wichita River and one point of div. on Antelope Creek with a max. combined rate of 0.67 cfs.

CA 02-5135 three points of div. on Wichita River with a max. combined rate of 7.33 cfs.

CA 02-5136 two points of div. on Wichita River with a max. combined rate of 1.70 cfs.

CA 02-5137 one point of div. on the perimeter of a reservoir on an unnamed tributary of Hay Creek with an unspecified rate by gravity and one point of div. on the perimeter of a reservoir on an unnamed tributary of Hay Creek with a max. rate of 0.19 cfs.

CA 02-5139 three points of div. on the Wichita River with a max. combined rate of 0.72 cfs.

CA 02-5142 three points of div. on the perimeter of three reservoirs on an unnamed tributary of Frog Creek with a max. combined rate of 4.67 cfs.

CA 02-5143 two points of div. on the Red River with a max. combined rate of 4.67 cfs.

CA 02-5144 three points of div. on the perimeter of Lake Kickapoo with a max. combined rate of 47.15 cfs.

CA 02-5148 one point of div. on pump sump on the South Fork Little Wichita River and one point of div. on the perimeter of Archer City Lake with a max. combined rate of 4.50 cfs.

CA 02-5150 two points of div. on the perimeter of Lake Arrowhead with a max. combined rate of 93.0 cfs.

CA 02-5152 two points of div. on the perimeter of two reservoirs on Little Wichita River with a max. rate of 5.50 cfs and 10.0 cfs.

CA 02-5182 one point of div. on Tierra Blanca Creek and one point of div. at the perimeter of a reservoir on Tierra Blanca Creek with a max. combined rate of 3.11 cfs (rate combined with 02-5183 and 02-5184).

CA 02-5183 one point of div. on Tierra Blanca Creek and one point of div. at the perimeter of a reservoir on Tierra Blanca Creek with a max. combined rate of 3.11 cfs (rate combined with 02-5182 and 02-5184).

CA 02-5184 one point of div. on Tierra Blanca Creek and one point of div. at the perimeter of a reservoir on Tierra Blanca Creek with a max. combined rate of 3.11 cfs (rate combined with 02-5182 and 02-5183).

CA 02-5197 four points of div. on the perimeter of two reservoirs on Middle Tule Draw with a max. combined rate of 3.11 cfs.

CA 02-5198 two points of div. on the perimeter of two reservoirs on Middle Tule Draw with a max. combined rate of 1.56 cfs.

CA 02-5199 two points of div. on the perimeter of two reservoirs on North Tule Draw with a max. combined rate of 4.89 cfs.

CA 02-5200 one point of div. on North Tule Draw and one point of div. on the perimeter of a reservoir on North Tule Draw with a max. combined rate of 1.0 cfs.

CA 02-5202 three points of div. on the perimeter of three reservoirs on North Tule Draw with a max. combined rate of 1.33 cfs.

CA 02-5225 two points of div. on North Groesbeck Creek with a max. combined rate of 1.33 cfs.

CA 02-5227 three points of div. on Groesbeck Creek with a max. combined rate of 3.50 cfs.

CA 02-5230 one point of div. on Groesbeck Creek with a max. rate of 5.56 cfs, one point of div. on the perimeter of Lake Pauline with a max. rate of 0.16 cfs for irrigation purposes and 186.40 cfs for industrial purposes.

CA 02-5233 one point of div. on Salt Fork Red River with a max. rate of 20.22 cfs, one point of div. on the perimeter of Greenbelt Reservoir with a max. rate of 4.67 cfs, and one point of div. on Lelia Lake Creek with a max. rate of 3.33 cfs.

CA 02-5236 one point of div. on Salt Fork Red River, one point of div. on Panther Creek, and two points of div. on the perimeter of two reservoirs on Tolbert Creek with a max. combined rate of 1.11 cfs.

CA 02-5250 two points of div. on Salt Creek with a max. combined rate of 0.33 cfs.

CA 02-5253 two points of div. on Sweetwater Creek and one point of div. on the perimeter of a reservoir on an unnamed tributary of Sweetwater Creek with a max. combined rate of 1.33 cfs.

CA 02-5259 two points of div. on Cody Creek and one point of div. on the perimeter of a reservoir on Cody Creek with a max. rate of 0.89 cfs.

CA 02-5260 two points of div. on a unnamed tributary of Wolf Creek with a max. rate of 1.33 cfs.

CA 02-5261 point of div. along the unnamed tributary of Wolf Creek and Wolf Creek with a max. combined rate of 1.33 cfs.

Permit 3885 two points of div. on Salt Creek with a max. combined rate of 0.7 cfs.

Permit 3888 one point of div. on an unnamed tributary of Red River and one point of div. on Red River with a max. combined rate of 2.2 cfs.

Permit 3889 two points of div. on an unnamed tributary of Salt Fork Red River with a max. combined rate of 1.0 cfs.

Permit 3924 two points of div. on Bois d'Arc Creek with a max. combined rate of 2.68 cfs.

Permit 3965 two points of div. on Little Wichita River with a max. combined rate of 20.0 cfs.

Permit 4033 four points of div. on the Red River at a max. combined rate of 49.19 cfs.

Permit 4044 points of div. (unspecified number) area on the Red River with a max. combined rate of 22.3 cfs.

Permit 4058 two points of div. on Red River with a max. combined rate of 13.4 cfs.

Permit 4059 two points of div. on Red River with a max. combined rate of 6.7 cfs.

Permit 4099 two points of div. on the Wichita River with a max. combined rate of 2.7 cfs.

Permit 5233 two points of div. on the north bank of Pine Creek with a max. combined rate of 13.37 cfs, one point of div. on north bank of Pine Creek with max. rate of 1.23 cfs, two points of div. on south bank of Pine Creek with max. combined rate of 3.23 cfs.

Permit 5393 two points of div. on a reservoir on Beaver Creek with a max. combined rate of 1.67 cfs.

Canadian River Basin

CA 01-3779 one point of div. on the perimeter of a reservoir on Tecoras Creek and two points of div. on two reservoirs on an unnamed tributary of Tecoras Creek with a max. combined rate of 2.22 cfs.

CA 01-3799 two points of div. on the perimeter of two reservoirs on an unnamed tributary of South Palo Duro Creek with a max. combined rate of 1.44 cfs.

4.2.3.5 Saline Water Rights

There are no saline water rights in the Red or Canadian River Basins.

4.2.3.6 Rights Requiring Special Consideration

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

4.2.4 Data for Basin-Specific Features Added to WRAP (DECEMBER, 2001)

There were no basin specific modifications made to WRAP for the Red and Canadian River Basins WAM.

4.2.5 Red River Compact Issues

The Red River Compact was modeled as described in Appendices D and T.

4.3 Significant Assumptions Affecting Water Availability Modeling

The single most significant assumption in this study regarding water availability is the estimation of watershed parameters for both basins. Parameters in the Red River were estimated throughout the basin; however, the primary concern is those parameters that were estimated on the Red River from the panhandle of Texas into the Louisiana. The parameters that were estimated for the Canadian River Basin consisted of those upstream of control point A10000. All results will be affected by these estimations and the results section of the report will be presented in detail in the final deliverable. Additional modeling assumptions, which have a significant impact on water availability, are described in the following sections.

4.3.1 Reuse

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

4.3.2 Return Flow/Constant Inflow Assumptions

The gain/loss CI record can be utilized by the WRAP (DECEMBER, 2001) model to account for inflow of groundwater and/or surface water from other basins. In this study, the gain/loss CI record was used to incorporate inflows from groundwater. There were several interbasin transfers modeled in the Red and Canadian River Basins. Appendix Q lists which control points had constant inflows to represent groundwater or interbasin transfer sources.

4.3.3 Off-channel reservoirs

There are numerous off-channel reservoirs in the Red and Canadian River Basins. Generally, for those water rights with multiple off-channel reservoirs, a single reservoir representing the sum total of all capacities was simulated. A total of 20 off-channel reservoirs were modeled in the Red and Canadian Basins. WRAP simulates off-channel reservoirs by limiting the streamflow depletions which are made to meet diversions and refill storage. These constraints are defined as annual limits, which limits the cumulative annual streamflow depletion and a monthly limit, which defines the maximum streamflow depletion for any given month. Water rights with off-channel impoundment and how they were modeled are described below:

Red River Basin

CA 02-4883	42 acre-foot combined from four off-channel res.
CA 02-4898	24 acre-foot off-channel res.
CA 02-4902	2.50 acre-foot off-channel res.
CA 02-4912	20.25 acre-foot off-channel res.
CA 02-4933	10 acre-foot off-channel res.
	20 acre-foot off-channel res.
	30 acre-foot off-channel res.

CA 02-4935	56 acre-foot combined from two off-channel res.
CA 02-4938	176 acre-foot off-channel res.
CA 02-5121	30 acre-foot off-channel res.
	1.30 acre-foot off-channel res.
CA 02-5124	60 acre-foot off-channel res.
CA 02-5138	40 acre-foot off-channel res.
CA 02-5140	3.6 acre-foot off-channel res.
CA 02-5152	380 acre-foot off-channel res.
CA 02-5187	8 acre-foot off-channel res.
Permit 3901	1.5 acre-foot off-channel res.
Permit 4127	1.3 acre-foot off-channel res.
Permit 5129	92 acre-foot off-channel res.
Permit 5558	9.42 acre-foot off-channel res.

Canadian Basin

None

4.3.4 Term Permits

Term permits are issued primarily to industrial, mining, and agricultural enterprises, usually for ten years. The term can be renewed if, after ten years, water in the basin is still not being used by other water right holders. There are two water rights in the Red and Canadian River Basins, which have term permits.

Red River Basin

CA 02-5117A	12/31/2042
Permit 5119	07/14/86, or when land lease expires

Canadian River Basin

None

These term permits are only modeled in Scenario 8.

4.3.5 Interbasin Transfers

The TNRCC maintains a list of interbasin transfers (IBTs) in the State of Texas. According to the list there are 15 permitted interbasin transfers in the Red and Canadian River Basins. There were numerous interbasin transfers listed in the master list of IBTs received from the TNRCC that were not modeled. The TNRCC list indicated that the following water rights had IBTs into or out of the Red River Basin: CA 02-4898, CA 02-4899, CA 02-4943, CA 02-4961, CA 02-5145, CA 03-4836 and CA 08-2319. After review of these water rights and conversations with the owners of these water rights, it was determined that none of the rights had IBTs or planned to use IBT in the future. Therefore, none of these water rights were modeled with IBTs. Table 15 lists those water rights, which are authorized to divert water from the Red and Canadian Rivers for subsequent use in other basins or import water into the Red and Canadian River Basins. A detailed description of how these IBTs were modeled in each scenario is given in the water rights assumptions memo found in Appendix D.

Table 15 Interbasin Transfers in the Red and Canadian River Basin Models

Basin From	Basin To	WR	Owner	Authorized Amount
Canadian	Red	CA 01-3782	Canadian MWA	*100,000 Mun, 51,200 Ind (in any basin)
Red	Trinity	CA 02-4881	City of Gainesville	4,500 Mun,
Red	Sulphur	CA 02-4940	City of Paris	1,115 Mun, 20,000 Ind
Red	Trinity	**Permit 5003	North Texas MWD	84,000 Mun
Red	Brazos	CA 02-5144	City of Wichita Falls	1,120 Mun
Red	Brazos	CA 02-5146	City of Olney	35 Irr
Red	Brazos	CA 02-5211	Mackenzie MWA	2,000 Mun, 600 Ind

* CA 01-3782 authorizes an interbasin transfer from Red River Basin to any basin in the amount of 100,000 ac-ft/yr for municipal purposes and 51,200 ac-ft/yr for industrial purposes.

5.0 WATER AVAILABILITY IN THE BASIN

5.1 Descriptions of Scenarios Models

The purpose of the TNRCC WAM effort is to determine the water availability and/or reliability of individual water rights in the Red and Canadian River Basins based on a number of different scenarios. A total of nine water availability scenarios were developed for the Red and Canadian River Basins: eight TNRCC "Base" scenarios and one basin specific scenario. The nine different scenarios include: three simulating various levels of reuse, four simulating partial/total cancellation, a current conditions scenario. The basin specific scenario a firm yield determination for all permitted reservoirs with capacities greater than 5,000 ac-ft per year. A description of the reuse and cancellation scenarios is outlined in the following sections.

A summary table containing all nine modeling scenarios and the respective diversion amounts is shown in Table 16. Table 17 describes the simulation conditions in each of the nine model scenarios. Scenario 9 determines the firm yield of the major existing reservoirs in the basin based on the priority date of impoundment. There are three different annual diversion amounts entered into the modeling scenarios. The three categories include:

- full authorized diversions as defined in the water rights (excluding term permits).
- total and partial cancellation of water rights (total cancellation simulated for those water rights reporting zero use in the last ten years, and partial cancellation of water rights simulated by limiting the modeled diversion amount to the maximum use in the last ten years)

Reliabilities determined in this study are dependant on the estimated watershed parameters in the Red and Canadian River Basin.

5.1.1 Reuse

Scenarios 1, 2, and 3 evaluate the impact of wastewater reuse on water availability in the basin. This is accomplished by varying the return flow percentage between each model scenario while using permitted diversion amounts and authorized reservoir area-capacity relationships.

Scenario 1 assumes existing levels of reuse based on the levels of return flow for the past five years. The full return flow factor was utilized to estimate return flows occurring from surface water diversions and no adjustment was made to return flows, which appear as a result of groundwater use, and/or interbasin transfers. Scenarios 2 and 3 assume 50% and 100% reuse, respectively. The 50% reuse in Scenario 2 was calculated by decreasing return flow factors and constant return flows originated by groundwater and/or interbasin transfer return flows to half the initial value as set in Scenario 1. In Scenario 3, all return flows were assumed to be zero to represent the full reuse of diverted water.

Table 16 Summary of Diversions by Run

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
10203859301	10340		60	60	60	60	60	60	60	60	60	60
10203877301	10210		0	90	90	90	90	0	0	0	0	0
10203885201	10050		90	90	90	90	90	90	90	90	90	90
10203891001	A10060		125	132	132	132	132	132	125	132	125	125
10203888001	X10170		200	200	200	200	200	200	200	200	200	200
10203889001	B10020		75	75	75	75	75	75	75	75	75	75
10203901001	10290		25	25	25	25	25	25	25	25	25	25
10203924002	X10190		150	320	320	320	320	320	150	320	150	150
10203965101	U10020		3,220	3,600	3,600	3,600	3,600	3,600	3,220	3,600	3,220	3,220
10203976001	10390		0	18	18	18	18	0	0	0	0	0
10204033002	X10390		1,286	2,157.57	2,157.57	2,157.57	2,157.57	2,157.57	1,286.00	2,157.57	1,286	1,286
10204033003	X10390		0	1,379.43	1,379.43	1,379.43	1,379.43	1,379.43	0	1,379.43	0	0
10204033004	X10380		0	3,699	3,698.70	3,698.70	3,698.70	3,698.70	0	3,698.70	0	0
10204044001	X10360		0	500	500	500	500	500	0	500	0	0
10204044101	X10350		684	3,728.28	3,728.28	3,728.28	3,728.28	3,728.28	684	3,728.28	684	684
10204058002	Y10120		0	500	500	500	500	0	0	0	0	0
10204059002	X10420		360	360	360	360	360	360	360	360	360	360
10204099101	P10100		83	300	300	300	300	300	83	300	83	83
10204265301	B10030		46	80	80	80	80	80	46	80	46	46
10204294301	X10120		94.19	103	103	103	103	103	94.19	103	94.19	94.19
10204301301	W10060		7,462	15,000	15,000	15,000	15,000	15,000	7,462	15,000	7,462	7,462
10204301302	W10060		0	10,000	10,000	10,000	10,000	10,000	0	10,000	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
10205003301	W10060		38,353	84,000	84,000	84,000	84,000	84,000	38,353	84,000	38,353	38,353
10205022301	C10050		0	2	2	2	2	0	0	0	0	0
10205078601	10450		8	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95
10205113301	W10130		76	125	125	125	125	125	76	125	76	76
10205119001	Y10310	Term	14	300	300	300	300	300	14	300	14	14
10205129301	X10080		144	92	92	92	92	92	92	92	92	92
10205152001	Q10040		0	2,352	2,352	2,352	2,352	0	0	0	0	0
10205233002	Y10260		0	2,700	2,700	2,700	2,700	2,700	0	2,700	0	0
10205233004	Y10250		0	250	250	250	250	250	0	250	0	0
10205233005	Y10240		0	650	650	650	650	650	0	650	0	0
10205276001	X10140		100	2,535	2,535	2,535	2,535	2,535	100	2,535	100	100
10205393301	O10010		230	300	300	300	300	300	230	300	230	230
10205393302	O10010		0	150	150	150	150	150	0	150	0	0
10205434302	V10040		10	10	10	10	10	10	10	10	10	10
10205434303	V10040		13	13	13	13	13	13	13	13	13	13
10205530001	P10040		32	32	32	32	32	32	32	32	32	32
10205558401	Y10290		0	85	85	85	85	0	0	0	0	0
10205605001	V10090		60	100	100	100	100	100	60	100	60	60
10205630001	X10610		0	797.40	797.40	797.40	797.40	0	0	0	0	0
10205632001	Y10040		300	800	800	800	800	800	300	800	300	300
60204874301	V10150		23	30	30	30	30	30	23	30	23	23
60204875301	V10130		0	133	133	133	133	0	0	0	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60204875303	V10130		0	9	9	9	9	0	0	0	0	0
60204876301	V10120		1,234	1,286	1,286	1,286	1,286	1,286	1,234	1,286	1,234	1,234
60204879301	V10070		671	644.96	644.96	644.96	644.96	644.96	671	644.96	671	671
60204879302	V10070		26.04	435.04	435.04	435.04	435.04	435..04	26.04	435..04	26.04	26.04
60204879303	V10070		100	100	100	100	100	100	100	100	100	100
60204879304	V10070		0	80	80	80	80	80	0	80	0	0
60204881301	V10020		0	4,500	4,500	4,500	4,500	0	0	0	0	0
60204883301	W10320		0	80	80	80	80	0	0	0	0	0
60204884301	W10330		0	16	16	16	16	0	0	0	0	0
60204884302	W10340		0	56	56	56	56	0	0	0	0	0
60204884303	W10350		0	0	0	0	0	0	0	0	0	0
60204884304	W10360		0	2	2	2	2	0	0	0	0	0
60204884305	W10340		0	0	0	0	0	0	0	0	0	0
60204884306	W10350		0	1	1	1	1	0	0	0	0	0
60204884307	W10360		0	3	3	3	3	0	0	0	0	0
60204885303	W10310		0	1	1	1	1	0	0	0	0	0
60204885304	W10300		0	0	0	0	0	0	0	0	0	0
60204886301	W10290		0	33.30	33.30	33.30	33.30	0	0	0	0	0
60204887301	W10280		0	0	0	0	0	0	0	0	0	0
60204889301	W10270		9	30	30	30	30	30	9	30	9	9
60204890301	W10260		30	20	20	20	20	20	20	20	20	20
60204891301	W10250		130	130	130	130	130	130	130	130	130	130

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60204892301	W10240		8	20	20	20	20	20	8	20	8	8
60204893301	W10230		0	24	24	24	24	0	0	0	0	0
60204895001	W10170		0	208	208	208	208	0	0	0	0	0
60204896301	W10090		0	21.25	21.25	21.25	21.25	0	0	0	0	0
60204897301	W10080		0	10	10	10	10	0	0	0	0	0
60204898301	W10060		163	250	250	250	250	250	163	250	163	163
60204898302	W10060		0	1650	1650	1650	1650	1650	0	1650	0	0
60204898303	W10060		100	100	100	100	100	100	100	100	100	100
60204899301	W10060		192	250	250	250	250	250	192	250	192	192
60204900301	X10490		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
60204901301	W10020		5,191	5,280	5,280	5,280	5,280	5,280	5,191	5,280	5,191	5,191
60204901303	W10020		0	24,400	24,400	24,400	24,400	24,400	0	24,400	0	0
60204902301	W10030		46	120	120	120	120	120	46	120	46	46
60204903001	W10010		0	4,000	4,000	4,000	4,000	0	0	0	0	0
60204904003	X10630		0	482	482	482	482	0	0	0	0	0
60204907001	X10530		0	200	200	200	200	0	0	0	0	0
60204908001	X10520		0	135	135	135	135	0	0	0	0	0
60204911302	X10570		30	30	30	30	30	30	30	30	30	30
60204912301	X10500		141	987	987	987	987	987	141	987	141	141
60204912401	X10510		136	140	140	140	140	140	136	140	136	136
60204913002	X10480		0	30	30	30	30	0	0	0	0	0
60204914301	X10470		0	30	30	30	30	0	0	0	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60204916001	X10450		160	160	160	160	160	160	160	160	160	160
60204917003	X10430		100	219	219	219	219	219	100	219	100	100
60204918101	X10410		0	360	360	360	360	0	0	0	0	0
60204919001	X10400		0	20	20	20	20	0	0	0	0	0
60204920001	X10200		440	640	640	640	640	640	440	640	440	440
60204921001	X10340		0	109	109	109	109	0	0	0	0	0
60204922301	X10320		0	362	362	362	362	0	0	0	0	0
60204923301	X10290		2	20	20	20	20	20	2	20	2	2
60204925301	X10270		2,220	5,340	5,340	5,340	5,340	5,340	2,220	5,340	2,220	2,220
60204926101	X10260		0	520	520	520	520	0	0	0	0	0
60204930001	X10160		48	48	48	48	48	48	48	48	48	48
60204931301	X10175		10	10	10	10	10	10	10	10	10	10
60204933301	X10130		109	110	110	110	110	110	109	110	109	109
60204934301	X10110		50	50	50	50	50	50	50	50	50	50
60204935301	X10090		40	40	40	40	40	40	40	40	40	40
60204935302	X10090		60	60	60	60	60	60	60	60	60	60
60204936301	X10060		20	20	20	20	20	20	20	20	20	20
60204937301	X10050		25	30	30	30	30	30	25	30	25	25
60204938301	X10070		220	220	220	220	220	220	220	220	220	220
60204939301	X10040		78	78	78	78	78	78	78	78	78	78
60204940301	X10010		13,545	23,885	23,885	23,885	23,885	23,885	13,545	23,885	13,545	13,545
60204940302	X10010		0	1,115	1,115	1,115	1,115	1,115	0	1,115	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60204940303	X10010		6,552	16,610	16,610	16,610	16,610	16,610	6,552	16,610	6,552	6,552
60204940304	X10010		0	20,000	20,000	20,000	20,000	20,000	0	20,000	0	0
60204941002	Y10370		180	885	885	885	885	885	180	885	180	180
60204941003	Y10370		0	2,085	2,085	2,085	2,085	2,085	0	2,085	0	0
60204941301	Y10360		0	298	298	298	298	298	0	298	0	0
60204941302	Y10360		0	702	702	702	702	702	0	702	0	0
60204943301	Y10330		2,872	12,000	12,000	12,000	12,000	12,000	2,872	12,000	2,872	2,872
60204945001	Y10280		0	110	110	110	110	0	0	0	0	0
60204946002	Y10220		565	1,000	1,000	1,000	1,000	1,000	565	1,000	565	565
60204946003	Y10180		0	350	350	350	350	350	0	350	0	0
60204946004	Y10190		0	250	250	250	250	250	0	250	0	0
60204947301	Y10210		0	225	225	225	225	0	0	0	0	0
60204948301	Y10200		0	150	150	150	150	0	0	0	0	0
60204949002	Y10170		0	550	550	550	550	0	0	0	0	0
60204950301	Y10160		0	102	102	102	102	0	0	0	0	0
60204951302	Y10150		40	40	40	40	40	40	40	40	40	40
60204952002	Y10140		0	100	100	100	100	0	0	0	0	0
60204953002	Y10110		750	750	750	750	750	750	750	750	750	750
60204954002	Y10080		1,875	1,875	1,875	1,875	1,875	1,875	1,875	1,875	1,875	1,875
60204955301	Y10070		0	380.74	380.74	380.74	380.74	0	0	0	0	0
60204956001	Y10060		0	81	81	81	81	0	0	0	0	0
60204957003	Y10050		0	66.7	66.7	66.7	66.7	0	0	0	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60204958301	Y10030		7	7	7	7	7	7	7	7	7	7
60204959002	Y10020		620	2,556	2,556	2,556	2,556	2,556	620	2,556	620	620
60204960301	10420		0	160	160	160	160	0	0	0	0	0
60204961301	10380		0	1,920	1,920	1,920	1,920	0	0	0	0	0
60204961302	10380		0	300	300	300	300	0	0	0	0	0
60204962001	10400		80	80	80	80	80	80	80	80	80	80
60205099301	F10220		0	116.8	116.8	116.8	116.8	0	0	0	0	0
60205100301	F10200		0	19	19	19	19	0	0	0	0	0
60205101301	F10190		0	37	37	37	37	0	0	0	0	0
60205102301	F10170		50	50	50	50	50	50	50	50	50	50
60205102302	F10170		33	33	33	33	33	33	33	33	33	33
60205103301	F10150		0	28	28	28	28	0	0	0	0	0
60205104301	F10160		17	17	17	17	17	17	17	17	17	17
60205105301	F10140		8	30	30	30	30	30	8	30	8	8
60205106301	F10130		0	80	80	80	80	0	0	0	0	0
60205107301	F10110		0	101	101	101	101	0	0	0	0	0
60205109301	U10030		0	200	200	200	200	0	0	0	0	0
60205110302	F10050		0	40	40	40	40	0	0	0	0	0
60205111001	F10020		0	22.7	22.7	22.7	22.7	0	0	0	0	0
60205112303	G10010		0	45	45	45	45	0	0	0	0	0
60205113302	H10040		0	150	150	150	150	0	0	0	0	0
60205114301	I10010		35	35	35	35	35	35	35	35	35	35

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60205115001	J10020		0	3,050	3,050	3,050	3,050	0	0	0	0	0
60205116301	J10010		0	0	0	0	0	0	0	0	0	0
60205117001	K10010		5,010	1,240	1,240	1,240	1,240	1,240	1,240	1,240	1,240	1,240
60205117002	K10010	Term	3,770	3,770	0	0	0	0	0	0	0	3,770
60205118001	L10010		0	3,770	3,770	3,770	3,770	0	0	0	0	0
60205119301	M10020		0	20	20	20	20	0	0	0	0	0
60205120301	M10010		28	85	85	85	85	85	28	85	28	28
60205121101	N10050		360	2,153	2,153	2,153	2,153	2,153	360	2,153	360	360
60205122002	Q10060		0	7,289	7,289	7,289	7,289	0	0	0	0	0
60205122003	Q10060		0	672	672	672	672	0	0	0	0	0
60205123001	P10080		0	16,660	16,660	16,660	16,660	16,660	0	16,660	0	0
60205123303	Q10080		1,516	25,150	25,150	25,150	25,150	25,150	1,516	25,150	1,516	1,516
60205123304	Q10080		0	5,850	5,850	5,850	5,850	5,850	0	5,850	0	0
60205123306	P10110		2,530	40,000	40,000	40,000	40,000	40,000	2,530	40,000	2,530	2,530
60205123308	P10110		2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
60205123310	P10110		60,491	103,340	103,340	103,340	103,340	103,340	60,491	103,340	60,491	60,491
60205124101	O10040		0	75.1	75.1	75.1	75.1	75.1	0	75.1	0	0
60205124301	O10090		161.12	3,000	3,000	3,000	3,000	3,000	161.12	3,000	161.12	161.12
60205125002	O10070		350.02	675	675	675	675	675	350.02	675	350.02	350.02
60205126301	O10050		60	60.48	60.48	60.48	60.48	60.48	60	60.48	60	60
60205127001	O10060		30	30	30	30	30	30	30	30	30	30
60205127002	O10060		55	54.65	54.65	54.65	54.65	54.65	55	54.65	55	55

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60205128301	O10020		693.38	600	600	600	600	600	600	600	600	600
60205129001	P10090		120	256	256	256	256	256	120	256	120	120
60205129002	P10090		0	148	148	148	148	148	0	148	0	0
60205130002	P10070		0	40	40	40	40	0	0	0	0	0
60205131301	P10060		840	840	840	840	840	840	840	840	840	840
60205132301	P10050		500	500	500	500	500	500	500	500	500	500
60205133301	P10030		200	300	300	300	300	300	200	300	200	200
60205134102	Q10100		125	125	125	125	125	125	125	125	125	125
60205135003	Q10020		0	357	357	357	357	0	0	0	0	0
60205136002	Q10010		0	200	200	200	200	0	0	0	0	0
60205137301	U10160		0	125	125	125	125	125	0	125	0	0
60205137302	U10150		59	100	100	100	100	100	59	100	59	59
60205138401	U10170		0	55	55	55	55	0	0	0	0	0
60205139003	U10140		0	30	30	30	30	0	0	0	0	0
60205140001	U10130		78	270	270	270	270	270	78	270	78	78
60205142301	U10100		0	200	200	200	200	0	200	0	200	200
60205143001	U10070		0	200	200	200	200	0	200	0	200	200
60205144301	R10010		15,340	38,880	38,880	38,880	38,880	38,880	15,340	38,880	15,340	15,340
60205144303	R10010		0	1,120	1,120	1,120	1,120	1,120	0	1,120	0	0
60205145301	R10060		64	70	70	70	70	70	64	70	64	64
60205146301	R10080		450	450	450	450	450	450	450	450	450	450
60205146302	R10070		308	810	810	810	810	810	308	810	308	308

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60205146304	R10070		28.18	35	35	35	35	35	28.18	35	28.18	28.18
60205147301	R10050		0	30	30	30	30	0	0	0	0	0
60205148001	R10040		285.27	506	506	506	506	506	285.27	506	285.27	285.27
60205148301	R10030		0	300	300	300	300	300	0	300	0	0
60205149301	S10050		60	60	60	60	60	60	60	60	60	60
60205149302	S10050		40	40	40	40	40	40	40	40	40	40
60205150301	S10030		22,236.89	25,000	25,000	25,000	25,000	25,000	22,236.89	25,000	22,236.89	22,236.89
60205152301	U10060		100	100	100	100	100	100	100	100	100	100
60205152303	U10060		579	1459	1459	1459	1459	1459	579	1459	579	579
60205152304	U10060		0	1	1	1	1	1	0	1	0	0
60205153301	U10040		30	50	50	50	50	50	30	50	30	30
60205154301	U10050		0	15	15	15	15	0	0	0	0	0
60205179001	C10220		160	796	796	796	796	796	160	796	160	160
60205180301	C10210		0	0	0	0	0	0	0	0	0	0
60205181301	C10190		36	80	80	80	80	80	36	80	36	36
60205182101	C10170		4	37	37	37	37	37	4	37	4	4
60205183101	C10150		13	13	13	13	13	13	13	13	13	13
60205184101	C10130		0	54	54	54	54	0	0	0	0	0
60205185301	C10120		0	125	125	125	125	0	0	0	0	0
60205186301	C10110		200	200	200	200	200	200	200	200	200	200
60205187401	C10090		0	40	40	40	40	0	0	0	0	0
60205189301	C10070		0	164	164	164	164	0	0	0	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60205190301	C10070		0	0	0	0	0	0	0	0	0	0
60205191301	C10070		0	164	164	164	164	0	0	0	0	0
60205192301	C10070		0	164	164	164	164	0	0	0	0	0
60205194302	C10040		32.61	37.5	37.5	37.5	37.5	37.5	32.61	37.5	32.61	32.61
60205195301	C10020		168	400	400	400	400	400	168	400	168	168
60205196301	C10100		50	124	124	124	124	124	50	124	50	50
60205197302	D10190		60	60	60	60	60	60	60	60	60	60
60205197303	D10190		20	20	20	20	20	20	20	20	20	20
60205197304	D10190		60	69	69	69	69	69	60	69	60	60
60205198301	D10180		57	57	57	57	57	57	57	57	57	57
60205199301	D10260		173	173	173	173	173	173	173	173	173	173
60205199302	D10250		57	90	90	90	90	90	57	90	57	57
60205200301	D10240		0	12	12	12	12	0	0	0	0	0
60205202301	D10230		0	61	61	61	61	0	0	0	0	0
60205203301	D10220		26	26	26	26	26	26	26	26	26	26
60205204301	D10210		0	34	34	34	34	0	0	0	0	0
60205206301	D10160		0	24	24	24	24	0	0	0	0	0
60205207301	D10150		0	8	8	8	8	0	0	0	0	0
60205208301	D10290		0	55	55	55	55	0	0	0	0	0
60205209301	D10280		90	284	284	284	284	284	90	284	90	90
60205210301	D10270		0	60	60	60	60	0	0	0	0	0
60205211301	D10130		1,000	2,000	2,000	2,000	2,000	2,000	1,000	2,000	1,000	1,000

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60205211302	D10130		0	600	600	600	600	600	0	600	0	0
60205211304	D10130		1,103.37	2,000	2,000	2,000	2,000	2,000	1,103.37	2,000	1,103.37	1,103.37
60205211305	D10130		0	600	600	600	600	600	0	600	0	0
60205212301	D10120		107	107	107	107	107	107	107	107	107	107
60205220301	D10050		5.18	20	20	20	20	20	5.18	20	5.18	5.18
60205221301	D10030		0	397	397	397	397	0	0	0	0	0
60205223001	H10160		0	38.5	38.5	38.5	38.5	0	0	0	0	0
60205225001	E10040		0	96	96	96	96	0	0	0	0	0
60205226001	E10030		3	60	60	60	60	60	3	60	3	3
60205227001	E10010		3	100	100	100	100	100	3	100	3	3
60205228001	E10020		0	63	63	63	63	0	0	0	0	0
60205229301	H10140		3	30	30	30	30	30	3	30	3	3
60205230301	H10110		16	16	16	16	16	16	16	16	16	16
60205230302	H10110		16	600	600	600	600	600	16	600	16	16
60205230304	H10110		119	3,000	3,000	3,000	3,000	3,000	119	3,000	119	119
60205231001	H10120		0	41	41	41	41	0	0	0	0	0
60205232001	B10070		200	200	200	200	200	200	200	200	200	200
60205233003	B10050		3,711	3,711	3,711	3,711	3,711	3,711	3,711	3,711	3,711	3,711
60205233004	B10050		0	128	128	128	128	128	0	128	0	0
60205233005	B10050		0	191	191	191	191	191	0	191	0	191
60205233301	B10060		0	250	250	250	250	250	0	250	0	0
60205233302	B10060		1,029	10,819	10,819	10,819	10,819	10,819	1,029	10,819	1,029	1,029

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60205233303	B10060		0	372	372	372	372	372	0	372	0	0
60205233304	B10060		0	559	559	559	559	559	0	559	0	0
60205234001	B10040		0	184	184	184	184	0	0	0	0	0
60205235001	B10010		0	108	108	108	108	0	0	0	0	0
60205236001	10350		130	130	130	130	130	130	130	130	130	130
60205236003	10350		43	43	43	43	43	43	43	43	43	43
60205237301	10320		0	300	300	300	300	0	0	0	0	0
60205238301	H10090		80	160	160	160	160	160	80	160	80	80
60205239301	10190		75	5	5	5	5	5	5	5	5	5
60205240301	10180		95	100	100	100	100	100	95	100	95	95
60205241301	10170		20	4	4	4	4	4	4	4	4	4
60205242301	10160		0	9	9	9	9	0	0	0	0	0
60205243301	10150		140	217	217	217	217	217	140	217	140	140
60205245301	10130		0	129	129	129	129	0	0	0	0	0
60205246301	10120		0	70	70	70	70	0	0	0	0	0
60205247301	10100		0	100	100	100	100	0	0	0	0	0
60205248301	10090		4	30	30	30	30	30	4	30	4	4
60205249301	10080		0	10	10	10	10	0	0	0	0	0
60205250002	10060		0	33	33	33	33	0	0	0	0	0
60205251301	A10070		50	60	60	60	60	60	50	60	50	50
60205252301	A10050		0	20	20	20	20	0	0	0	0	0
60205253002	A10010		0	319	319	319	319	0	0	0	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Red River Basin												
60205254001	10040		0	125	125	125	125	0	0	0	0	0
60205256001	10280		36	50	50	50	50	50	36	50	36	36
60205257101	10270		0	70	70	70	70	0	0	0	0	0
60205258001	10260		0	140	140	140	140	0	0	0	0	0
60205259001	10240		0	34	34	34	34	0	0	0	0	0
60205260002	10230		100	100	100	100	100	100	100	100	100	100
60205261102	10220		0	59	59	59	59	0	0	0	0	0
60205262101	10200		0	29	29	29	29	0	0	0	0	0
60205264301	10020		0	70	70	70	70	0	0	0	0	0
60205267301	F10210		0	100	100	100	100	0	0	0	0	0
Canadian River Basin												
10103968301	F10025		184	240	240	240	240	240	184	240	184	184
10104106302	A10060		0	169	169	169	169	0	0	0	0	0
10104184301	A10080		0	0	0	0	0	0	0	0	0	0
10105049301	A10030		0	0	0	0	0	0	0	0	0	0
60103777301	A10140		0	0	0	0	0	0	0	0	0	0
60103777302	A10150		0	30	30	30	30	0	0	0	0	0
60103778301	A10130		0	0	0	0	0	0	0	0	0	0
60103779301	A10110		0	180	180	180	180	0	0	0	0	0
60103779302	A10111		0	0	0	0	0	0	0	0	0	0
60103779303	A10112		0	0	0	0	0	0	0	0	0	0
60103780301	B10140		10	10	10	10	10	10	0	10	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Canadian River Basin												
60103781301	B10150		0	0	0	0	0	0	0	0	0	0
60103782301	B10130		84,652	100,000	100,000	100,000	100,000	100,000	84,652	100,000	84,652	84,652
60103782302	B10130		7,617	51,200	51,200	51,200	51,200	51,200	7,617	51,200	7,617	7,617
60103783301	B10100		0	0	0	0	0	0	0	0	0	0
60103784301	B10100		230	230	230	230	230	230	230	230	230	230
60103785301	B10100		60	60	60	60	60	60	60	60	60	60
60103786301	B10050		250	250	250	250	250	250	250	250	250	250
60103787101	B10030		220	640	640	640	640	640	220	640	220	220
60103788301	B10020		0	4	4	4	4	0	0	0	0	0
60103791301	C10020		167	190	190	190	190	190	167	190	167	167
60103792301	C10010		40	40	40	40	40	40	40	40	40	40
60103793301	D10050		0	90	90	90	90	0	0	0	0	0
60103794301	D10040		150	150	150	150	150	150	150	150	150	150
60103795001	D10020		125	125	125	125	125	125	125	125	125	125
60103795301	D10100		0	0	0	0	0	0	0	0	0	0
60103796301	D10100		148	195	195	195	195	195	148	195	148	148
60103798301	D10070		0	50	50	50	50	0	0	0	0	0
60103799302	D10060		0	106	106	106	106	0	0	0	0	0
60103800001	D10010		0	90	90	90	90	0	0	0	0	0
60103801001	F10070		0	0	0	0	0	0	0	0	0	0
60103802301	F10040		120	120	120	120	120	120	120	120	120	120
60103803301	F10020		0	10,460	10,460	10,460	10,460	0	0	0	0	0

Table 16 Summary of Diversions by Run (Continued)

Water Right ID No.	Control Point	Term	Maximum Reported Annual Use (ac-ft/yr)	Authorized Annual Use (ac-ft/yr)	Total Annual Diversions Included in Each Model Scenario (ac-ft/yr)							
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Canadian River Basin												
60103804301	F10010		40	40	40	40	40	40	40	40	40	40
60103805001	F10080		102	102	102	102	102	102	102	102	102	102
60103807001	F10110		20	20	20	20	20	20	20	20	20	20

Table 17 TNRCC Red and Canadian River Basin Water Availability Model

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

Definition

A	Authorized area-capacities (original) and Authorized diversion amounts (full permitted)
M	Modified diversion amounts (10 years nonuse = 0)
MAX	Modified diversion amounts (Max use for last10 years)
Yr 2000	Year 2000 area-capacity curve
All	Return Flow factor determined based on minimum historical flows
50%	50% of computed return flow above
None	No return flow
No	No use to term water rights
Yes	Term water rights used
Yld	Diversions at reservoir set to firm yield amounts

5.1.2 Cancellation

Scenarios 4, 5, 6 and 7 evaluate the impact of simulated cancellation of water rights, in addition to wastewater reuse on water availability in the basin. Water rights which have not been used within the last ten years (the statutory minimum) have been cancelled in the four model scenarios listed above. Water rights utilized, which reported a partial non-use of permitted diversions, were *not* cancelled in any of the scenarios. Table 18 lists the water right's authorized diversion amount, maximum ten-year-use, and whether the right was cancelled.

Scenario 4 simulates water availability if specific water rights were cancelled (no reported use in ten years). In the scenario, all remaining rights were set to permitted authorized diversions and return flows were based on no reuse. Scenario 5 is identical to Scenario 4, with the exception that the diversion amounts for those water rights which were not cancelled were set to the maximum reported use in the last ten years.

Scenarios 6 and 7 are similar to Scenarios 4 and 5 in terms of diversion amount; but no return flows were incorporated, in order to represent 100% wastewater reuse.

Appendix D lists specific assumptions made for selected water rights in the Red and Canadian River Basins.

Table 18 Cancellation of Water Rights in the Red and Canadian River Basins
(excluding recreational rights)

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
Red River Basin							
2006	1	4301	W10060	Mun	15,000	7462	No
2006	1	4301	W10060	Ind	10,000	0	No
2855	1	2616	D10210	Irr	197	0	Yes
4130	1	3891	A10060	Irr	132	125	No
4184	1	3859	10340	Irr	60	60	No
4193	1	3877	10210	Irr	90	0	Yes
4194	1	3885	10050	Irr	90	90	No
4198	1	3901	10290	Irr	25	25	No
4207	1	3889	B10020	Irr	75	75	No
4209	1	3888	X10170	Irr	200	200	No
4228	1	3924	X10190	Irr	320	150	No
4268	1	3965	U10020	Irr	3,600	3220	No
4317	1	3976	10390	Irr	18	0	Yes
4363	1	4033	X10390	Irr	7,236	1286	No
4371	1	4044	X10350	Irr	4,228	684	No
4391	1	4127	F10070	Rec	36	36	No
4392	1	4058	Y10120	Irr	500	0	Yes
4397	1	4059	X10420	Irr	360	360	No
4433	1	4099	P10100	Irr	300	83	No
4576	1	4265	B10030	Irr	80	46	No
4582	1	4294	X10120	Irr	103	94.19	No
4610	1	4290	P10020	Rec	30	0	Yes
4874	6		V10150	Irr	30	23	No
4875	6		V10130	Irr	133	0	Yes
4875	6		V10130	Mining	9	0	Yes
4876	6		V10120	Mun	1,286	1234	No
4879	6		V10070	Mun	1,080	671	No
4879	6		V10070	Irr	100	100	No
4879	6		V10070	Rec	80	0	No
4881	6		V10020	Mun	4,500	0	Yes
4883	6		W10320	Irr	80	0	Yes
4884	6		W10330	Irr	16	0	Yes
4884	6		W10340	Irr	56	0	Yes
4886	6		W10290	Irr	33	0	Yes
4887	6		W10280	Ind	0	0	No
4889	6		W10270	Irr	30	9	No
4890	6		W10260	Irr	20	30	No

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
4891	6		W10250	Irr	130	130	No
4892	6		W10240	Irr	20	8	No
4893	6		W10230	Irr	24	0	Yes
4895	6		W10170	Irr	208	0	Yes
4896	6		W10090	Irr	21	0	Yes
4897	6		W10080	Irr	10	0	Yes
4898	6		W10060	Mun	1,650	0	No
4898	6		W10060	Irr	250	192	No
4898	6		W10060	Mining	100	100	No
4899	6		W10060	Mun	250	163	No
4900	6		X10490	Ind	10,000	10000	No
4901	6		W10020	Mun	29,680	5191	No
4902	6		W10030	Irr	120	46	No
4903	6		W10010	Ind	4,000	0	Yes
4904	6		X10630	Irr	482	0	Yes
4907	6		X10530	Irr	200	0	Yes
4908	6		X10520	Irr	135	0	Yes
4911	6		X10570	Irr	30	30	No
4912	6		X10500	Irr	987	141	No
4912	6		X10510	Mining	140	136	No
4913	6		X10480	Irr	30	0	Yes
4914	6		X10470	Irr	30	0	Yes
4916	6		X10450	Irr	160	160	No
4917	6		X10430	Irr	219	100	No
4918	6		X10410	Irr	360	0	Yes
4919	6		X10400	Irr	20	0	Yes
4920	6		X10200	Irr	640	440	No
4921	6		X10340	Irr	109	0	Yes
4922	6		X10320	Irr	362	0	Yes
4923	6		X10290	Mun	20	2	No
4925	6		X10270	Mun	5,340	2200	No
4926	6		X10260	Irr	520	0	Yes
4930	6		X10160	Irr	48	48	No
4931	6		X10175	Irr	10	10	No
4933	6		X10130	Irr	110	109	No
4934	6		X10110	Irr	50	50	No
4935	6		X10090	Irr	60	60	No
4935	6		X10090	Irr	40	40	No
4936	6		X10060	Irr	20	20	No
4937	6		X10050	Irr	30	25	No
4938	6		X10070	Irr	220	220	No

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
4939	6		X10040	Irr	78	78	No
4940	6		X10010	Mun	25,000	13545	No
4940	6		X10010	Ind	36,610	6551.79	No
4941	6		Y10370	Irr	2,970	180	No
4943	6		Y10330	Mun	12,000	2872	No
4945	6		Y10280	Irr	110	0	Yes
4946	6		Y10220	Irr	1,600	565	No
4947	6		Y10210	Irr	225	0	Yes
4948	6		Y10200	Irr	150	0	Yes
4949	6		Y10170	Irr	550	0	Yes
4950	6		Y10160	Irr	102	0	Yes
4951	6		Y10150	Irr	40	40	No
4952	6		Y10140	Irr	100	0	Yes
4953	6		Y10110	Irr	750	750	No
4954	6		Y10080	Irr	1,875	1875	No
4955	6		Y10070	Irr	381	0	Yes
4956	6		Y10060	Irr	81	0	Yes
4957	6		Y10050	Irr	67	0	Yes
4958	6		Y10030	Ind	7	7	No
4959	6		Y10020	Irr	2,556	620	No
4960	6		10420	Irr	160	0	Yes
4961	6		10380	Mun	1,920	0	Yes
4961	6		10380	Irr	300	0	Yes
4962	6		10400	Irr	80	80	No
5003	1	5003	W10060	Mun	84,000	38353	No
5022	1	5022	C10050	Mun	2	0	Yes
5078	1	5078	10450	Irr	8	8	No
5099	6		F10220	Irr	117	0	Yes
5100	6		F10200	Irr	19	0	Yes
5101	6		F10190	Irr	37	0	Yes
5102	6		F10170	Mun	50	50	No
5102	6		F10170	Irr	33	33	No
5103	6		F10150	Irr	28	0	Yes
5104	6		F10160	Irr	17	17	No
5105	6		F10140	Irr	30	8	No
5106	6		F10130	Irr	80	0	Yes
5107	6		F10110	Irr	101	0	Yes
5109	6		U10030	Irr	200	0	Yes
5110	6		F10050	Irr	40	0	Yes
5111	6		F10020	Irr	23	0	Yes
5112	6		G10010	Irr	45	0	Yes

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
5113	1	5113	W10130	Irr	125	76	No
5113	6		H10040	Irr	150	0	Yes
5114	6		I10010	Irr	35	35	No
5115	6		J10020	Other	3,050	0	Yes
5116	6		J10010	Other	0	0	Yes
5117	6		K10010	Other	5,010	5010	No
5118	6		L10010	Other	3,770	0	Yes
5119	1	5119	Y10310	Irr	300	14	No
5119	6		M10020	Irr	20	0	Yes
5120	6		M10010	Irr	85	28	No
5121	6		N10050	Irr	2,153	360	No
5122	6		Q10060	Mun	7,289	0	Yes
5122	6		Q10060	Irr	672	0	Yes
5123	6		Q10080	Mun	25,150	1516	No
5123	6		P10110	Ind	40,000	2530	No
5123	6		P10110	Mining	2,000	2000	No
5123	6		P10110	Irr	120,000	60491	No
5124	6		O10090	Irr	3,075	161.12	No
5125	6		O10070	Irr	675	350.02	No
5126	6		O10050	Mun	60	60	No
5127	6		O10060	Mun	55	55	No
5127	6		O10060	Mining	30	30	No
5128	6		O10020	Mun	1,400	693.38	No
5129	1	5129	X10080	Irr	496	144	No
5129	6		P10090	Irr	404	120	No
5130	6		P10070	Irr	40	0	Yes
5131	6		P10060	Mun	840	840	No
5132	6		P10050	Mun	500	500	No
5133	6		P10030	Mun	300	200	No
5134	6		Q10100	Irr	125	125	No
5135	6		Q10020	Irr	357	0	Yes
5136	6		Q10010	Irr	200	0	Yes
5137	6		U10150	Mun	225	59	No
5138	6		U10170	Irr	55	0	Yes
5139	6		U10140	Irr	30	0	Yes
5140	6		U10130	Ind	270	78	No
5142	6		U10100	Irr	200	0	Yes
5143	6		U10070	Irr	200	0	Yes
5144	6		R10010	Mun	40,000	15340	No
5145	6		R10060	Mun	70	64	No
5146	6		R10070	Mun	1,260	758	No

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
5146	6		R10070	Irr	35	28.18	No
5147	6		R10050	Irr	30	0	Yes
5148	6		R10030	Mun	806	285.27	No
5149	6		S10050	Mun	100	100	No
5150	6		S10030	Mun	45,000	22236.89	No
5152	6		U10060	Mun	1,559	679	No
5152	6		U10060	Mining	1	0	No
5153	6		U10040	Irr	50	30	No
5154	6		U10050	Irr	15	0	Yes
5179	6		C10220	Irr	796	160	No
5180	6		C10210	Other	0	0	No
5181	6		C10190	Irr	80	36	No
5182	6		C10170	Irr	37	4	No
5183	6		C10150	Irr	13	13	No
5184	6		C10130	Irr	54	0	Yes
5185	6		C10120	Irr	125	0	Yes
5186	6		C10110	Irr	200	200	No
5187	6		C10090	Irr	40	0	Yes
5189	6		C10070	Irr	164	0	Yes
5190	6		C10070	Irr	10	0	Yes
5191	6		C10070	Irr	164	0	Yes
5192	6		C10070	Irr	164	0	Yes
5194	6		C10040	Irr	38	32.61	No
5195	6		C10020	Irr	400	168	No
5196	6		C10100	Irr	124	50	No
5197	6		D10190	Irr	149	140	No
5198	6		D10180	Irr	57	57	No
5199	6		D10250	Irr	263	230	No
5200	6		D10240	Irr	12	0	Yes
5202	6		D10230	Irr	61	0	Yes
5203	6		D10220	Irr	26	26	No
5204	6		D10210	Irr	34	0	Yes
5206	6		D10160	Irr	24	0	Yes
5207	6		D10150	Irr	8	0	Yes
5208	6		D10290	Irr	55	0	Yes
5209	6		D10280	Irr	284	90	No
5210	6		D10270	Irr	60	0	Yes
5211	6		D10130	Mun	4,000	2103.37	No
5211	6		D10130	Ind	1,200	0	No
5212	6		D10120	Irr	107	107	No
5220	6		D10050	Mun	20	5.18	No

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
5221	6		D10030	Mun	397	0	Yes
5223	6		H10160	Irr	39	0	Yes
5225	6		E10040	Irr	96	0	Yes
5226	6		E10030	Irr	60	3	No
5227	6		E10010	Irr	100	3	No
5228	6		E10020	Irr	63	0	Yes
5229	6		H10140	Irr	30	3	No
5230	6		H10110	Ind	600	16	No
5230	6		H10110	Ind	3,000	119	No
5230	6		H10110	Irr	16	16	No
5231	6		H10120	Irr	41	0	Yes
5232	6		B10070	Irr	200	200	No
5233	1	5233	Y10240	Irr	3,600	0	Yes
5233	6		B10050	Mun	14,530	4740	No
5233	6		B10050	Ind	500	0	No
5233	6		B10050	Irr	250	0	No
5233	6		B10050	Mining	750	0	No
5234	6		B10040	Irr	184	0	Yes
5235	6		B10010	Irr	108	0	Yes
5236	6		10350	Irr	173	173	No
5237	6		10320	Irr	300	0	Yes
5238	6		H10090	Irr	160	80	No
5239	6		10190	Irr	85	75	No
5240	6		10180	Irr	100	95	No
5241	6		10170	Irr	34	20	No
5242	6		10160	Irr	9	0	Yes
5243	6		10150	Irr	217	140	No
5245	6		10130	Irr	129	0	Yes
5246	6		10120	Irr	70	0	Yes
5247	6		10100	Irr	100	0	Yes
5248	6		10090	Irr	30	4.4	No
5249	6		10080	Irr	10	0	Yes
5250	6		10060	Irr	33	0	Yes
5251	6		A10070	Irr	60	50	No
5252	6		A10050	Irr	20	0	Yes
5253	6		A10010	Irr	319	0	Yes
5254	6		10040	Irr	125	0	Yes
5256	6		10280	Irr	50	36	No
5257	6		10270	Irr	70	0	Yes
5258	6		10260	Irr	140	0	Yes
5259	6		10240	Irr	34	0	Yes

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
5260	6		10230	Irr	100	100	No
5261	6		10220	Irr	59	0	Yes
5262	6		10200	Irr	29	0	Yes
5264	6		10020	Irr	70	0	Yes
5267	6		F10210	Irr	100	0	Yes
5276	1	5276	X10140	Irr	2,535	1000	No
5393	1	5393	O10010	Irr	450	230	No
5434	1	5434	V10040	Irr	23	23	No
5530	1	5530	P10040	Irr	32	32	No
5558	1	5558	Y10290	Irr	85	0	Yes
5605	1	5605	V10090	Irr	100	60	No
5630	1	5630	X10610	Irr	797	0	Yes
5632	1	5632	Y10040	Irr	800	300	No
Canadian River Basin							
3777	6		A10140	Mining	30	0	Yes
3778	6		A10130	Ind	0	0	No
3779	6		A10110	Irr	180	0	Yes
3780	6		B10140	Irr	10	10	No
3781	6		B10150	Other	0	0	No
3782	6		B10130	Mun	100,000	84,652	No
3782	6		B10130	Ind	51,200	7,617	No
3783	6		B10100	Ind	0	384	No
3784	6		B10100	Ind	0	451	No
3785	6		B10100	Ind	0	53	No
3786	6		B10050	Irr	250	250	No
3787	6		B10030	Irr	640	220	No
3788	6		B10020	Irr	4	0	Yes
3791	6		C10020	Irr	190	167	No
3792	6		C10010	Irr	40	40	No
3793	6		D10050	Irr	90	0	Yes
3794	6		D10040	Irr	150	150	No
3795	6		D10020	Irr	125	125	No
3796	6		D10100	Irr	195	148	No
3797	6		D10100	Irr	0	1,000	No
3798	6		D10070	Irr	50	0	Yes
3799	6		D10060	Irr	106	0	Yes
3800	6		D10010	Irr	90	0	Yes
3801	6		F10070	Irr	0	0	No
3802	6		F10040	Irr	120	120	No
3803	6		F10020	Mun	10,460	0	Yes
3804	6		F10010	Irr	40	40	No

Water Right Number	Type	Permit #	Control Point	Use Type	Authorized Diversion (Ac-Ft/Yr)	Max Use 10 Years (Ac-Ft/Yr)	Cancel
3805	6		F10080	Irr	102	102	No
3807	6		F10110	Irr	20	0	Yes
4297	6	3968	F10025	Irr	240	184	No
4427	6	4106	A10060	Irr	169	0	Yes
4489	6	4184	A10080	Other	0	0	No

Note: Although some records indicate the maximum reported use the last 10 years as being zero, the water right was not canceled because another portion of the water right was used.

5.1.3 Current Conditions Scenario

Scenario 8, a TNRCC base scenario, was performed to estimate water availability under current conditions of water use and storage capacity. In Scenario 8, term permits are accounted for in the model. Thus, Scenario 8 is similar to Scenario 5 with year-2000 capacities utilized and term permits in effect. Conditions of this scenario include:

- Setting the annual diversion amounts to the maximum reported use in the last ten years
- Basing return flows on no wastewater reuse.
- Developing area-capacity relationships for all major reservoirs to reflect year-2000 conditions, as a result of sedimentation.
- Term permits

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

The current conditions scenario, Scenario 8, consists of diverting the maximum amount used by a water right holder in the last ten years, using year-2000 area-capacity curves, with term permits.

5.1.4 Firm Yield Scenario

The firm yield run (Scenario 9) is a basin specific scenario to identify the yield of any permitted reservoir, which goes dry under authorized diversions. The firm yield analysis was performed using Scenario 3 (full authorized diversions, no return flows). If the reservoir did not go dry during Scenario 3 then the firm yield of the reservoir is simply the diversion amount used in Scenario 3. If the reservoir did have a value of zero during any one month of the simulation then the diversion amount was adjusted. Diversions from each reservoir were made such that the remaining volume left in storage was within 1 percent of the total original storage capacity. Diversions were adjusted up or down, maintaining the existing seasonal use patterns and existing priority dates until the reservoir went dry. The firm yields were developed using only the drainage area of the reservoir; no additional water was added to any reservoir from water supply contracts.

Results of the firm yield analysis are shown in the Section 5.2.4.

5.2 Results of Water Availability Model

Appendix R provides the results from the WRAP (DECEMBER, 2001) model and illustrates the reliability of individual water rights. The tables in Appendix R list all water rights in the Red and Canadian River Basins with permitted diversions along with their period and volume reliability. Period reliability, expressed in percent is defined as the ratio of number of months for which no shortages occurred to the total number of months in the simulation period. Volumetric reliability, expressed as a percent, represents the ratio of the mean volume of shortages divided by the corresponding annual diversion amount.

Also shown in Appendix R are the results of the modeling simulations on specific reservoirs in the Red and Canadian River Basins. Results were reported for the following ten reservoirs in the Red River Basin:

- Lake Greenbelt,
- Mackenzie Lake,
- Lake Kemp,
- Lake Diversion,
- Lake Arrowhead,
- Lake Nocona,
- Lake Texoma,
- Pat Mayse Reservoir,
- Lake Bonham, and
- Lake Crook.

Results were reported for the following three reservoirs in the Canadian River Basin:

- Lake Rita Blanca,
- Lake Meredith, and
- Palo Duro Lake.

These reservoirs in the Red and Canadian River Basins were chosen to illustrate the results the modeling simulations had on the reservoirs based on size and location of the reservoirs.

Additional interest, in a water availability context, is the regulated and unappropriated flows at the primary control points for the Red and Canadian River Basins. Regulated flows are defined as the actual streamflows at that control point, including releases from upstream reservoirs for downstream water rights and instream flow requirements that are not available for appropriation. Unappropriated flows are those streamflows at a control point that remain after all water rights in the simulation have made their depletions. Unappropriated streamflows reflect that amount of water, which may be available for future use. Future appropriations are subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code. Environmental flow needs will be considered when granting new water rights or amending existing water rights, thereby affecting the amount of water available for appropriation.

Appendix R contains the study results for the selected reservoirs and the primary control points in order to compare the impacts of various scenarios for the Red and Canadian River Basins.

5.2.1 Reuse

Reliability for Scenarios 1, 2, and 3 are presented in Table R-Red-1 and Table R-Canadian-4 in Appendix R for the Red and Canadian River Basins, respectively. Graphical plots for the selected reservoirs and primary control points are presented in Appendix R, Figures R-R-1 through R-R-87 for the Red River Basin and R-C-1 through R-C-36 for the Canadian River Basin. The effects of wastewater reuse on the selected reservoirs are minimal in both basins, as shown in Figures R-R-1 through R-R-10 for the Red River Basin and Figures R-C-1 through R-C-3 for the Canadian River Basin. Out of both basins, Lake Kemp in the Red River is the only reservoir with a slight difference in reservoir storage cause by reuse. The maximum monthly reservoir storage decline between Scenario 1 and Scenario 3 was approximately 9,000 ac-ft and occurred in 1959. The minimal impact of reuse is caused by many different factors. In the Canadian River Basin there are few major return flow discharges. The arid region and high infiltration rates also contribute to the minimal impact. Likewise in the Red River Basin, there are only a few large return flow facilities. In the Red River Basin the amount of flow from Oklahoma in the Red River also minimizes the effects of these return flows. Finally, in the Red River Basin, the precipitation and runoff increase from west to east, thus adding water to the system. The remaining reservoirs in the Red and Canadian River Basin show little to no visible effect.

5.2.1.1 Specific Large Rights

In general, most of the large water rights in the Red River Basin do not differ significantly between the reuse scenarios. The majority of the reliabilities for the large water rights decline no more than two to three percent when the reuse is set to 100% in Scenario 3. However, between Scenario 1 and Scenario 3, the reliability for the 16,600 ac-ft/yr diversion associated with CA 5123 declines from 91.01% to 68.46% and from 96.07% to 72.36% for the monthly and volume reliabilities, respectively. This water right was the only water right in the Red River Basin that declined considerably as a result of reuse. As a whole, the reliabilities do not differ significantly because there are few large return flows in the Red River Basin. The reliabilities for each water right in Scenarios 1, 2 and 3 for the Red River Basin is shown in Appendix R, Table R-Red-1.

Generally, the reliabilities for the water rights in the Canadian River Basin remain the same as the reuse increases in Scenarios 1 through 3. However, CA 01-3787 had a substantial impact in water supply reliability in Scenarios 2 and 3 versus Scenario 1, while the remaining water rights in the basin showed no impact. In addition, the Canadian River

MWA's industrial portion of CA 01-3782 had a slight decrease in reliability from 83.01% to 82.84% between Scenario 1 and Scenario 3 (see Table R-Canadian-4, Appendix R).

5.2.1.2 Unappropriated Flows at Selected Locations

Annual unappropriated flows in the Red River Basin resulting from different levels of wastewater reuse are shown in Appendix R as Figures R-R-12, R-R-15, R-R-18, R-R-21, R-R-24, R-R-27, R-R-30, R-R-33, R-R-36, R-R-39, R-R-42, R-R-45, R-R-48, R-R-51, R-R-54, R-R-57, R-R-60, R-R-63, R-R-66, R-R-69, R-R-72, R-R-75, R-R-78, R-R-81, R-R-84, and R-R-87. The majority of the primary control points exhibit minimal effects from reuse scenarios on unappropriated flow. However, a few primary control points do show an impact either consistently over the study time period or only for a few years. The annual unappropriated flows for primary control points SF_WL (Figure R-R-15), WR_WF (Figure R-R-57), and WR_CH (Figure R-R-60) are consistently lower with 100% reuse. The maximum difference in unappropriated flow for SF_WL, WR_WF and WR_CH is 861 ac-ft/yr, 30,671 ac-ft/yr and 79,285 ac-ft/yr, respectively. Primary control point WR_CH is affected the most out of these control points with a maximum percent difference of approximately 16%. The annual unappropriated flows for primary control points SW_KT (Figure R-R-12) and BC_ET (Figure R-R-54) are noticeably lower with 100% reuse for only a few years of the study. The maximum difference in unappropriated flow for SW_KT and BC_ET is 2,726 ac-ft/yr and 6,091 ac-ft/yr, respectively. Primary control point SW_KT is affected the most with a maximum percent difference of approximately 42%. The remaining 20 primary control points show minimal effects on unappropriated flow from 100% reuse. Again, the differences between the reuse scenarios are typically minimal because there are few significant return flows in the Red River Basin.

Annual unappropriated flows in the Canadian River Basin using varying levels of wastewater reuse are shown in Figures R-C-6 and R-C-7, Appendix R. Primary control points CR_AM and CR_CN show minimal effects on unappropriated flows from reuse scenarios. Primary control point CR_AM shows no unappropriated flows since 1961 because Lake Meredith is using the remaining streamflow to fill storage.

5.2.1.3 Regulated Flows at Selected Locations

Annual regulated flows in the Red River Basin resulting from different levels of wastewater reuse are shown in Appendix R as Figures R-R-11, R-R-14, R-R-17, R-R-20, R-R-23, R-R-26, R-R-29, R-R-32, R-R-35, R-R-38, R-R-41, R-R-44, R-R-47, R-R-50, R-R-53, R-R-56, R-R-59, R-R-62, R-R-65, R-R-68, R-R-71, R-R-74, R-R-77, R-R-80, R-R-83, and R-R-86. The majority of the primary control points exhibit minimal effects from reuse scenarios on regulated flow. However, a few primary control points do show an impact either consistently over the study time period or only for a few years. The annual regulated flows for primary control points SF_WL (Figure R-R-14), WR_WF (Figure R-R-56), WR_CH (Figure R-R-59), and RR_TR (Figure R-R-71) are consistently lower with 100% reuse. The maximum difference in regulated flow for SF_WL, WR_WF, WR_CH, and RR_TR is 7,850 ac-ft/yr, 30,671 ac-ft/yr, 79,285ac-ft/yr and 63,459 ac-ft/yr, respectively. Primary control point SF_WL has the greatest difference with a maximum percent difference of approximately 33%. The annual regulated flow for primary control point WR_MB (Figure R-R-50) is lower with 100% reuse for only the years when the regulated flow decreases. The maximum difference in regulated flow for WR_MB is 12,017 ac-ft/yr and the maximum percent difference is 10%. The regulated flow for the remaining 20 primary control points show minimal effects due to 100% reuse. Again, the differences between the reuse scenarios are typically minimal because there are few significant return flows in the Red River Basin.

Annual regulated flows in the Canadian River Basin using varying levels of wastewater reuse are shown in Figures R-C-4 and R-C-5, Appendix R, for control points CR_AM and CR_CN. These control points show minimal effects on regulated flows from reuse scenarios.

5.2.2 Cancellation Scenarios

In the Red River Basin, there are 181 water rights with a total authorized diversion amount of approximately 572,367 ac-ft/yr modeled in the cancellation Scenarios 4 and 6. There is a difference of 40,047 ac-ft/yr between the diversion amounts used in Scenarios 4 (and 6) and Scenario 1. This difference represents the total amount of diversions that were cancelled because of no use in the last ten years. This amount represents only 7 percent of the total diversion amount. Therefore, the partial cancellation of these rights has minimal affect on the reliabilities. The total diversion amount modeled for Scenario 5 and 7 is approximately 224,003 ac-ft/yr. There is a difference of 388,411 ac-ft/yr between Scenarios 5 (and 7) and Scenarios 1. This amount represents the difference between the full authorized amount and the maximum ten years of use for all water rights. This amount is approximately 68 percent of the total authorized diversion amounts. Therefore, the impact of only allowing the water rights to divert the maximum use amount for the last ten years is substantial. Water rights that have been cancelled are shown in Table 18.

In the Canadian River Basin, approximately 153,612 ac-ft/yr was modeled as the total diversion in the cancellation Scenarios 4 and 6. The diversion amount for Scenario 5 and 7 is approximately 94,125 ac-ft/yr. There is a difference of 11,179 ac-ft/yr between Scenarios 4 (and 6) and Scenario 1. This difference represents the total amount of diversions that were cancelled because of no use in the last ten years. This amount represents only 7 percent of the total diversion amount. Therefore, the partial cancellation of these rights has minimal affect on the reliabilities in the Canadian River Basin. There is a difference of 70,666 ac-ft/yr between Scenarios 5 (and 7) and Scenarios 1. This amount represents the difference between the full-authorized amount and the maximum ten years of use for all water rights.

This amount is approximately 43 percent of the total authorized diversion amounts. Therefore, the impact of only allowing the water rights to divert the maximum use amount for the last ten years is substantial. Water rights in the Canadian River Basin that have been cancelled are shown in Table 18.

5.2.2.1 Specific Large Rights

The reliability of each water right in Scenarios 4, 5, 6 and 7 for the Red River Basin is shown in Appendix R, Table R-Red-2. In general, the reliabilities for Scenarios 4 and 6 are higher than those for Scenario 1 but are lower than those for Scenarios 5 and 7. As described earlier, partial cancellation of the water rights in runs 4 and 6 has minimal impact on the reliabilities of the water rights. However, the reliabilities are impacted in certain water rights in cancellation scenarios 5 and 7. For example, for municipal water right CA 4940, the reliability increases from 82.35 % to 100 % from Scenario 1 to 5. The increase in reliability is primarily caused by the decrease the in diversion amount from 23,885 ac/ft to 13,545 ac-ft from Scenario 1 to 5, respectively.

The reliability of each water right in Scenarios 4, 5, 6 and 7 is shown in Table R-Canadian-5. Reservoir storage, as well as unappropriated and regulated flows, for the cancellation scenarios are presented in Figures R-C-8 through R-C-21. The following discussion describes the effects of the cancellation scenarios on the three large reservoirs in the Canadian River Basin.

- Lake Rita Blanca – Figure R-C-8 illustrates that cancellation Scenario 4 is approximately the same as reuse Scenario 1. Both scenarios utilize full return flows and full authorized amounts. The only difference is 11,179 ac-ft/yr of cancelled water rights. This amount of cancellation does not change the reservoir storage between the two scenarios. Scenario 5 utilizes full return flows and the maximum use demand, a difference of 70,666 ac-ft/yr when compared to Scenario 1. The scenario does not change the reservoir storage during the critical period. There was no impact to Lake Rita Blanca because none of the cancelled water rights were located close to the reservoir. Scenario 6 is equivalent to Scenario 3 (no return flow), again the only difference between the scenarios is the 11,179 ac-ft of cancelled water rights. The reservoir storage in Scenario 1 (with return flows) is the same as in Scenario 6. Scenario 7 is similar to Scenario 5 with negligible change between Scenarios 1 and 7. Again, no impact from these cancellation scenarios indicates that the cancelled water rights were not located close to Lake Rita Blanca. Scenarios 6 and 7 are shown in Figure R-C-15.

- Lake Meredith – Scenarios 4 and 5 for the cancellation scenarios for Lake Meredith are illustrated in Figure R-C-9. The Scenario 4 diversion amount is 11,179 ac-ft/yr less than that of Scenario 1. This difference has a negligible effect on the reservoir storage. The Scenario 5 diversion amount is 70,666 ac-ft/yr less than that of Scenario 1. This difference has a drastic effect on the reservoir storage. The maximum change between Scenario 1 and Scenario 5 is in 1976 and is approximately 587,000 ac-ft (See Figure R-C-9). Scenario 6 and 7 are shown in Figure R-C-16. Scenario 6 illustrates that the return flows above Lake Meredith have little effect on the reservoir. Scenario 7 and Scenario 3 both have 100% reuse. The results of these two scenarios indicate that Lake Meredith storage is driven more by the cancellation of water rights to their maximum ten year historical use upstream than by return flow.

- Palo Duro Reservoir – Scenarios 4 and 5 are shown in Figure R-C-10 and Scenarios 6 and 7 in Figure R-C-17. Palo Duro Reservoir is driven more by the cancellation of water rights than by return flows in the Canadian River Basin. Scenarios 4, 5, 6, and 7 show substantially higher monthly storage values in all critical time periods. The scenarios are impacted substantially in 1963, with a maximum 47,000 ac-ft/yr. increase over Scenario 1.

In general water rights showed a slight increase in water supply reliability in Scenarios 4 and 6 versus Scenario 1, while there were substantial impacts in Scenarios 5 and 7. Generally, the reliabilities for the water rights increase as the allowed diversion amounts decrease in Scenario 5. The general increase would be due to the decrease in permitted amounts between the scenarios.

5.2.2.2 Unappropriated Flows at Selected Locations

The effect on annual unappropriated flows differed in all cancellation scenarios. The difference was from minimal to significant. The difference in magnitude is due to the varying levels of return flow, cancellation of water rights, and the maximum historical use being significantly less than the authorized diversion amount. As described in Section 5.2.2, reuse partial cancellation of the water rights in Scenarios 4 and 6 had minimal impact on reliabilities. The partial cancellation of these water rights also had minimal effect on the unappropriated flows because the amount of water rights cancelled was not significant (11,179 ac-ft). However, the unappropriated flows were significantly impacted by the cancellation of the water rights to the maximum historical use in Scenarios 5 and 7.

The effect on annual unappropriated flows also differed in the cancellation scenarios for the Canadian River Basin. The difference in magnitude is due to the varying levels of return flow, cancellation of water rights, and the maximum historical use being significantly less than the authorized diversion amount. Figures R-C-13, R-C-14, R-C-20, and R-C-21 illustrate the unappropriated flow at CR_AM and CR_CN for Scenarios 4 and 5, and 6 and 7, respectively. In general, maximum historical use of individual water rights had significant effect (as much as 250,000 ac-ft/yr) on unappropriated flows while reuse and cancellation of individual water rights had a negligible effect

5.2.2.3 Regulated Flows at Selected Locations

Annual regulated streamflow values for cancellation were similar to those in the unappropriated flows.

Annual regulated streamflow values for cancellation Scenarios 4 and 5 in the Canadian River Basin are illustrated in Figures R-C-11 through R-C-12, and Figures R-C-18 through R-C-19 for Scenarios 6 and 7. Maximum historical use, reuse, and cancellation of individual water rights had a negligible effect on annual regulated flows at control point CR_AM. At control point CR_CN, maximum historical use had the greatest impact (267,000 ac-ft/yr in 1960) on annual regulated flows.

5.2.3 Current Conditions Scenario

Scenario 8 is the current conditions scenario including maximum use demands, current reservoir capacities, term permits and full return flows. In Appendix R the Scenario 8 results for reservoir storage, regulated and unappropriated streamflow in the Red River Basin are shown as Figure R-R-1 through Figure R-R-87 and Figures R-C-22 through R-C-28 for the Canadian River Basin. In general, the results of Scenario 8 were similar to those results from Scenario 5 because of the minimal impact of term permits. However, some of the reservoir storage values were different due to the 2000 area-capacity relationships. These differences are described in Section 5.2.3.1 for certain reservoirs.

5.2.3.1 Specific Large Rights

Reliabilities for water rights in the Red River Basin for Scenario 8 are shown in Appendix R, Table R-Red-3. In general, since the maximum use in the last ten years is modeled in Scenario 8, the reliabilities are higher in Scenario 8 than in Scenario 1. There are significant differences in reservoir storage, regulated and unappropriated flows between reuse Scenario 1 and current conditions Scenario 8. The differences in reservoir storage for the selected reservoirs in the Red River Basin are shown in Figure R-R-1 through R-R-10. Again, the difference in storage between Scenarios 1 and 8 are from differing diversion amounts (full authorized amounts in Scenario 1 and maximum ten years of use for Scenario 8.

- Lake Greenbelt – The reservoir storage is presented in Appendix R, Figure R-R-1. As can be seen, there is a significant impact (approximately 56,000 ac-ft in 1960) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts. The reservoir storage appears to begin higher, but again this is caused by the minimal diversion amounts in Scenario 8.

- Mackenzie Lake - The reservoir storage is presented in Appendix R, Figure R-R-2. As can be seen, there is a significant impact (approximately 11,000 ac-ft in 1964) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts. The reservoir storage appears to begin higher, but again this is caused by the minimal diversion amounts in Scenario 8.

- Lake Kemp - The reservoir storage is presented in Appendix R, Figure R-R-3. As can be seen, there is a significant impact (approximately 230,000 ac-ft in 1975) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts.

- Lake Diversion - The reservoir storage is presented in Appendix R, Figure R-R-4. As can be seen, there is a significant impact (approximately 24,000 ac-ft in 1980) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts. The reservoir storage appears to begin higher, but again this is caused by the minimal diversion amounts in Scenario 8.

- Lake Arrowhead - The reservoir storage is presented in Appendix R, Figure R-R-5. As can be seen, there is a significant impact (approximately 20,000 ac-ft in 1957) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts. This reservoir was impact less throughout the period of record than the other reservoirs.

- Lake Nocona - The reservoir storage is presented in Appendix R, Figure R-R-6. Lake Nocona is not impacted by the cancellation of water rights. The only difference in reservoir storage capacities is the sedimentation of the reservoir. The sedimentation reduces the storage amount in the reservoir as shown in Figure R-R-6.

- Lake Texoma - The reservoir storage is presented in Appendix R, Figure R-R-7. Lake Texoma is also not impacted by the cancellation of water rights. The only difference in reservoir storage capacities is the sedimentation of the reservoir. The sedimentation reduces the storage amount in the reservoir as shown in Figure R-R-7.

- Pat Mayse Reservoir - The reservoir storage is presented in Appendix R, Figure R-R-8. As can be seen, there is a significant impact (approximately 120,000 ac-ft in 1961) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts. The reservoir storage appears to begin higher, but again this is caused by the minimal diversion amounts in Scenario 8.

- Lake Bonham - The reservoir storage is presented in Appendix R, Figure R-R-9. As can be seen, there is a significant impact (approximately 10,000 ac-ft in 1961) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts. The reservoir storage begins lower due to sedimentation.

- Lake Crook - The reservoir storage is presented in Appendix R, Figure R-R-10. As can be seen, there is a significant impact (approximately 10,000 ac-ft in 1979) to the reservoir storage between Scenarios 1 (and 3) from Scenario 8 caused by the differing diversion amounts. The reservoir storage appears to begin higher, but again this is caused by the minimal diversion amounts in Scenario 8.

There are significant differences in reservoir storage, unappropriated, and regulated flows between reuse Scenario 1 and current condition Scenario 8 for the Canadian River Basin. Differences in reservoir storage are shown in Figure R-C-22 through R-C-24.

- Lake Rita Blanca – Scenario 8 has maximum use demands, all return flows, and term permits. The reservoir capacity is the current condition. The increased amounts of diversions in Scenario 1 (maximum permitted amount) are indicated by the differences in magnitude during critical periods, as shown in Figure R-C-22.

- Lake Meredith –Scenario 8 is similar to Scenario 5, exceptions being that the reservoir capacity is the current condition and term permits are accounted for. Therefore, Scenario 8 has a maximum storage value lower than Scenario 1. The increased amounts of diversions in Scenario 1 (maximum permitted amount) are indicated by the differences in magnitude during critical periods, as shown in Figure R-C-23.

- Palo Duro Reservoir – Again, Scenario 8 has maximum use demands, all return flows, and term permits. The reservoir capacity is the current condition. The increased amounts of diversions in Scenario 1 (maximum permitted amount) are indicated by the differences in magnitude during critical periods, as shown in Figure R-C-24.

5.2.3.2 Unappropriated Flows at Selected Locations

Annual unappropriated flows for the control points are shown in Figures R-R-12, R-R-15, R-R-18, R-R-21, R-R-24, R-R-27, R-R-30, R-R-33, R-R-36, R-R-39, R-R-42, R-R-45, R-R-48, R-R-51, R-R-54, R-R-57, R-R-60, R-R-63, R-R-66, R-R-69, R-R-72, R-R-75, R-R-78, R-R-81, R-R-84, and R-R-87. As can be seen in these figures, the unappropriated flow varies depending on the control point. In general, there is minimal impact in unappropriated flow between Scenarios 1 and 8. However, at the control points represented by Figures R-R-36, R-R-39, R-R-45, R-R-48 and R-R-51 there is significant difference in the unappropriated flows. Primarily, the difference is from no unappropriated flows in Scenario 1 and some amount of unappropriated flow in Scenario 8. Again, the magnitude of the unappropriated flows is caused by the difference in diversion between Scenario 1 and 8. Diversions are based on maximum use and therefore are significantly less than the full authorized amount in Scenario 1.

Annual unappropriated flows in the Canadian River Basin for control points CR_AM and CR_CN were larger in Scenario 8 than in Scenario 1 during critical periods, as shown in Figures R-C-27 and R-C-28. This increase in streamflow is a direct result of the reduced amount of water being diverted under Scenario 8. Actual diversions are significantly less in Scenario 8 than the authorized diversions of the water rights in Scenario 1.

Comparisons of annual unappropriated flows for Scenarios 1, 3, and 8 at control points A10000, B10000, D10000, and E10000 are shown in Figures R-C-33 through R-C-36. Annual unappropriated flows at each control point show no differences in flow from Scenario 3 to Scenario 1. At control points A10000, B10000, and D10000, annual unappropriated flows were larger in Scenario 8 than in Scenarios 1 and 3. This increase in streamflow is a direct result of the reduced amount of water being diverted under Scenario 8. At control point E10000 there are no differences in unappropriated flow amounts between the various scenarios. Actual diversions are significantly less in Scenario 8 than the authorized diversions of the water rights in Scenarios 1 and 3.

5.2.3.3 Regulated Flows at Selected Locations

Regulated streamflow values are shown in Figures R-R-11, R-R-14, R-R-17, R-R-20, R-R-23, R-R-26, R-R-29, R-R-32, R-R-35, R-R-38, R-R-41, R-R-44, R-R-47, R-R-50, R-R-53, R-R-56, R-R-59, R-R-62, R-R-65, R-R-68, R-R-71, R-R-74, R-R-77, R-R-80, R-R-83, and R-R-86. In most control points the regulated flow are similar in Scenarios 1 and 8. However, the regulate flows shown in Figures R-R-41 and R-R-50 lower in Scenario 8 and in Scenario 1. The remaining results of the regulated flows are similar to those described in the previous section.

Annual regulated flows for CR_AM in the Canadian River Basin were only slightly larger in Scenario 8 than in Scenario 1, as shown in Figure R-C-25. For CR_CN, the annual regulated flows were larger during the critical period in Scenario 8 than in Scenario 1. This increase in streamflow is a direct result of the amount of water being diverted under Scenario 8. Actual diversions are significantly less in Scenario 8 than the authorized diversions of the water rights in Scenario 1.

Comparisons of annual regulated flows for Scenarios 1, 3, and 8 at control points A10000, B10000, D10000, and E10000 are shown in Figures R-C-29 through R-C-32. Annual regulated flows at each control point show no differences in flow from Scenario 3 to Scenario 1. At control points A10000, D10000, and E10000, annual regulated flows were similar in Scenarios 1, 3, and 8. At control point B10000 annual regulated flows were larger in Scenario 8 than in Scenarios 1 and 3. This increase in streamflow is a direct result of the reduced amount of water being diverted under Scenario 8. Actual diversions are significantly less in Scenario 8 than the authorized diversions of the water rights in Scenarios 1 and 3.

5.2.4 Firm Yield Scenario

The firm yield run (Scenario 9) is a basin specific scenario to identify the yield of any reservoir that goes dry under authorized diversions. The firm yield analysis was performed using Scenario 3 (full authorized diversions, no return flows). If the reservoir did not go dry during Scenario 3 then the firm yield of the reservoir is simply the diversion amount used in Scenario 3 and is the “permitted firm yield”. If the reservoir did have a value of zero during any one month of the simulation then the diversion amount was adjusted. Diversions from each reservoir were made such that the remaining volume left in storage was within one percent of the total original storage capacity. Diversions were adjusted up or down, maintaining the existing seasonal use patterns and existing priority dates until the reservoir went dry. The firm yields were developed using only the drainage area of the reservoirs; no additional water was added to any reservoir from water supply contracts. The results from the firm yield analyses are shown in Table 19.

Table 19 Red and Canadian River Basin Firm Yield Results

Reservoir / System	Permitted Diversion (ac-ft/yr)	Firm Yield (ac-ft/yr)
Red River Basin		
Lake Nocona	1,080	1,080
Hubert H. Moss Lake	4,500	4,500
Valley Lake	10,000	1,000
Randall Lake	29,680	1,100
Coffee Mill Lake	0	Recreational[1]
Lake Bonham	5,340	3,250
Pat Mayse	61,610	29,000
Lake Crook	12,000	7,500
Truscott Brine	0	No Use
Lake Kemp	0	Recreational[1]
Lake Diversion	145,340	38,750
Santa Rosa Lake	3,000	3,000
Lake Electra	600	450
North Fork Buffalo Creek	840	840
Lake Kickapoo	40,000	18,500
Lake Arrowhead	25,000	17,500
Bivins	0	No Use
Buffalo Lake	0	Recreational[1]
Mackenzie	5,200	4,100
Baylor Creek	397	150
Greenbelt	12,000	5,000
Cibola National Forest	0	Recreational[1]
Lake Wichita	31,000	0
Lake Texoma	116,528	116,528
Canadian River Basin		
Palo Duro	10,460	4,000
Lake Rita Blanca	0	Recreational[1]
Lake Meredith	894,889[2]	107,000

[1]Recreational means that there are no authorized diversions from the reservoir
[2]Total permitted diversion 904,000 acre-feet, 9,111 acre-feet was subtracted for the Red River Compact Restrictions

Red River Basin

- Lake Bivins - The firm yield of Lake Bivins was not analyzed because there is no diversion from the reservoir. Firm yields for all reservoirs in the Red River Basin are shown in Table 19. No previous firm yields have been developed for Lake Bivins (See Appendix F).

- Buffalo Lake – The firm yield of Buffalo Lake was not analyzed because there is no diversion from the reservoir. The reservoir is used for recreational purposes and therefore has no diversion amount. No previous firm yields have been developed for Rita Blanca Lake (See Appendix F).

- Mackenzie Lake - The annual diversion from Mackenzie Lake is 5,200 ac-ft and the firm yield calculated in this study was 4,100 ac-ft/yr. There were no previous firm yield calculations found for this reservoir (See Appendix F).

- Baylor Creek Reservoir - The annual diversion from Baylor Creek Reservoir is 397 ac-ft and the firm yield calculated in this study was 150 ac-ft/yr. There were no previous firm yield calculations found for this reservoir (See Appendix F).

- Greenbelt Reservoir - The firm yield of Greenbelt Reservoir was calculated to be 5,000 ac-ft/yr in this study. Previous studies have estimated the firm yield to be 7,699 ac-ft/yr (See Appendix F). The firm yield calculated in this study was expected to be lower in this study because all senior water rights were taken before Greenbelt Reservoir was allowed to fill.

- Truscott Brine Lake – Truscott Brine Lake is utilized as an evaporation lake to reduce salt levels in the Red River. The firm yield of Truscott Brine Lake was not analyzed because there is no diversion from the reservoir. No previous firm yields have been developed for Truscott Brine Lake (See Appendix F).

- Lake Wichita - The firm yield of Lake Wichita was calculated to be 0 ac-ft/yr in this study. There are no previous studies for the estimation the firm yield because the lake is silted and is useful only as a recreational and flood detention facility (See Appendix F).

- Lake Kemp – No diversions were modeled from Lake Kemp so no firm yield was calculated. All diversions were modeled downstream of Lake Kemp backed by storage from Lake Kemp.

- Lake Diversion – The firm yield of Lake Diversion was calculated to be 38,750 ac-ft/yr. In previous studies, the 2050 firm yield of the Lake Diversion and Lake Kemp system has been estimated to be 101,540 ac-ft/yr (See Appendix F). These reservoirs were analyzed separately in the firm yield calculations in this report.

- Santa Rosa Lake – The "permitted firm yield" of Santa Rosa Lake is 3,000 ac-ft/yr. This is the amount of diversion that is authorized to be withdrawn from Santa Rosa Lake. No previous firm yields have been developed for Santa Rosa Lake (See Appendix F).

- North Fork Buffalo Creek Reservoir - The “permitted firm yield” of North Fork Buffalo Creek Reservoir is 840 ac-ft/yr. This is the amount of diversion that is authorized to be withdrawn from North Fork Buffalo Creek Reservoir. No previous firm yields have been developed for North Fork Buffalo Creek Reservoir (See Appendix F).

- Lake Kickapoo - The firm yield of Lake Kickapoo was calculated to be 18,500 ac-ft/yr. In previous studies, projected firm yields for Lake Kickapoo in the years 2000 and 2050 are 15,945ac-ft/yr and 15,343 ac-ft/yr, respectively (See Appendix F).

- Lake Arrowhead – The firm yield of Lake Arrowhead was calculated to be 17,500 ac-ft/yr. There are no available firm yield studies for Lake Arrowhead (See Appendix F).

- Lake Electra – The firm yield of Lake Electra was calculated to be 450 ac-ft/yr. Previous studies indicate a firm yield of 460 ac-ft/yr (See Appendix F).

- Coffee Mill Lake – The firm yield of Coffee Mill Lake was not analyzed in this study because there is no diversion from the reservoir. The reservoir is used for recreational purposes and therefore has no diversion amount. No previous firm yield studies have been developed for Coffee Mill Lake (See Appendix F).

- Lake Nocona - The “permitted firm yield” of Lake Nocona is 1,080 ac-ft/yr. This is the amount of diversion that is authorized to be withdrawn from Lake Nocona. Previous studies indicate a firm yield of 1,260 ac-ft/yr (See Appendix F).

- Moss Lake - The “permitted firm yield” of Moss Lake is 4,500 ac-ft/yr. This is the amount of diversion that is authorized to be withdrawn from Moss Lake. Previous studies also indicate a firm yield of 4,500 ac-ft/yr (See Appendix F).

- Valley Lake – The firm yield of Valley Lake was calculated to be 1,000 ac-ft/yr. Valley Lake is a cooling pond for the Valley Creek Generating Plant and receives makeup water from Lake Texoma. The firm yield calculated in this study was based soley on the drainage area of the reservoir and not additional water received from Lake Texoma. There are no previous firm yield studies available for Valley Lake (See Appendix F).

- Randall Lake – The firm yield of Randall Lake was calculated to be 1,100 ac-ft/yr. Randall Lake is supplemented by water from Lake Texoma. The firm yield calculated in this study was based soley on the drainage area of Randall

Lake and did not include supplemental water from Lake Texoma. There are no previous firm yield studies available for Randall Lake (See Appendix F).

- Lake Bonham - The firm yield of Lake Bonham was calculated to be 3,250 ac-ft/yr. No previous firm yield studies are available for Lake Bonham; however, the current estimate of the quantity of water available for diversion is 7,840 ac-ft/yr (See Appendix F).

- Lake Crook – The firm yield of Lake Crook was calculated to be 7,500 ac-ft/yr. Lake Crook has a previous firm yield estimate of 1,000 ac-ft/yr (See Appendix F).

- Pat Mayse Lake - The firm yield of Pat Mayse Lake was calculated to be 29,000 ac-ft/yr. The previous firm yield estimate for Pat Mayse Lake is 59,000 (See Appendix F).

- Lake Texoma - The "permitted firm yield" of Lake Texoma is 116,528 ac-ft/yr. This is the amount of diversion that is authorized to be withdrawn from Lake Texoma. Previous studies indicate a firm yield of 168,000 ac-ft/yr (See Appendix F).

Canadian River Basin

- Rita Blanca Lake- The firm yield of Rita Blanca Lake was not analyzed because there is no diversion from the reservoir. The reservoir is used for recreational purposes and therefore has no diversion amount. Firm yields for all reservoirs in the Canadian River Basin are shown in Table 19. No previous firm yields have been developed for Rita Blanca Lake (See Appendix F).

- Lake Palo Duro – The firm yield of Lake Palo Duro was calculated to be 4,000 ac-ft/yr in this study. As shown in Appendix F, there have been two previous firm yields calculated of 8,700 ac-ft/yr and 6,543 ac-ft/yr. The firm yield calculated in this study was expected to be lower because it takes into account all water rights downstream that have a senior priority date.

- Lake Meredith – The firm yield of Lake Meredith was calculated to be 107,000 ac-ft/yr in this study. Previous studies have estimated the firm yield to be 76,000 ac-ft/yr (See Appendix F). The firm yield calculated in this study was larger because all water rights and reservoir storage upstream of Lake Meredith with a junior priority date were required to release inflow to fill Lake Meredith. The difference in firm yield could also be attributed to the full authorized capacity of the reservoir (1,407,572 ac-ft) being modeled in this study.

5.3 Comparison to Existing River Basin Model

No other water availability models have been created for either the Red or Canadian River Basins.

5.4 Factors Affecting Water Availability and Modeling Results

There are several factors that affect the water availability modeling. One of the most important issues with regard to the water availability analyses performed for the Red and Canadian Basins and the results from the WRAP model relates to naturalized streamflow development.

- Distribution of naturalized flows can also affect the results of the modeling process. The TNRCC has required that the calculated naturalized streamflow be distributed based only on the drainage areas. Curve numbers and mean annual precipitation were also generated by the TNRCC and may need to be incorporated in the distribution method. These watershed parameters are developed by the CRWR at the University of Texas and have a direct effect on the results of the WAM model. The accuracy of the drainage areas derived using GIS procedures must be manually checked and verified. For this study, refined digital elevation data (30 meter-square cells) were used to create the drainage areas. With regard to NRCS curve numbers assigned to the watersheds of individual control points in the model, the small watersheds may only have enough area to cover one curve number type. Therefore, it is extremely important to verify the correct curve number is being used for these areas.
- Modeling of the Red and Canadian River Compacts (curtailment of certain water rights depending on compact requirements).
- Input of historical inflows from Oklahoma into the Red River to allow those water rights on the Red River in Texas to have access to that flow.
- Modeling 404,000 ac-ft of dead and silt storage in Lake Meredith (Canadian River Basin) and the impact on water rights upstream.
- Filling of downstream reservoirs with senior water rights take precedence over diversion by upstream junior water rights. The firm yield analysis of this study maximizes the amount of diversions that could be made from the reservoir under their respective priority dates up to the authorized diversion amount. Watershed parameters used in this study to distribute naturalized flows between control points were received from the TNRCC are assumed to be correct.
- Reservoirs less than 5,000 ac-ft are modeled using a regression relationship to relate reservoir storage to surface area (described in Section 3.4.2).
- The model uses a monthly time step. Therefore, this type of analysis does not account for travel times between control points or flow requirements that depend on instantaneous flows, such as instream flow requirements.
- In general, the amounts of appropriated water covered by existing rights are

determined by the permitted diversion for each water right and are not based on firm yields, geographical location, or other practical limits. Thus, the remaining unappropriated water at any point in the basin is based on the assumption that all rights are taking their full paper values of diversions whenever that much water is available.

- For water rights with off-channel storage, WRAP limits the streamflow depletions, which are made to meet diversions and refill storage on a monthly and annual basis.

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

The model can be re-run with any standard computer equipment. Issues that might be evaluated in the future include the use of curve number and precipitation in the distribution process for naturalized streamflows.

6.0 SUMMARY AND CONCLUSIONS

The Texas A&M WRAP model (DECEMBER, 2001) has been applied to the Red and Canadian River Basins in Texas to determine the water availability. All of the 271 water rights in the Red River Basin and 37 water rights in the Canadian River Basin were included in the model. Water availability was calculated in three basic scenarios: (1) Reuse (full authorized diversions with varying return flow amounts), (2) Cancellation (varying diversion and return flow amounts based on cancellation of water rights), and (3) Current Conditions (maximum use diversions with return flows using year-2000 area-capacity reservoir relationships. All scenarios utilized:

- 51-year period of naturalized flows (1948 thought 1998).
- Water rights information for all water rights issued by the TNRCC through February 1999.

The WR, WS and OR records in WRAP (DECEMBER, 2001) characterize the written permit and other pertinent information required for input into the computer model. No system operations were modeled unless authorized in the written permit. Nine scenarios were performed; eight base scenarios and one basin specific scenario (firm yield). Primary conclusions of this water availability study are presented in general terms because of the estimated drainage areas. Specific conclusions and recommendations will be included in the final report once the final watershed parameters are received. The primary conclusions for the Red and Canadian River Basins include:

- The Red River Basin, located in northern Texas, drains an area of approximately 94,450 sq mi, of which 73,671 sq mi lie within Texas. There are a total of 271 water rights with approximately 642,933 ac-ft/yr authorized annual diversions.

- The Canadian River Basin, located in northern Texas, drains an area of approximately 22,866 sq mi, of which 12,700 sq mi lie within Texas. There are a total of 37 water rights with approximately 153,807 ac-ft/yr authorized annual diversions.

- Comparisons of the three reuse scenarios show that in general reuse has a minimal impact on the water supply in both the Red and Canadian River Basins. In the Red River Basin there few large wastewater discharge facilities that contribute substantial percentages to the streamflow in the river. Likewise, in the Canadian River Basin, there are few discharge facilities and the arid climate and groundwater interactions generally minimize any wastewater return flows. However, when small impacts did occur, the reliability of a water right generally decreases as the level of reuse increases.

- Hypothetical partial cancellation of water rights based on maximum ten years historical use (Scenario 4 and 6) had minimal impact in both the Red and Canadian River Basins. However, scenarios that utilize the ten-year maximum use as the diversion amount, Scenarios 5, 7, and 8, can significantly affect the amount of reservoir storage, unappropriated and regulated flow because the actual historical diversions during the last ten years were substantially less than the fully appropriated amounts. The diversion amount used in these scenarios (Scenarios 5, 7, and 8) was 388,411 ac-ft/yr and 70,666 ac-ft ac-ft/yr less than the demand in Scenarios 1 for the Red and Canadian River Basins, respectively. This difference represents 68% and 43% of diversion amount in Scenario 1 for the Red and Canadian River Basins, respectively. Scenarios 5 and 7 had a greater impact on the water availability (when compared to Scenario 1) than the cancellation scenarios with full-authorized amounts (Scenarios 4 and 6).

- Although there were 24 major reservoirs in the Red River Basin that were included in the firm yield analysis, only Moss Lake, Lake Texoma and Santa Rose Lake met their diversion targets during the critical period. Therefore, these three reservoirs have “permitted firm yields” equal to their authorized diversion amounts. The majority of the reservoirs in the Red River Basin had significantly lower firm yields than previous studies. Firm yields calculated in this study were expected to be lower than those calculated in previous studies because this study allowed releases of inflow from upstream reservoirs that had a junior priority date. The Canadian River Basin has three major reservoirs and none of those reservoirs met their authorized diversion amount. References to previous studies can be viewed in Appendix F. Appendix F does not contain information or comparisons of firm yield data.

- Reliabilities of the water rights located on the Red River were generally higher because of the contributing flow from Oklahoma. Flows entering the Red River from Oklahoma were modeled based on the historical streamflows.

- The Red River Compact was modeled to curtail diversions of water rights based on flow requirements outlined in the Compact. In general the flow at the Arkansas-Louisiana State border was sufficient and most of these rights were not cu

Reliabilities determined in this study are dependant on the estimated watershed parameters in the Red and Canadian River Basin.

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