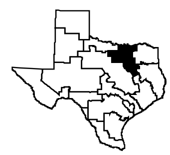
Region C Water Plan

January 2001

Prepared for
Region C Water Planning Group



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Region C Water Plan

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REGION C WATER PLAN

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EXECUTIVE SUMMARY

REGION C WATER PLAN

January 2001

Executive Summary

This report presents the Senate Bill One regional water plan developed in the year 2000 for Region C. Region C covers all or part of 16 counties in North Central Texas, as shown in Figure ES-1.

The Region C water plan was developed under the direction of the 19-member Region C Water Planning Group. The planning process included the following steps, which are presented in this executive summary and described in greater detail in the main report and the appendices:

- Description of Region C
- Population and Water Demand Projections
- Analysis of Water Supply Currently Available to Region C
- Comparison of Water Supply and Projected Water Demand
- Evaluation and Selection of Water Management Strategies
- Regulatory, Administrative, Legislative, and Other Recommendations
- Plan Approval Process and Public Participation

ES-1 Description of Region C

As of 1998, the estimated population of Region C was 4,779,210 - 24.4 percent of Texas' total population. The two most populous counties in Region C, Dallas and Tarrant, have 70.6 percent of the region's population. There are 38 cities in Region C with an estimated 1998 population of more than 20,000. These cities include 80.5 percent of the 1998 population of the region.

Economic Activity in Region C

Region C includes most of the Dallas and Fort Worth-Arlington metropolitan statistical areas, which have experienced strong economic growth in the 1990s. Payroll and employment in

Region C are concentrated in the central urban counties of Dallas and Tarrant. The largest business sectors in Region C in terms of payroll are services and manufacturing.

Water-Related Physical Features in Region C

Most of Region C is in the upper portion of the Trinity Basin, with smaller parts in the Red, Brazos, Sulphur, and Sabine Basins. Figure ES-1 shows the major streams in Region C. Precipitation increases west to east in Region C from slightly more than 30 inches per year in western Jack County to more than 44 inches per year in the northeast corner of Fannin County. The average annual runoff in the region also increases from the west to the east. Evaporation is higher in the western part of Region C. The patterns of rainfall, runoff, and evaporation result in more abundant water supplies in the eastern part of Region C than in the west.

There are 34 reservoirs in Region C with conservation storage over 5,000 acre-feet, all of which are shown in Figure ES-1. These reservoirs and others outside of Region C provide most of the region's water supply. Reservoirs are necessary to provide a reliable surface water supply in this part of the state because of the wide variations in natural streamflow. Reservoir storage serves to capture high flows when they are available and save them for use during times of normal or low flow.

The Trinity aquifer supplies most of the groundwater used in Region C. Other aquifers in the region include the Carrizo-Wilcox, the Woodbine, the Nacatoch, and the Queen City.

Current Water Uses and Demand Centers in Region C

Water use in Region C has increased significantly since 1980, primarily in response to increasing population and municipal demand. The historical record shows years of high use, including 1988, 1996, and 1998. High use years are associated with dry weather, which causes higher municipal demands due to increased outdoor water use. It is interesting to note that Region C, with 24.4 percent of Texas' population, had only 7.2 percent of the state's water use in 1997. This is primarily because Region C has very limited water use for irrigation. About 85 percent of the current water use in Region C is for municipal supply, followed by manufacturing use as the second largest category, then by steam electric power generation. Irrigation, mining, and livestock are relatively minor uses of water in Region C.

Current Sources of Water Supply

Total water use in Region C has increased significantly since 1980, but groundwater use has actually decreased in that period. Since 1990, over 90 percent of the water use in Region C has been supplied by surface water, but groundwater is still an important source of supply, especially in some rural areas. Most of the surface water supply in Region C comes from major reservoirs. Another significant water source for Region C is surface water imported from other regions. The Trinity aquifer is by far the largest source of groundwater in Region C, with the Woodbine, Carrizo-Wilcox and other minor aquifers also used. Current use of groundwater exceeds the reliable long-term supply available in many parts of Region C.

Over half of the water used for municipal supply in Region C is discharged as treated effluent from wastewater treatment plants, making wastewater reclamation and reuse a potentially significant source of additional water supply for the region. At present, only a fraction of the region's treated wastewater is actually reclaimed and reused in the region. Many of the region's water suppliers are considering reuse projects, and it is clear that reuse of treated wastewater will be a significant part of future water planning for Region C.

Water Providers in Region C

Water providers in Region C include regional wholesale suppliers (river authorities and water districts) and retail suppliers (cities and towns, water supply corporations, special utility districts, and private water companies). Cities and towns provide most of the retail water service in Region C. Table ES-1 shows some basic data on sales to others by the five major water providers in Region C, which are the only water suppliers in the region with over 20,000 acre-feet per year in wholesale sales.

Agricultural and Natural Resources in Region C

Agricultural and natural resources in Region C are dependent on the region's water resources. Wetlands often rely on water from streams and reservoirs. Wetlands provide food and habitat for fish and wildlife, water quality improvement, flood protection, shoreline erosion control, and groundwater exchange, in addition to opportunities for human recreation, education, and research. Threatened or endangered species can depend on habitat associated with rivers and streams. The Texas Parks and Wildlife Department has identified several Region C stream segments as having significant natural resources based on their high water quality, exceptional

Table ES-1
Major Water Providers in Region C

Major Water Provider	1997 Wholesale Sales (Acre-Feet)			Number of Wholesale Customers		
	Raw	Treated	Total	Cities	Water Suppliers	Others
Tarrant Regional WD	258,448	0	258,448	12	11	16
North Texas MWD	0	168,247	168,247	23	14	1
Dallas	13,324	148,281	161,605	17	4	2
Fort Worth	427	39,521	39,948	28	2	4
Trinity River Authority	15,220	22,217	37,437	8	2	1

aquatic life, high aesthetic value, fisheries, spawning areas, unique state holdings, endangered or threatened species, priority bottomland hardwood habitat, wetlands, springs, and pristine areas.

Region C includes almost 6,000,000 acres in farms and over 2,500,000 acres of cropland. Less than 1 percent of the cropland in Region C is irrigated, but there are localized areas of irrigation. The market value of agriculture products is significant in all Region C counties, with a total value for 1997 of almost $500,000,000. For the region as a whole, the market value of livestock is almost twice that of crops. There are large areas classified as prime farmland by the Natural Resources Conservation Service in Cooke, Denton, Collin, Tarrant, Dallas, and Ellis Counties.

Oil and natural gas fields are significant natural resources in portions of Region C. There is a high density of oil wells in Jack, Wise, Cooke, and Grayson Counties, with a lesser density in Denton, Parker, Navarro, Henderson, and Kaufman Counties. There is a high density of producing natural gas wells in Freestone, Parker, Jack, and Wise Counties, with a lesser density in Navarro, Henderson, Denton, Cooke, and Grayson Counties.

There are some lignite coal resources in Region C. The most significant current lignite production in Region C is in Freestone County to supply TXU Electric's Big Brown Steam Electric Station on Lake Fairfield.

Summary of Threats and Constraints to Water Supply in Region C

The most significant potential threats to existing water supplies in Region C are surface water quality concerns, groundwater drawdown, and groundwater quality. Constraints on the development of new supplies include the availability of sites and unappropriated water for new water supply reservoirs and the challenges imposed by environmental concerns and permitting.

Most of the water suppliers in Region C will have to develop additional supplies before 2050. The major water suppliers have supplies well in excess of current needs, but they will require additional water to meet projected growth. Some smaller water suppliers face a more urgent need for water.

Surface water quality concerns that might affect Region C water supplies include the following:

- Detection of atrazine at low levels in some water supply reservoirs
- Nutrient levels in water supply reservoirs
- Total organic carbon (TOC) levels in source waters
- Elevated levels of dissolved solids in some reservoirs and stream reaches
- Trace levels of arsenic in some waters.

In general, these concerns can be addressed by standard water treatment methods and do not pose a significant threat to water supplies in the region.

Drawdown of aquifers poses a threat to small water suppliers and to household water use in rural areas. As water levels decline, the cost of pumping water grows and water quality generally suffers. Water level declines have been reported in localized areas in each of the aquifers in Region C. In particular, the region-wide pumping from the Trinity and Nacatoch aquifers is estimated to be greater than the recharge. Concern about groundwater drawdown is likely to prevent any substantial increase in groundwater use in Region C and may require conversion to surface water in some areas.

Groundwater quality in Region C aquifers is generally acceptable for most municipal and industrial purposes. However, natural concentrations of arsenic, fluoride, nitrate, chloride, iron, manganese, sulfate, and total dissolved solids in excess of either primary or secondary drinking water standards occur in some areas.

Water-Related Threats to Agricultural and Natural Resources in Region C

Water-related threats to agricultural and natural resources in Region C include changes to natural flow conditions, water quality concerns, and inundation of land due to reservoir development. In general, there are few significant water-related threats to agricultural resources in Region C due to the limited use of water for agricultural purposes. Water-related threats to natural resources are more significant.

ES-2 Population and Water Demand Projections

Methodology for Projections of Population and Water Demand

The Texas Water Development Board's Senate Bill One planning guidelines require the use of TWDB's population and water demand projections from the 1997 *Texas Water Plan* unless revisions are approved by TWDB based on changed conditions or new information. The TWDB projects water demand separately for municipal, manufacturing, steam electric power generation, mining, irrigation, and livestock uses. Municipal demand is developed for each community with a population of over 500 and includes commercial, institutional, and residential water uses but does not include manufacturing use. A "county other" group for each county covers municipal use in rural areas and communities with less than 500 people. All demand categories except municipal are developed on a countywide basis.

To develop the population and water demand projections for Region C, the Region C water planning group went through the following steps:

- Assembled historical data and previous TWDB projections and developed tables and figures that could be reviewed by counties, cities, water suppliers, industries, and other interested entities.
- Sent the TWDB data and a questionnaire to all Region C counties, cities with a population over 1,000, regional water suppliers, retail water suppliers (supplying over 0.2 mgd), and large industries.
- Gathered population data from the State Data Center and the North Central Texas Council of Governments.
- Reviewed the previous TWDB population projections for each county and recommended changes to projections where current populations deviate significantly from the previous projections.
- Adjusted city population projections based on historical trends and knowledge of expected future development using the county population projections as controls.

- Compared TWDB's projections of per capita municipal water demand from the 1997 *Texas Water Plan* with actual per capita water demand in the 1990s from TWDB data.
- Developed data on 1998 per capita water use for Region C water providers.
- Adjusted previous TWDB projections in per capita water demand to reflect actual use in the 1990s, trends in water use, water conservation, reasonable minimum demands for water, knowledge of future development that might affect per capita needs, and other factors.
- Developed tables and graphs for each city in the region to assist in the review of the recommended projections.
- Revised projections of water demand for steam electric power generation based on input from TXU Electric.
- Checked previous TWDB projections for manufacturing, mining, irrigation, and livestock use and left them unchanged after comparison with recent historical data.
- Formed a Technical Review Committee consisting of experienced water resource planners to review the recommendations of the consultants on population and water use and report to the planning group.
- Held a public meeting to receive input on the water demand projections.
- Made a number of additional changes as a result of TWDB review and input.
- Submitted the revised projections to the TWDB board, which approved the revised projections in December of 1999.

Population Projections

Table ES-2 presents the adopted population projections by county for Region C. Figure ES-2 shows the historical and projected population for the region. All counties are projected to increase in population between now and 2050, and the projected 2050 population for Region C is 9,481,157. Once the county population projections were completed, city population projections were adjusted based on historical trends and knowledge of expected future development. The county populations served as controls in this process, and all population not assigned to a particular city was included as county other.

Water Demand Projections

Table ES-3 shows the adopted water demand projections for Region C by county. Table ES-4 and Figure ES-3 show the projected water demand for the region by type of use. The projected 2050 water demand for Region C is 2,536,902 acre-feet per year, which is more than double the 1996 use in the region. Most of the change from previous TWDB projections is in municipal

Table ES-2
Adopted County Population Projections for Region C

County	Historical 1996	2000	2010	2020	2030	2040	2050
Collin	373,095	443,000	635,455	923,309	1,150,001	1,351,000	1,501,395
Cooke	33,196	34,209	36,967	38,816	40,000	41,250	42,500
Dallas	1,999,926	2,104,858	2,326,828	2,556,793	2,784,704	3,045,931	3,259,995
Denton	349,566	423,327	591,350	802,461	1,033,731	1,200,000	1,349,999
Ellis	94,097	103,070	123,854	144,054	162,273	175,403	185,364
Fannin	27,435	30,000	33,601	37,000	39,501	40,499	41,001
Freestone	17,757	18,167	18,800	19,300	19,600	20,000	20,300
Grayson	100,611	106,119	110,226	114,702	117,865	120,981	122,000
Henderson (Partial)	45,761	46,562	51,261	55,515	57,704	58,690	60,476
Jack	7,435	7,819	8,139	8,591	8,934	9,175	9,353
Kaufman	61,646	68,368	87,106	108,291	129,359	147,108	162,417
Navarro	42,875	45,191	49,207	53,031	57,015	59,200	61,000
Parker	73,897	80,436	99,095	118,287	139,094	156,023	171,216
Rockwall	34,287	41,175	61,392	88,136	122,000	160,588	203,529
Tarrant	1,306,457	1,415,759	1,594,218	1,798,894	1,915,375	2,111,193	2,205,610
Wise	41,019	44,800	54,674	64,363	73,641	81,000	85,002
Region C Total	4,609,060	5,012,860	5,882,173	6,931,543	7,850,797	8,778,041	9,481,157

demands, with a smaller change in steam electric power demands. No changes were made to TWDB's previous projections for manufacturing, mining, irrigation, or livestock demands.

One of the most important reasons for the increase in projected per capita demand for Region C is the high water use recorded for many Region C water suppliers in 1996 and 1998. This high water use occurred despite significant water conservation efforts in the region and despite the impact of low flow plumbing fixtures. There are several factors that tend to increase per capita municipal water use in the region:

- In many communities, new development is large houses with large lots, sprinkler systems, swimming pools, and other water-using amenities.
- The number of people per household is decreasing in most of Region C. This tends to cause an increase in per capita use because household uses are spread over fewer people.
- Many Region C communities are experiencing rapid commercial development, which increases per capita water use.

Figure ES-2
Historical and Projected Population for Region C

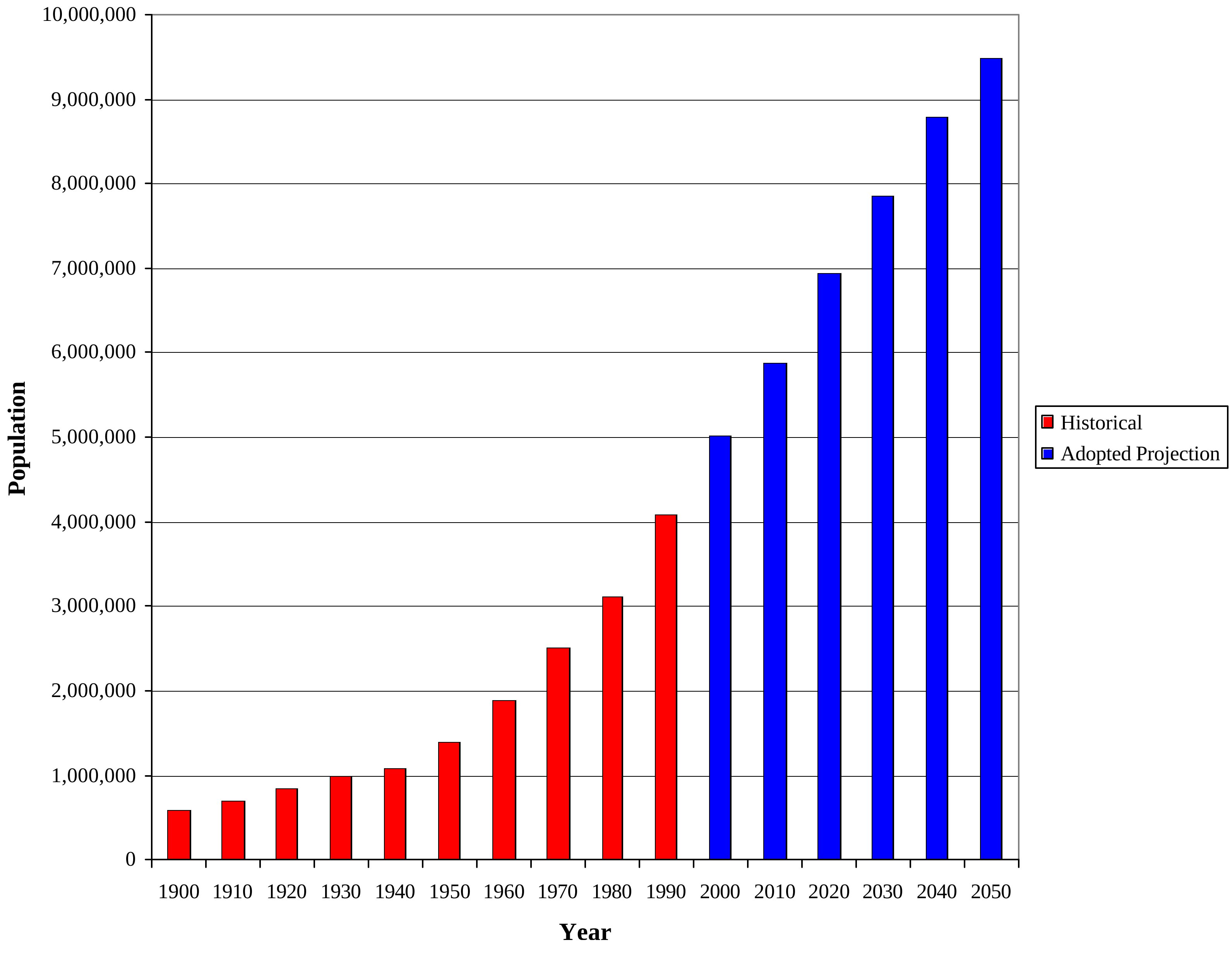


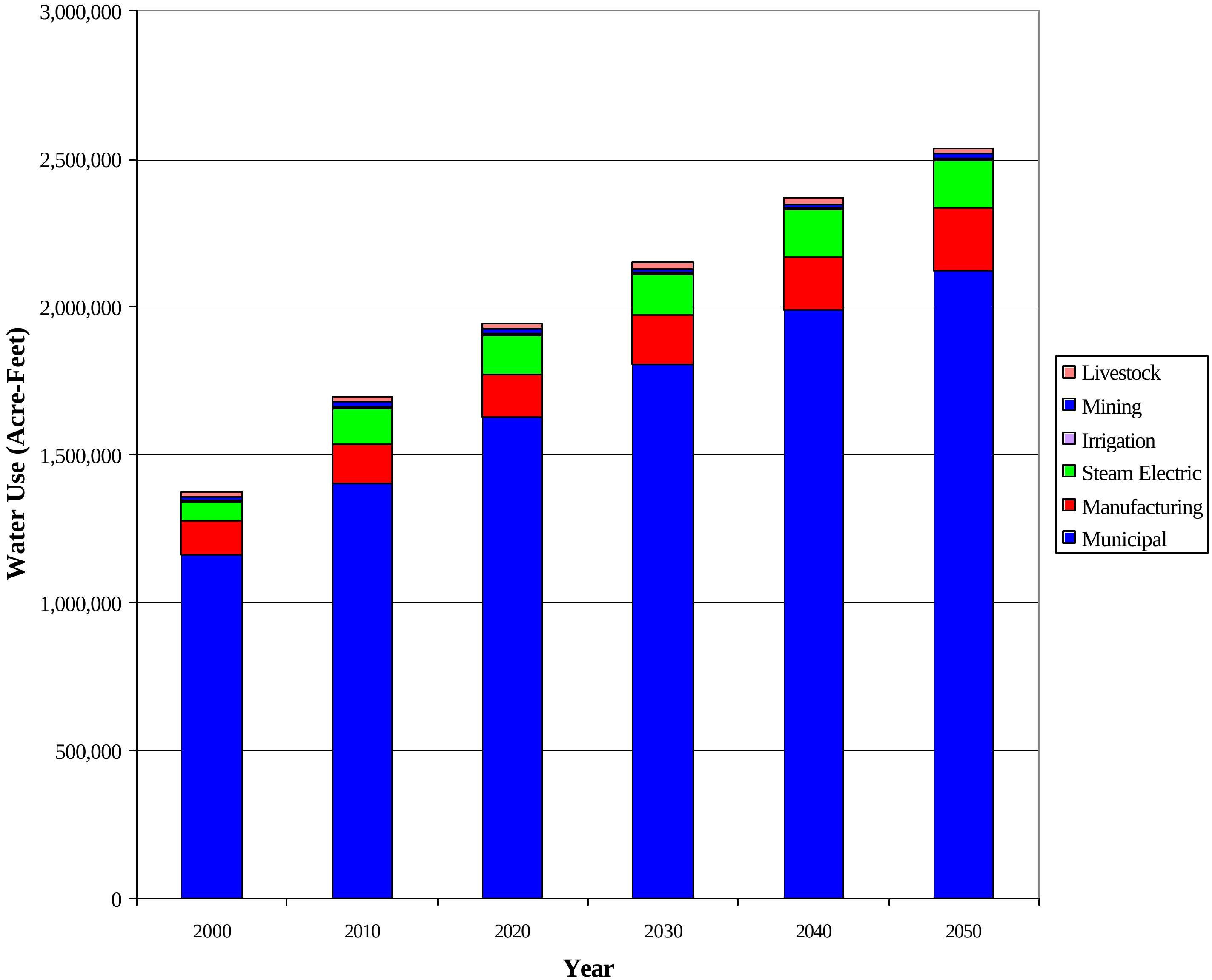
Table ES-3
Adopted County Water Demand Projections for Region C
- Values in Acre-Feet per Year -

County	Historical 1996	Projected Water Demand 2000	2010	2020	2030	2040	2050
Collin	89,230	129,015	199,964	262,520	312,307	363,821	401,007
Cooke	8,429	9,054	9,133	9,238	9,304	9,581	9,879
Dallas	505,423	594,937	683,097	751,767	810,356	883,850	940,289
Denton	65,075	90,209	135,740	185,725	230,286	257,410	281,989
Ellis	19,721	24,372	43,204	46,030	49,309	53,991	55,575
Fannin	17,515	12,100	13,330	14,500	15,597	16,572	17,515
Freestone	20,608	20,074	31,058	33,000	33,036	37,260	37,290
Grayson	29,152	29,060	29,760	30,242	31,347	32,508	33,688
Henderson (Partial)	10,785	12,697	13,169	13,478	13,697	13,737	13,908
Jack	3,337	2,644	2,589	2,574	2,591	2,615	2,652
Kaufman	10,653	21,219	24,401	27,392	32,361	34,832	42,017
Navarro	10,558	10,301	10,845	11,210	11,850	12,303	12,735
Parker	12,372	14,120	24,528	28,455	37,697	42,853	45,725
Rockwall	6,566	9,160	19,805	26,027	33,061	41,320	50,249
Tarrant	291,406	379,205	423,578	468,728	490,960	527,716	553,302
Wise	25,688	18,206	31,460	34,007	36,067	37,819	39,082
Region C Total	1,126,518	1,376,373	1,695,661	1,944,893	2,149,826	2,368,188	2,536,902

Table ES-4
Adopted Water Demand Projections for Region C by Type of Use
- Values in Acre-Feet per Year -

Use	Historical 1996	Projected Water Demand 2000	2010	2020	2030	2040	2050
Municipal	946,454	1,162,093	1,401,197	1,625,412	1,808,337	1,988,513	2,125,330
Manufacturing	71,366	117,577	135,114	148,798	162,714	183,188	207,637
Steam Electric Power	52,103	59,800	122,300	132,700	139,700	156,192	162,192
Mining	22,576	13,046	13,231	14,190	15,294	16,515	17,950
Irrigation	9,689	5,382	5,344	5,318	5,306	5,305	5,318
Livestock	24,330	18,475	18,475	18,475	18,475	18,475	18,475
Total	1,126,518	1,376,373	1,695,661	1,944,893	2,149,826	2,368,188	2,536,902

Figure ES-3
Adopted Projections
for Water Use by Category in Region C



ES-3 Analysis of Water Supply Currently Available to Region C

Total water use in Region C in 1996 was over 1,100,000 acre-feet. About 74 percent of the region's 1996 water use came from in-region reservoirs. The projected total reliable water supply available to Region C in 2050 from current sources will be about 2,023,000 acre-feet per year. (This figure does not consider supply limitations due to the capacities of current raw water transmission facilities and wells.) Figure ES-4 shows the projected total water availability for Region C. The sources of supply for Region C in 2050 include:

- 1,138,000 acre-feet per year (56%) from in-region reservoirs
- 181,000 acre-feet per year (9%) from groundwater
- 70,000 acre-feet per year (3%) from local supplies
- 82,000 acre-feet per year (4%) from reuse
- 552,000 acre-feet per year (28%) from imports from other regions

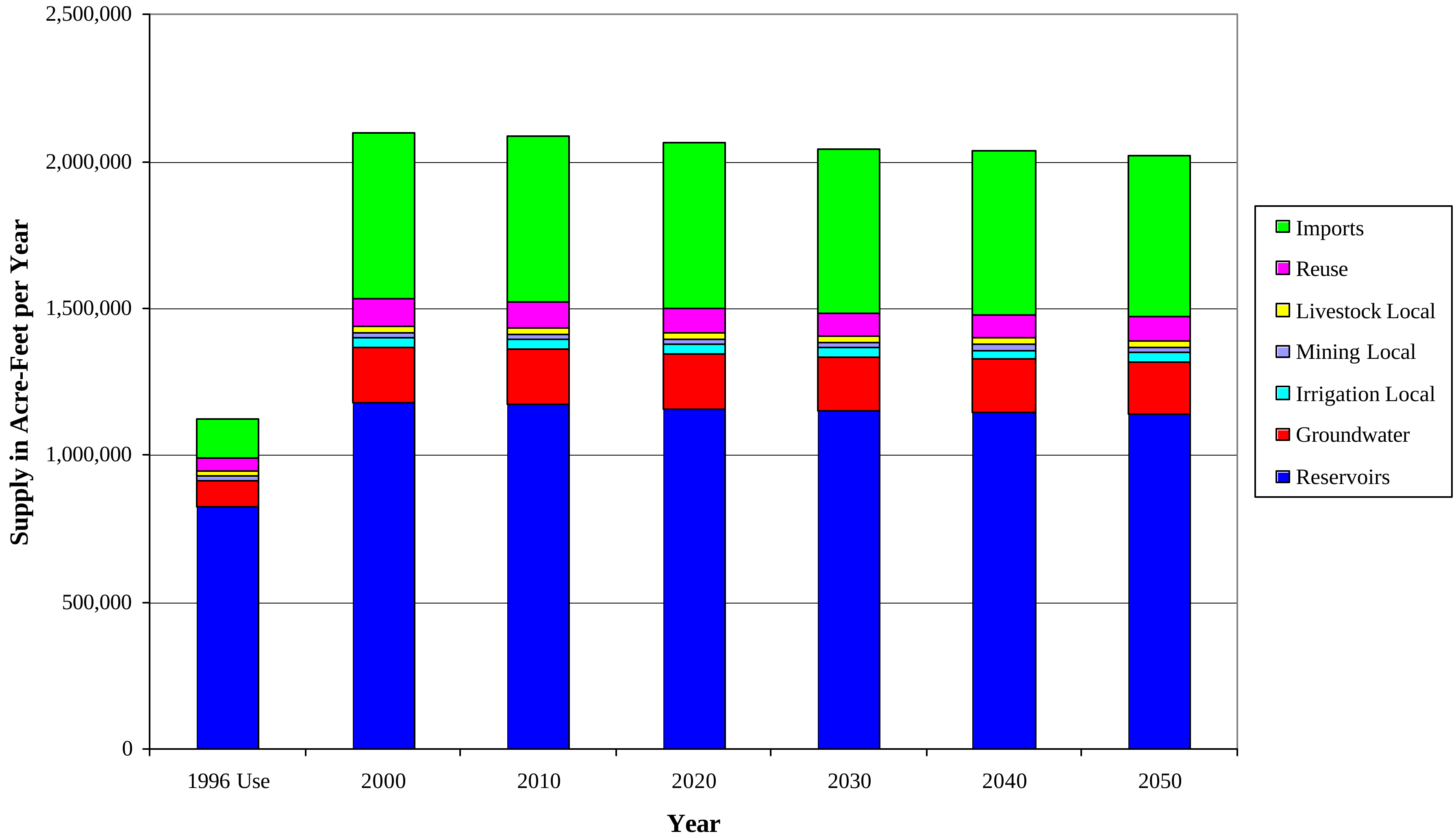
The projected supply available to Region C from existing sources in 2050 is significantly less than the projected 2050 water use.

If the supply limitations due to the capacities of current raw water transmission facilities and wells are considered, the available supply for Region C is reduced significantly. Most water user groups will have to make improvements to water transmission facilities or wells to provide for their projected needs. Several major Region C water supplies will require additional raw water transmission facilities before they can be utilized fully.

Current groundwater use in parts of Region C exceeds the projected long-term water supply availability. Supplies from other sources will be needed in these areas so that groundwater use can be reduced. Counties and aquifers where current use exceeds long-term supplies include the following:

- Trinity aquifer in Cooke County
- Trinity and Woodbine aquifers in Denton County
- Woodbine aquifer in Ellis County
- Trinity and Woodbine aquifers in Grayson County
- Nacatoch aquifer in Kaufman County
- Trinity aquifer in Parker County
- Trinity aquifer in Tarrant County.

Figure ES-4
Overall Water Supply Availability in Region C by Source



Some of the total supply shown as available to Region C will probably not be utilized fully during the period covered by this plan. This includes over 90,000 acre-feet per year of groundwater shown to be available in the Carrizo-Wilcox aquifer in Freestone County.

The five major water providers in Region C (City of Dallas, Tarrant Regional Water District, North Texas Municipal Water District, City of Fort Worth, and Trinity River Authority) provided over 903,000 acre-feet of water in 1996 (80% of the total provided in the region). They have 74% of the 2050 water supply currently available to the region.

The recent dry summers of 1996, 1998, 1999, and 2000 have caused very high water use for many Region C water suppliers. These droughts have put stress on some of the region's major reservoirs, which are designed for a 5 to 7 year drought like that of the 1950's. The high demands also exposed supply limitations for many smaller suppliers (especially those dependent on groundwater) and exposed treatment and distribution limitations for other suppliers.

ES-4 Comparison of Current Water Supply and Projected Water Demand

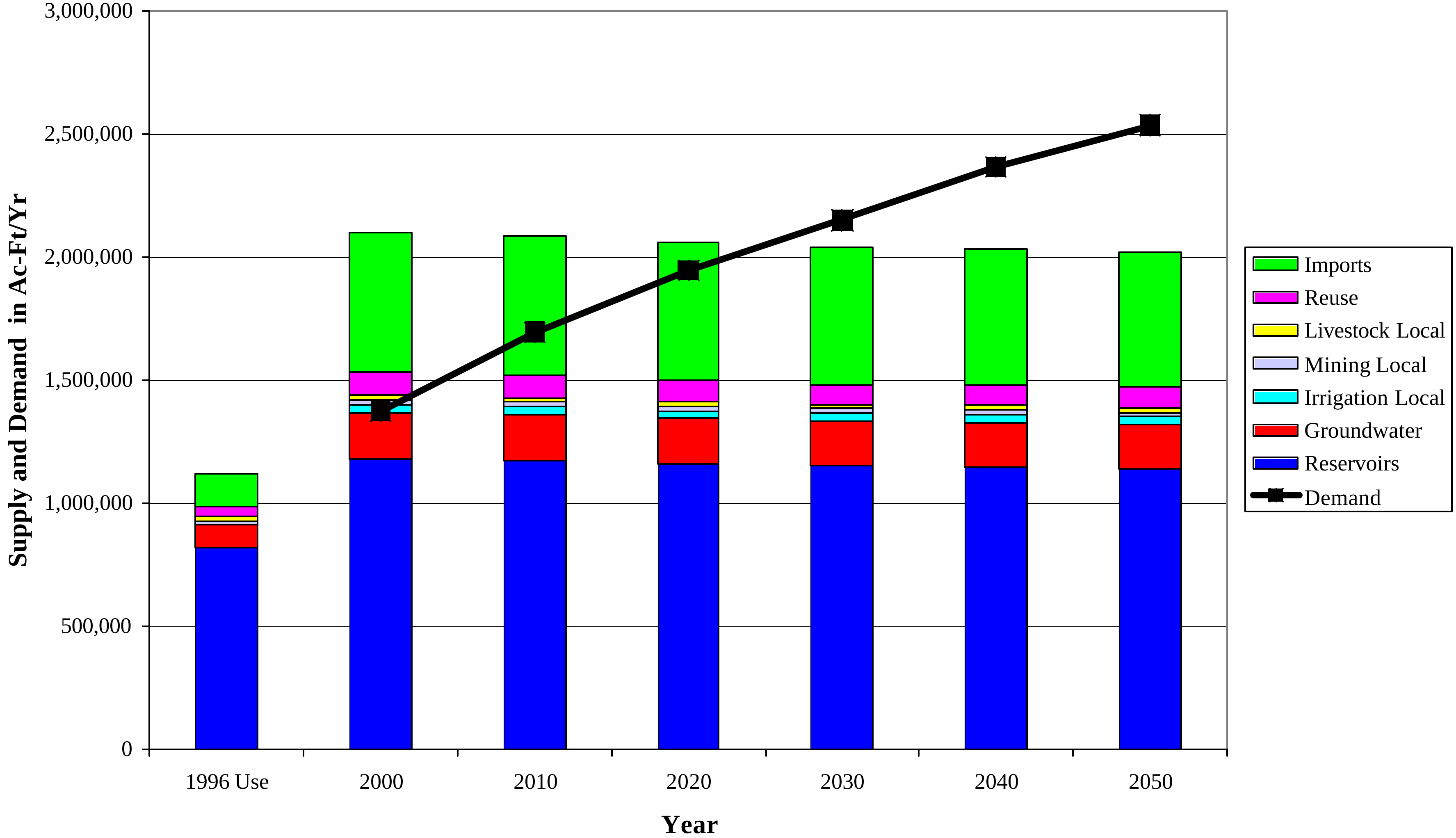
Comparison of Supply and Demand

Figure ES-5 shows the comparison of total supply with demand for Region C, including supplies that require additional water transmission facilities before they are available to the region. By 2030, the projected demand for Region C exceeds the total supply, even if all of the supplies available to the region are used in full.

Considering only currently connected supplies (those with transmission systems already in place), the following facts emerge for Region C:

- In 2000, three Region C counties (Cooke, Dallas, and Parker) show a net need for immediate additional supplies when all demands and all connected supplies are totaled.
- Significant additional supplies need to be connected before 2010 in Region C. (Several major projects to connect existing supplies are already underway.)
- By 2050, 11 out of the 16 Region C counties show a need for the connection or development of additional supplies to meet projected demands.
- By 2050, 193 out of 281 Region C water user groups show a need for the connection or development of additional supplies to meet projected demands.
- Current plans call for the connection of significant additional supplies for Region C over the next few years, including the following:
    - Irving and Upper Trinity Regional Water District's Lake Chapman pipeline is scheduled for completion by 2003 and will connect 65,700 acre-feet per year.

Figure ES-5
Comparison of Total Connected and Unconnected Supply with Demand for Region C



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- Dallas Water Utilities Lake Fork pipeline is scheduled for completion by 2004 and will connect 120,000 acre-feet per year.
- Tarrant Regional Water District is planning additional capacity for its pipeline to Richland-Chambers Lake that will connect an additional 110,000 acre-feet per year by 2005.

- Many Region C water suppliers depend on the region's major water providers (Dallas Water Utilities, Tarrant Regional Water District, North Texas Municipal Water District, Fort Worth, and Trinity River Authority) for all or part of their supplies. Each of those major water providers will need additional supplies by 2050.

Socio-Economic Impacts of Not Meeting Projected Water Needs

If no additional water supplies are developed, Region C will face substantial shortages in water supply over the next 50 years. The Texas Water Development Board provided technical assistance to regional water planning groups in the development of information on the socio-economic impacts of failing to meet projected water needs. TWDB's findings for Region C can be summarized as follows:

- The currently connected supplies in Region C would meet only 52.5 percent of the projected 2050 demand.
- Without any additional supplies, the region's projected 2050 population would be limited to 6,078,289, instead of 9,481,157, a reduction of 35.9 percent.
- Without any additional supplies, the region's projected 2050 employment would be limited to 2,605,111, instead of 4,425,184, a reduction of 41.1 percent.
- Without any additional supplies, the region's projected 2050 income would be limited to $109,505,000,000, instead of $171,199,000,000, a reduction of 36.3 percent.

ES-5 Evaluation and Selection of Water Management Strategies

The regional water planning group went through several steps in the evaluation and selection of water management strategies for Region C:

- Review of previous plans for water supply in Region C, including locally developed plans and the most recent state water plan
- Development of goals, issues, and concerns for the planning process
- General consideration of the types of water management strategies required by Senate Bill One regional planning guidelines
- Development of evaluation criteria for management strategies
- Evaluation of individual strategies

- Development of cost information for individual strategies
- Selection of strategies.

The development of a water plan covering fifty years for a region as large and populous as Region C is full of uncertainties. The implementation of the resulting plan must be flexible to allow for slower or faster than expected growth, unexpected obstacles in development of water management strategies, and unexpected opportunities. Specific points to remember include the following:

- The order in which steps are taken and the exact amount of supply available from each source are subject to variation.
- Water suppliers may need to turn to other alternatives if the recommended alternatives prove to be impractical.
- Changes in one element of the plan can affect other elements.
- Given the uncertainty in developing future supplies, flexibility in plan implementation is essential to success.
- The details of the plan will probably change as implementation proceeds.

Goals of the Planning Process

The goals for the Region C water planning effort are as follows:

- Provide sufficient water to meet realistic estimates of demand in a timely manner.
- Develop an effective continuing planning process to maintain reliable estimates of supply, maintain realistic estimates of demand, and identify appropriate programs and facilities to meet the water supply needs of Region C.
- Provide for the water supply needs of Region C in a manner that supports the continued economic strength of both Region C and the state as a whole.
- Develop a water supply plan that recognizes the economic, environmental, and cultural importance of natural resources and provides for the maintenance of those resources.
- Address the water supply needs of small cities and rural areas as well as large metropolitan areas.
- Provide for sustainable groundwater use in areas where groundwater is an essential component of the water supply plan.

Types of Water Management Strategies Considered

As required by Senate Bill One guidelines, the Region C Water Planning Group considered specific types of water management strategies as means of developing additional water supplies:

- Water conservation and drought response planning
- Reuse of wastewater
- Expanded use or acquisition of existing supplies
- Reallocation of reservoir storage to new uses
- Voluntary redistribution of water resources
- Voluntary subordination of water rights
- Enhancement of yields of existing sources
- Control of naturally occurring chlorides
- Interbasin transfers
- New supply development
- Water management strategies in the current state water plan
- Brush control, precipitation enhancement, and desalination
- Water right cancellation
- Aquifer storage and recovery
- Other measures.

Methodology for Evaluating Water Management Strategies

The Region C Water Planning Group considered the following factors in the evaluation of potential water management strategies:

- Quantity of water made available
- Reliability of supply
- Unit cost of delivered and treated water
- Difficulty of addressing environmental issues
    - Instream flows
    - Bay and estuary flows
    - Wildlife habitat
    - Cultural resources
    - Wetlands
    - Water quality
    - Other
- Impacts on water resources and other management strategies

- Impacts on agricultural and natural resources
- Consistency with plans of Region C water suppliers
- Consistency with other regions.

Development of cost estimates for water management strategies followed guidelines provided by the Texas Water Development Board. The costs include a 30 percent allowance for engineering and contingencies for pipelines and a 35 percent engineering and contingency allowance for other projects. Costs are for development of new supplies and do not include costs for:

- Facilities already in place
- Replacement or upgrading of aging facilities
- Improvements to meet changing regulatory requirements
- Improvements for water distribution to retail customers.

Recommended Water Management Strategies for Major Water Providers

A large part of the water supplied in Region C is provided by the five major water providers in the region: Dallas Water Utilities, Tarrant Regional Water District, North Texas Municipal Water District, Fort Worth, and Trinity River Authority. These five entities will continue to provide the majority of the water supply for Region C through 2050, and they will also develop most of the new supply developed in that time period. Recommended water management strategies to meet the needs of these major water providers include the following:

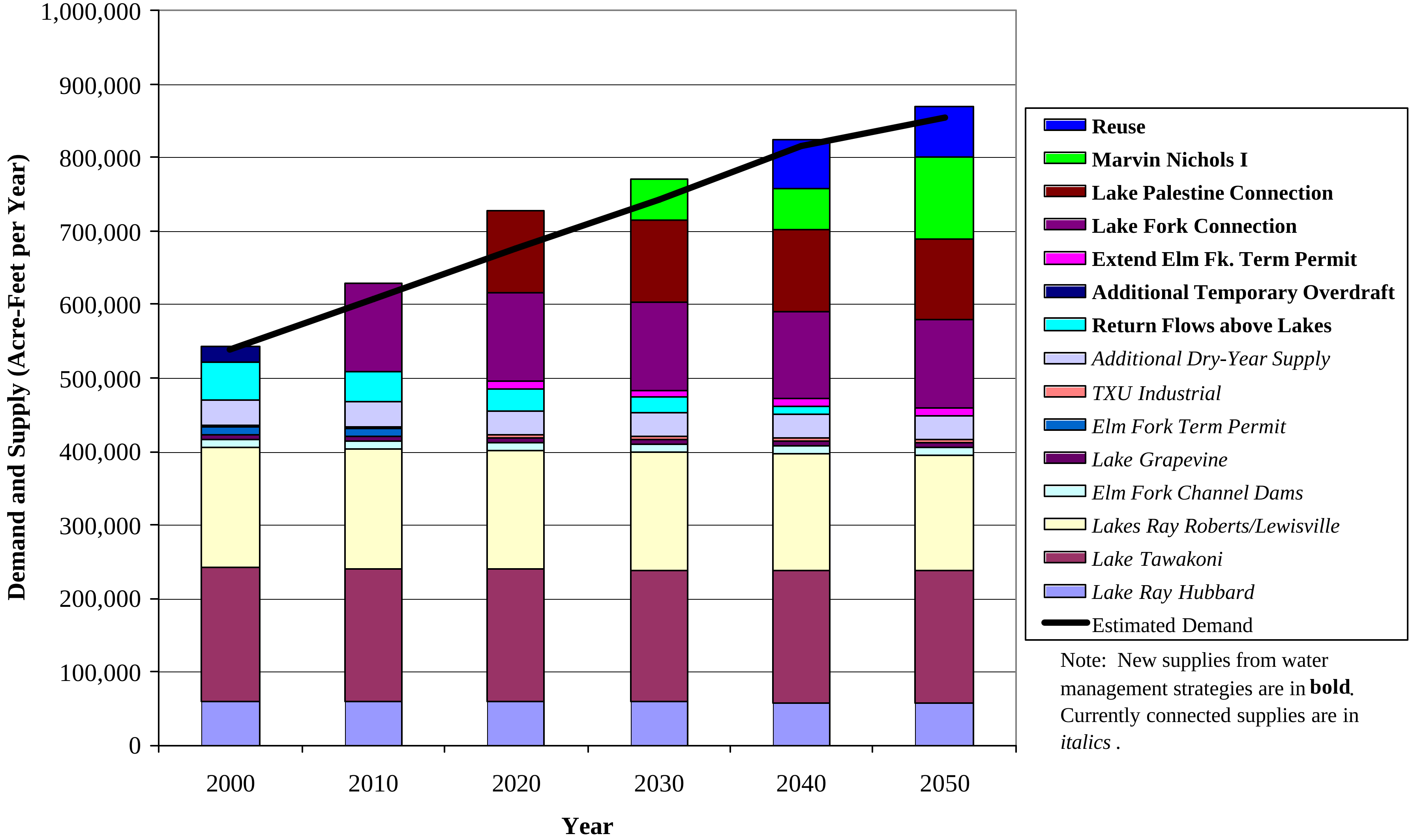
- **Marvin Nichols I Lake**
    - Major new reservoir in the Sulphur River Basin in the North East Texas Region (Region D)
    - Cooperative effort of Region C and Region D water suppliers
    - Total yield of 619,100 acre-feet per year
        - 123,800 acre-feet per year to Region D
        - 112,000 acre-feet per year to Dallas Water Utilities
        - 156,000 acre-feet per year to Tarrant Regional Water District
        - 163,300 acre-feet per year to North Texas Municipal Water District
        - 25,000 acre-feet per year to Irving
        - 39,000 acre-feet per year to meet other Region C needs.

- Estimated capital cost for Region C (including transmission to Region C but not including treatment) of $1,625,190,000.

- **Dallas Water Utilities**
  - Figure ES-6 shows the overall comparison of supply and demand for Dallas Water Utilities with recommended water management strategies.
  - Continue to use return flows above its lakes (50,000 acre-feet per year in 2000, decreasing to 0 by 2050).
  - Temporarily overdraft its reservoirs in 2000 (22,000 acre-feet per year in 2000).
  - Extend the Elm Fork permit for wet weather diversions (10,000 acre-feet per year).
  - Connect Lake Fork Reservoir to its system (120,000 acre-feet per year).
  - Connect Lake Palestine to its system (109,600 acre-feet per year).
  - Participate in the Marvin Nichols I project (112,000 acre-feet per year).
  - Develop a reuse project (68,300 acre-feet per year).
  - Renew contracts with existing customers as they expire.
  - Develop additional water treatment capacity as needed.
  - Other alternatives for Dallas Water Utilities include additional reuse and development of yield from return flows in the watersheds of water supply reservoirs.

- **Tarrant Regional Water District**
  - Figure ES-7 shows the overall comparison of supply and demand for Tarrant Regional Water District with recommended water management strategies.
  - Add pumps and a booster pump station to develop additional capacity in the pipeline from Richland-Chambers Lake to Tarrant County (110,000 acre-feet per year).
  - Develop the West Fork Connection to allow water to be transferred among the parts of the water supply system.
  - Develop the proposed reuse project to pump water from the Trinity River into Cedar Creek Lake and Richland-Chambers Lake to supplement yields (115,500 acre-feet per year).
  - Develop a water supply from existing water sources in Oklahoma (12,000 acre-feet per year)
  - Develop a third pipeline from Cedar Creek Lake and Richland-Chambers Lake to Tarrant County.
  - Participate in the Marvin Nichols I project (156,000 acre-feet per year).
  - Other alternatives for Tarrant Regional Water District include the development of Lake Tehuacana and obtaining water from Lake Texoma.

Figure ES-6
Dallas Water Utilities Supply and Demand



Note: New supplies from water management strategies are in **bold**. Currently connected supplies are in *italics* .

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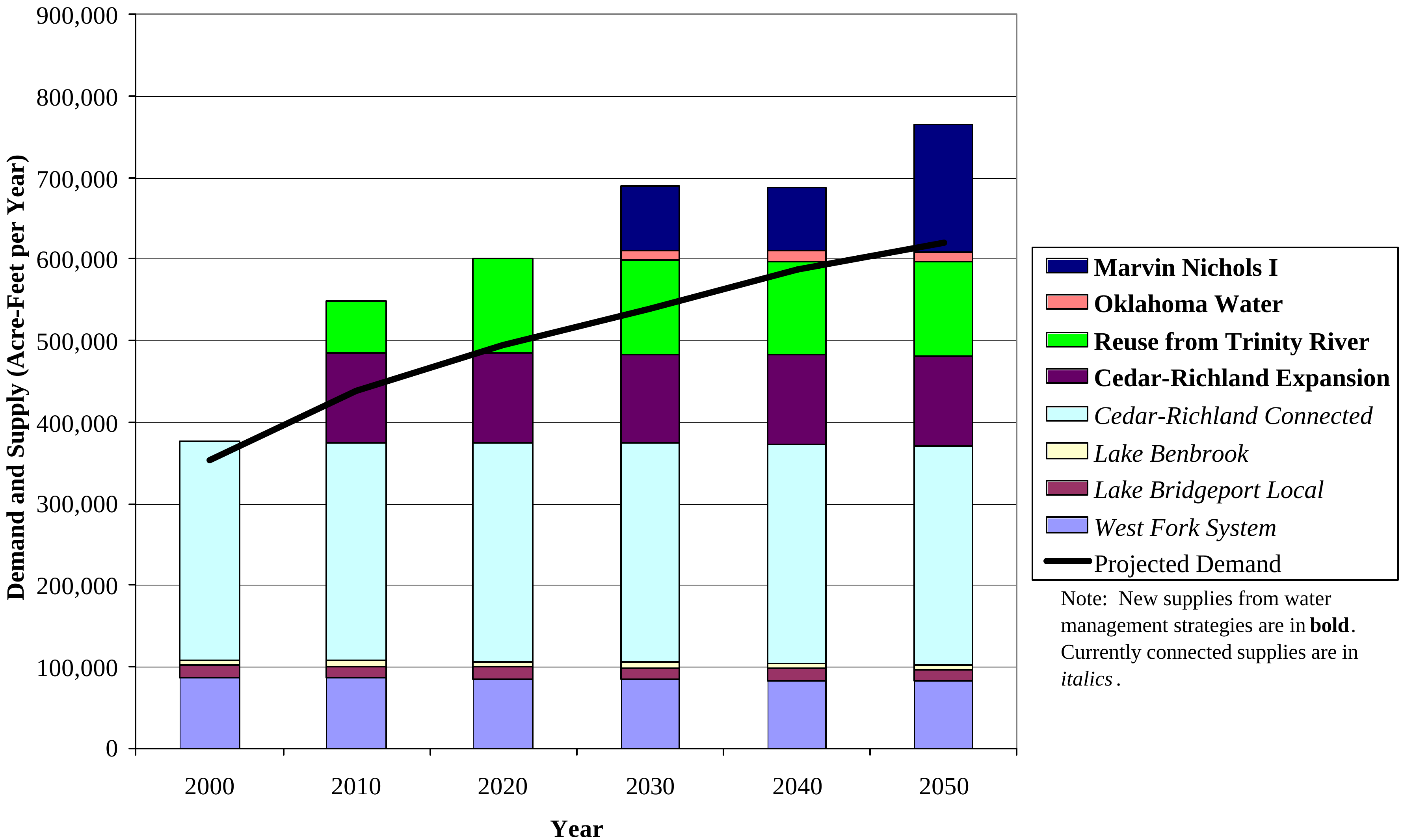
Figure ES-7
Tarrant Regional Water District Supply and Demand



Note: New supplies from water management strategies are in **bold**. Currently connected supplies are in *italics*.

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- **North Texas Municipal Water District**
    - Figure ES-8 shows the overall comparison of supply and demand for North Texas Municipal Water District with recommended water management strategies.
    - Develop additional water supplies in Lake Lavon from reuse (35,900 acre-feet per year).
    - Develop additional water supplies from Lake Texoma (10,000 acre-feet per year).
    - Develop a water supply from existing water sources in Oklahoma (50,000 acre-feet per year).
    - Develop Lower Bois d'Arc Creek Reservoir on Bois d'Arc Creek (98,000 acre-feet per year).
    - Participate in the Marvin Nichols I project (163,300 acre-feet per year).
    - Develop additional water treatment capacity and treated water transmission system improvements as needed.
    - Other alternatives for North Texas Municipal Water District include obtaining a substantial additional supply from Lake Texoma and extending the existing Lake Texoma pipeline to minimize channel losses.
- **City of Fort Worth**
    - Continue to obtain essentially all of its raw water from Tarrant Regional Water District.
    - Renew contracts with its existing customers as they expire.
    - Develop additional water treatment capacity as needed.
- **Trinity River Authority**
    - Continue to obtain raw water from Tarrant Regional Water District for its Tarrant County water supply project.
    - Expand Tarrant County water supply project raw water transmission, water treatment, and treated water transmission facilities as needed to meet growing demands.
    - Obtain raw water from Tarrant Regional Water District to implement the Ellis County water supply project.
    - Develop raw and treated water transmission lines to implement the Ellis County water supply project.
    - Develop reuse projects:
        - Additional golf course and landscape irrigation in the Las Colinas area.
        - Golf course and landscape irrigation in Denton and Tarrant Counties.
        - Steam electric power supply in Dallas and Ellis Counties
        - Reuse for municipal supply in Dallas County through Joe Pool Lake and Lake Grapevine.

Figure ES-8
North Texas Municipal Water District Supply and Demand

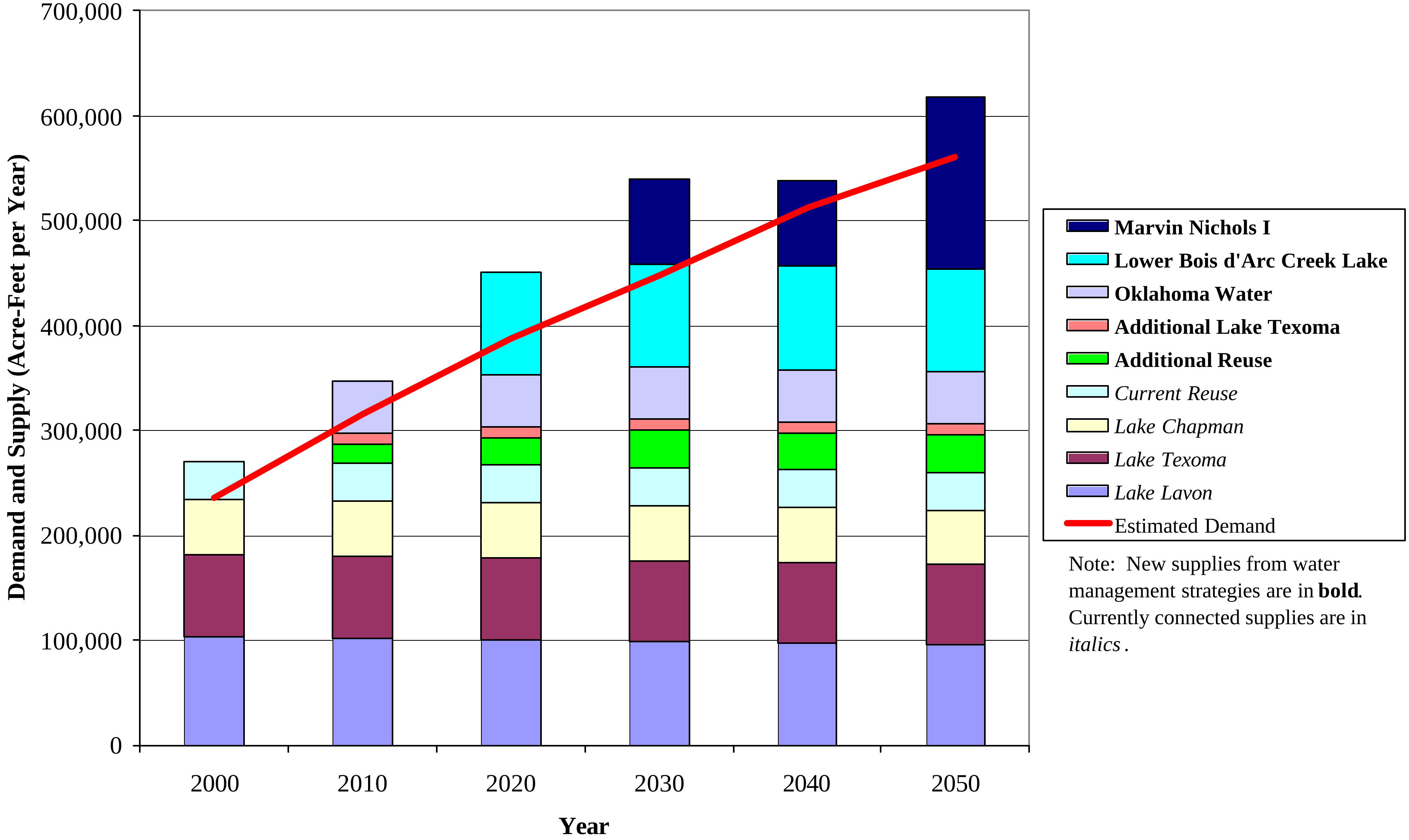


Table ES-5
New Supply from Water Management Strategies and
Estimated Capital Costs for Region C Major Water Providers

Major Water Provider	New Supply, 2000-2050 (Acre-Feet per Year)	Estimated Capital Cost
Dallas Water Utilities	419,900	$1,492,649,000
Tarrant Regional Water District	393,500	$1,167,652,000
North Texas Municipal Water District	357,200	$1,435,447,000
Fort Worth	- [a]	$221,475,000
Trinity River Authority	81,500[a]	$166,081,000
Total	1,252,100	$4,483,304,000

Note: (a) New supplies for Fort Worth and Trinity River Authority are included in the Tarrant Regional Water District total.

Table ES-5 shows the total new supply from 2000 through 2050 and the estimated capital cost to develop the supply for the five major water providers in Region C.

Recommended Water Management Strategies by County

The recommended strategies for each county in Region C are summarized below:

- **Collin County**
  - Most Collin County water user groups will continue to obtain treated water from North Texas Municipal Water District.
  - Blue Ridge will develop new wells and continue to rely on the Woodbine aquifer.
  - Celina will obtain treated water from the Upper Trinity Regional Water District.
  - Dallas Water Utilities will supply the part of Dallas in Collin County.
  - Prosper will purchase treated water from North Texas Municipal Water District and Upper Trinity Regional Water District.
  - Water suppliers will temporarily overdraft groundwater while developing surface supplies.
  - Water for steam electric power will be provided by a direct reuse project.
- **Cooke County**
  - Current groundwater use in Cooke County exceeds TWDB's estimated long-term reliable supply.
  - Gainesville is currently developing transmission and treatment facilities to connect to its existing Moss Lake surface water supply.

- Muenster is planning to develop a 500 acre-foot per year supply from the proposed Muenster Lake in the next few years.
- The Cooke County water supply system will be developed using raw water from Gainesville's Moss Lake to provide surface water supplies for water users in the county.
- Water users will temporarily overdraft groundwater while developing surface supplies.
- Water users in Cooke County might consider formation of a groundwater management district.
- The Upper Trinity Regional Water District will supply treated water to Valley View and a portion of Cooke County Other.

- **Dallas County**
  - Most water user groups in Dallas County will continue to obtain treated water from Dallas Water Utilities and North Texas Municipal Water District, renewing contracts as they expire.
  - Irving will complete facilities to bring its water supply from Lake Chapman to Lake Lewisville for treatment by Dallas and use by Irving.
  - Irving will develop a supply from Marvin Nichols I Reservoir.
  - Grapevine will implement its authorized direct reuse project.
  - Dallas County Other demands will be met from Dallas Water Utilities, Trinity River Authority reuse projects, and the proposed Marvin Nichols I project.
  - Water for steam electric power generation and mining will come from Dallas Water Utilities and a Trinity River Authority reuse project.
- **Denton County**
  - Current groundwater use in Denton County exceeds TWDB's estimated long-term reliable supply.
  - Upper Trinity Regional Water District will continue to develop its surface water supply system. Most Denton County water suppliers will purchase raw or treated water from UTRWD.
  - Upper Trinity Regional Water District will deliver raw water from Lake Chapman to Lewisville Lake through lines constructed by Irving.
  - Upper Trinity Regional Water District will develop reuse of the water imported from Lake Chapman.
  - Upper Trinity Regional Water District, Denton, and Lewisville will continue to purchase raw water from Dallas Water Utilities.
  - Lewisville will purchase raw water from Lake Chapman from UTRWD.

- Dallas Water Utilities, North Texas Municipal Water District, and Fort Worth will continue to supply treated water to current customers in Denton County, renewing contracts as they expire.
- Water users will temporarily overdraft groundwater while developing surface supplies.
- Water users in Denton County might consider formation of a groundwater management district.
- Trinity River Authority will develop a reuse project for golf course and landscape irrigation.
- Additional mining supplies will be obtained from other local supplies.
- Water for steam electric power will be provided by a direct reuse project.

- **Ellis County**
  - Current groundwater use in Ellis County exceeds TWDB's estimated long-term reliable supply.
  - The Trinity River Authority and water suppliers in Ellis County will develop the Ellis County water supply system using raw water from Tarrant Regional Water District, treatment capacity from Waxahachie, and transmission facilities developed for the project.
  - Dallas Water Utilities will continue to provide treated water to Ellis County water suppliers, renewing contracts as they expire.
  - Ennis, Mansfield, and Midlothian will obtain raw water from Tarrant Regional Water District.
  - Milford will continue to obtain treated water from Files Valley Water Supply Corporation.
  - Water users will temporarily overdraft groundwater while developing surface supplies.
  - Water for steam electric power will be provided from Trinity River Authority and Ennis reuse projects and TRA's Joe Pool Lake and Lake Bardwell.
- **Fannin County**
  - Fannin County water user groups will develop a regional surface water supply system.
  - Until that system is developed, Fannin County water suppliers will continue to rely on groundwater.
- **Freestone County**
  - Fairfield will develop an additional well in the Carrizo-Wilcox aquifer.
  - Wortham will obtain treated water from Mexia.
  - Water for steam electric power will be provided from TRWD's Richland-Chambers Lake.

- **Grayson County**
  - Current groundwater use in Grayson County exceeds TWDB's estimated long-term reliable supply.
  - Development of the Grayson County water supply system is proposed to deliver water to users throughout the county. The system includes a raw water pipeline from Lake Texoma, a treatment and desalination plant, and treated water pipelines.
  - Water users will temporarily overdraft groundwater while developing surface supplies.
  - Water users in Grayson County might consider formation of a groundwater management district.
  - Denison will sell treated water to Pottsboro (using raw water rights obtained by Pottsboro).
- **Henderson County**
  - Most Henderson County water user groups have an adequate supply to meet projected water demands through 2050.
  - Malakoff will develop a surface water supply system using raw water from TRWD's Cedar Creek Lake.
- **Jack County**
  - All Jack County water user groups have an adequate supply to meet projected water demands through 2050.
- **Kaufman County**
  - Current groundwater use in Kaufman County exceeds TWDB's estimate of long-term reliable supply.
  - North Texas Municipal Water District, Terrell, and Dallas Water Utilities will continue to supply their current customers in Kaufman County.
  - Treated wastewater from Garland will be reused for steam electric power demand.
  - Water users will temporarily overdraft groundwater while developing surface supplies.
  - TRWD will supply surface water for mining.
  - Additional irrigation local supplies will be developed for irrigation demands.
- **Navarro County**
  - Corsicana will continue to provide treated water for most of the water suppliers in Navarro County, and Corsicana has an adequate water supply.
  - A new well will be developed in the Carrizo-Wilcox aquifer for mining use.

- **Parker County**
  - Current groundwater use in Parker County exceeds TWDB's estimated long-term reliable supply.
  - Weatherford is constructing a pump station and 36-inch pipeline to bring water from Lake Benbrook to Lake Weatherford. That project is planned for completion in 2002.
  - Weatherford will treat raw water made available by Tarrant Regional Water District and sell treated water to Aledo, Annetta, Hudson Oaks, and Willow Park, all of which currently use the Trinity aquifer for their water supply.
  - TRWD will provide additional water for Azle, Briar, Reno (through Springtown), and Springtown.
  - Additional county other and manufacturing supplies will be developed from TRWD through Weatherford.
  - Water for steam electric power will be provided by reuse of treated wastewater from Weatherford and by water from TRWD's Lake Benbrook.
  - Water for mining will be provided by increased local water supply diversions.
  - Water users will temporarily overdraft groundwater while developing surface supplies.
  - Water users in Parker County might consider formation of a groundwater management district.
- **Rockwall County**
  - Dallas Water Utilities will continue to supply the part of Dallas in Rockwall County.
  - Most water suppliers in Rockwall County will continue to obtain treated water from North Texas Municipal Water District.
  - Water for steam electric power will be provided by reuse.
- **Tarrant County**
  - Current groundwater use in Tarrant County exceeds TWDB estimate of reliable long-term supply.
  - Tarrant Regional Water District will continue to provide raw water for most of the water suppliers in Tarrant County.
  - Fort Worth and the Trinity River Authority's Tarrant County water supply project will continue to supply treated water to many Tarrant County water suppliers, renewing contracts as they expire.
  - Arlington, Benbrook, Fort Worth, Mansfield and the Trinity River Authority Tarrant County water supply project will expand water treatment plants to keep pace with increasing demands.
  - Kennedale and Pantego will obtain treated water from Arlington and Fort Worth.

- Dallas Water Utilities will provide supplies for Grand Prairie and Grapevine, renewing contracts as they expire.
- Grapevine will develop its direct reuse project.
- Water for steam electric power and golf course and landscape irrigation will be provided from reuse.
- Water users will temporarily overdraft groundwater while developing surface supplies.

- **Wise County**
    - Walnut Creek Special Utility District will serve Aurora, Boyd, Newark, and Rhome with treated water, using water purchased from Tarrant Regional Water District.
    - Alvord will add an additional well and continue to use the Trinity aquifer.
    - Briar, Bridgeport, and Decatur will obtain additional supplies from the Tarrant Regional Water District.
    - Upper Trinity Regional Water District will supply a portion of county other needs through Bolivar WSC.
    - Steam electric power needs will be provided by sales from Tarrant Regional Water District.

Table ES-6 summarizes the estimated capital costs of the recommended water management strategies for major water providers and (by county) for others. The estimated capital costs for all recommended water management strategies in the Region C plan total $6,157,941,000.

Livestock Demands

In 13 of the 16 Region C counties, the estimated county-wide water supply for livestock purposes can meet projected demands for the county as a whole. However, these overall county-wide supply and demand figures do not show areas of shortages that exist within the counties under drought conditions. The Region C Water Planning Group recommends several special measures to address localized livestock water shortages

- Overdrafting of aquifers during droughts
- Local brush control projects
- Maintaining existing stock ponds and adding new stock ponds
- Improving and maintaining existing NRCS dams
- Survey on agricultural water use to gather data for future planning.

Table ES-6
Capital Costs for Region C Recommended Water Management Strategies

Major Water Provider/County	Estimated Capital Cost
Major Water Providers	
Dallas Water Utilities	$1,492,649,000
Tarrant Regional Water District	$1,167,652,000
North Texas Municipal Water District	$1,435,447,000
Fort Worth	$221,475,000
Trinity River Authority	$166,081,000
Subtotal for Major Water Providers	**$4,483,304,000**
Others (by County)	
Collin County	$14,371,000
Cooke County	$42,380,000
Dallas County	$553,801,000
Denton County	$581,277,000
Ellis County	$15,232,000
Fannin County	$70,658,000
Freestone County	$14,995,000
Grayson County	$98,785,000
Henderson County	$7,809,000
Jack County	$0
Kaufman County	$29,912,000
Navarro County	$5,670,000
Parker County	$83,017,000
Rockwall County	$4,795,000
Tarrant County	$83,452,000
Wise County	$68,483,000
Subtotal for Others	**$1,674,637,000**
TOTAL FOR REGION C	**$6,157,941,000**

Consistency with the Regional Water Plan

In evaluating consistency with this regional water plan, TNRCC and TWDB should consider the following factors:

- Willing buyer/willing seller transactions should be allowed.
- Maximum flexibility should be afforded to water suppliers. Changes in timing, order, amount of supply, and details of project development should be allowed.
- Consistency requirements should be waived, if appropriate.
- Small uses that do not affect water supplies should be regarded as consistent with this plan.

- Projects to repair or replace existing facilities should be regarded as consistent with this plan.
- Projects for internal distribution improvements and other projects that do not involve development or connection of a new supply should be regarded as consistent with this plan.
- Projects intended to improve water quality or meet regulatory requirements should be regarded as consistent with this plan.
- Projects that promote regional cooperation should receive state support and be regarded as consistent with this plan.
- TWDB and TNRCC should support fast-track efforts by water suppliers when such efforts are needed.

ES-6 Regulatory, Administrative, Legislative, and Other Recommendations

The Region C Water Planning Group makes the following recommendations for regulatory, administrative, legislative, and other changes:

- Recommendations related to the Senate Bill One planning process
    - Allow alternative strategies for near and long term planning needs.
    - Encourage TWDB to exercise discretion in the consideration and approval of funding for alternatives not presented as part of the regional water plan.
    - Encourage TNRCC to exercise discretion in the consideration and approval of water right permit applications not part of the regional water plan.
    - Allow regional water planning groups to assume that contracts for water supply will be renewed when they expire.
    - Provide clarification of the impact of designating a unique stream segment.
- Recommendations related to TNRCC policy and water rights
    - Make some water rights exempt from cancellation for ten years of non-use.
    - Reduce the regulatory and legislative obstacles to indirect reuse of treated wastewater.
    - Remove barriers to interbasin transfers of water.
- Recommendations for state and federal programs to address water supply issues
    - Increase funding for Texas Water Development Board loans and the state participation program to assist with the development of water supply projects.
    - Accelerate studies of groundwater availability for the Trinity aquifer.
    - Increase state participation in water conservation efforts.

- Provide a program for education of board members of Water Supply Corporations, Special Utility Districts, and Municipal Utility Districts.
- Increase state participation in watershed protection planning.
- Encourage federal funding for development, maintenance, and upgrading of NRCS structures.
- Provide state assistance with maintenance and construction of stock ponds.
- Encourage the Texas Agricultural Statistics Service to include water supply questions on its survey of farmers and ranchers.

- Recommendations for ecologically unique river and stream segments
  - Provide clarification of the impacts of designating a unique stream segment.
- Recommendations for unique sites for reservoir construction
  - Marvin Nichols I
  - Lower Bois d'Arc Creek
  - Muenster
  - Tehuacana

ES-7 Plan Approval Process and Public Participation

The Region C Water Planning Group made special efforts to inform and seek input from the general public, water suppliers, and others with special interest in the planning process.

Regional Water Planning Group

The original legislation for Senate Bill One and the Texas Water Development Board planning guidelines establish regional water planning groups to control the planning process. The Region C Water Planning Group held regular meetings open to the public during development of the plan, including nine meetings in 1998, 11 meetings in 1999, and 15 meetings in 2000.

Outreach to Water Suppliers and Regional Planning Groups

The Region C Water Planning Group made special efforts to contact water suppliers in the region and obtain their input in the planning process.

- The planning group sent out questionnaires early in the Region C planning seeking information on population and water use projections and other water supply issues.
- The planning group appointed a technical review committee composed of experienced water resource planners to review population and water demand projections.

- The planning group instructed its consultants to contact water suppliers as planning progressed.

The Region C and Region D water planning groups formed the Sulphur River Task Group, including members of both water planning groups, to coordinate water supply planning involving the Sulphur River Basin. As a result of cooperative efforts, both planning groups support the development of Marvin Nichols I Reservoir on the Sulphur River in Region D

Outreach to the Public

The Region C Water Planning Group outreach efforts for the public included the following:

- Publication of newsletters to inform the public.
- Public awareness presentations to interested groups throughout the region.
- Media outreach program to involve the news media.
- Publication of the draft of the *Initially Prepared Region C Water Plan* on the Freese and Nichols web page, at http://www.freese.com/senbill1/regionc/index.htm.

Public Meetings and Public Hearings

The Region C Water Planning Group has held the following public meetings and hearings to bring the Region C Water Plan to the public:

- Required initial meeting on the planning process.
- Public Hearing on population and water use
- Five public meetings throughout the region on water needs and potential strategies
- Five public meetings and a public hearing on draft initially prepared plan in September of 2000.

Implementation Strategies

Section 7.2 of the report includes a discussion of implementation strategies for complex elements of the water supply plan for Region C:

- Conservation
- Reuse of reclaimed wastewater
- Marvin Nichols I Reservoir
- Water from Oklahoma.

Figure ES-4
Overall Water Supply Availability in Region C by Source

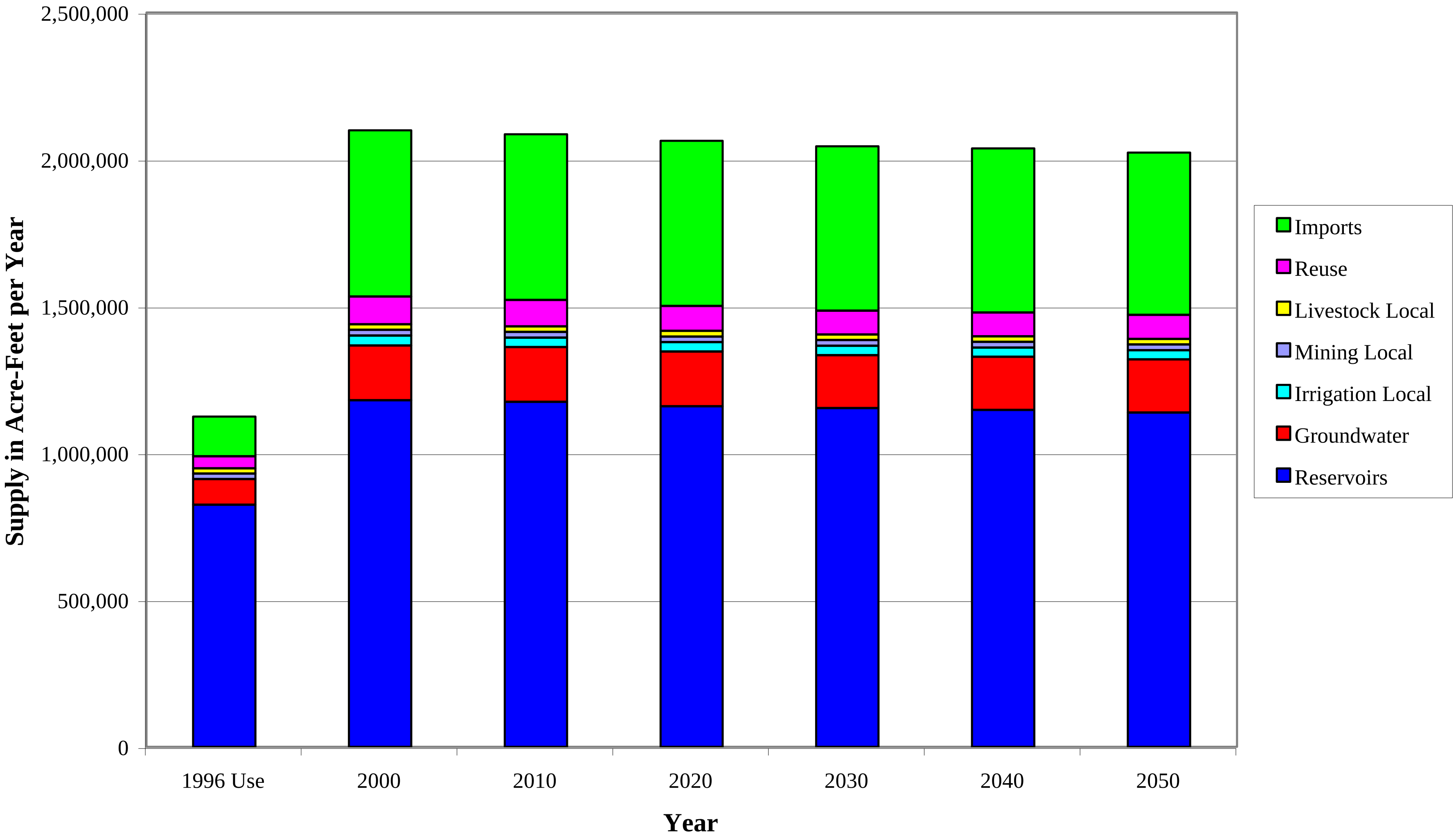


Figure ES-5
Comparison of Total Connected and Unconnected Supply with Demand for Region C

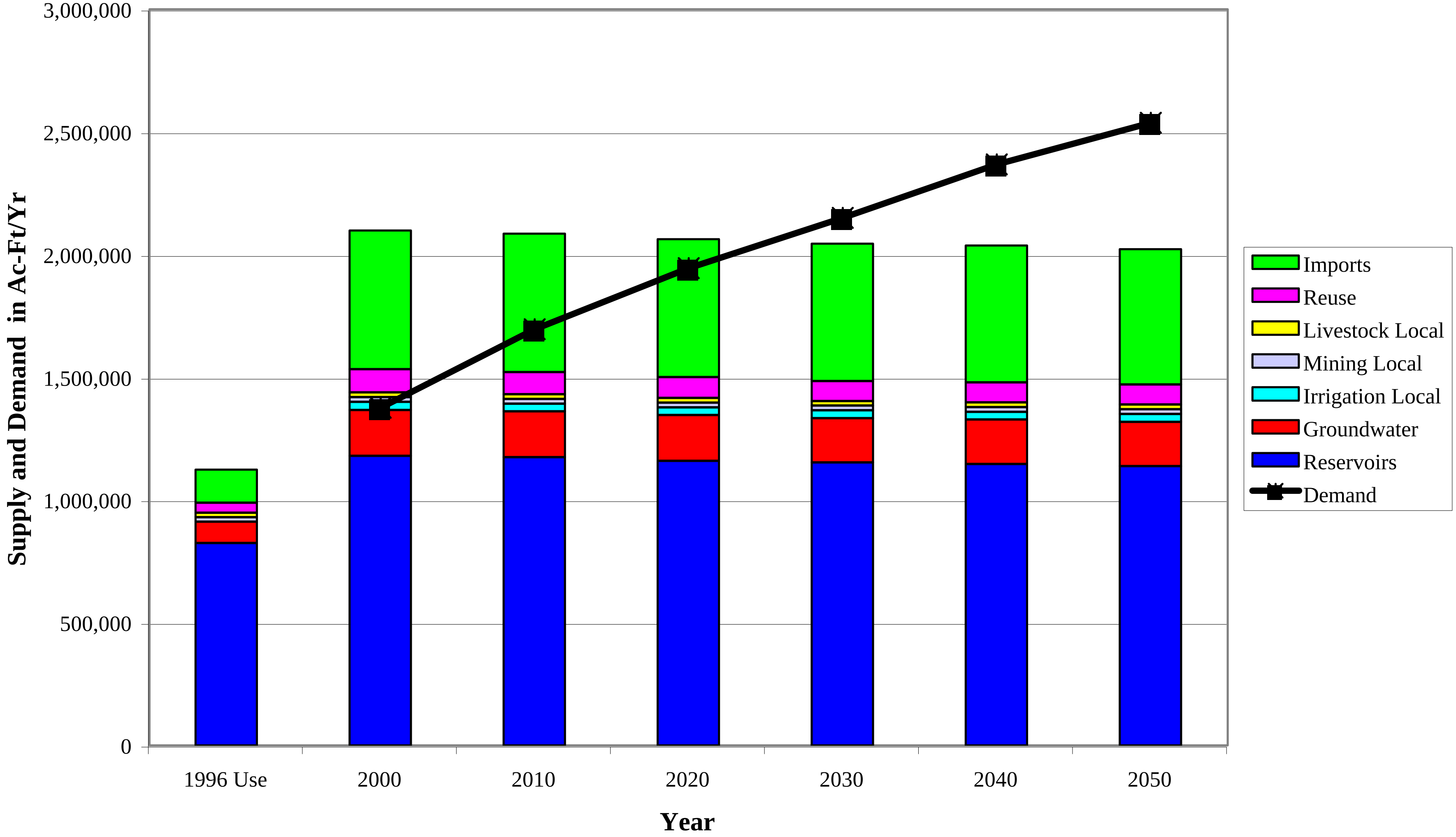
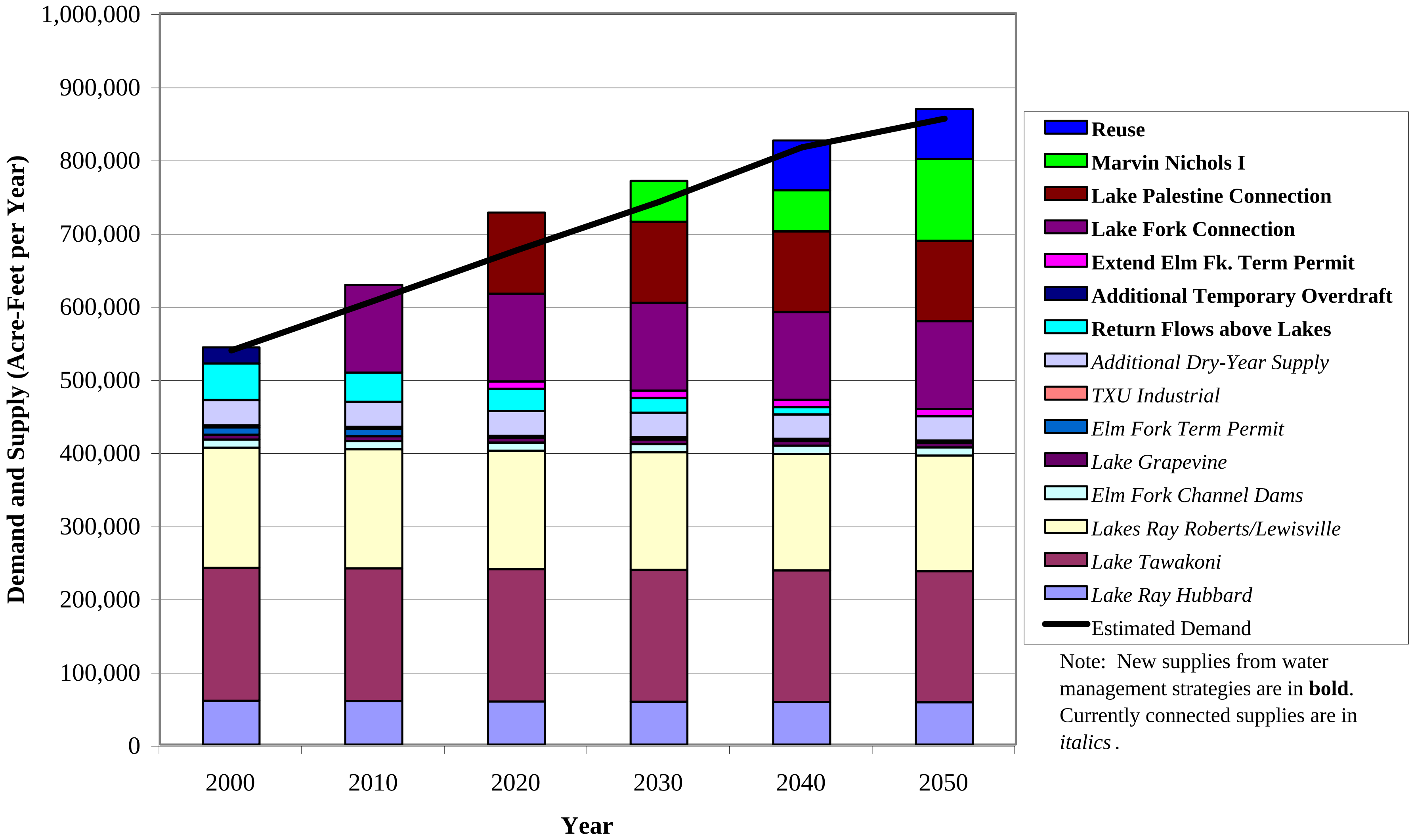
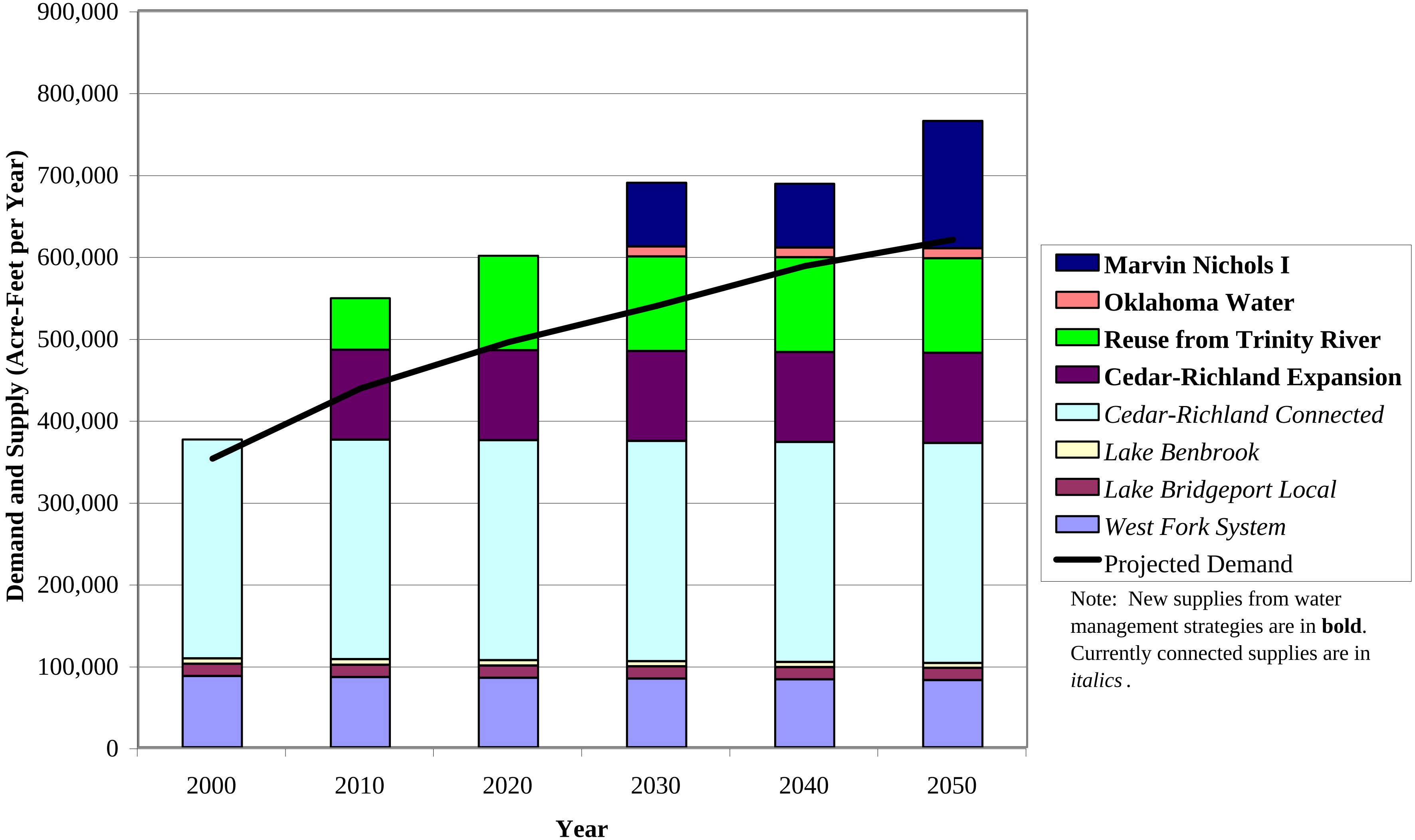


Figure ES-6
Dallas Water Utilities Supply and Demand



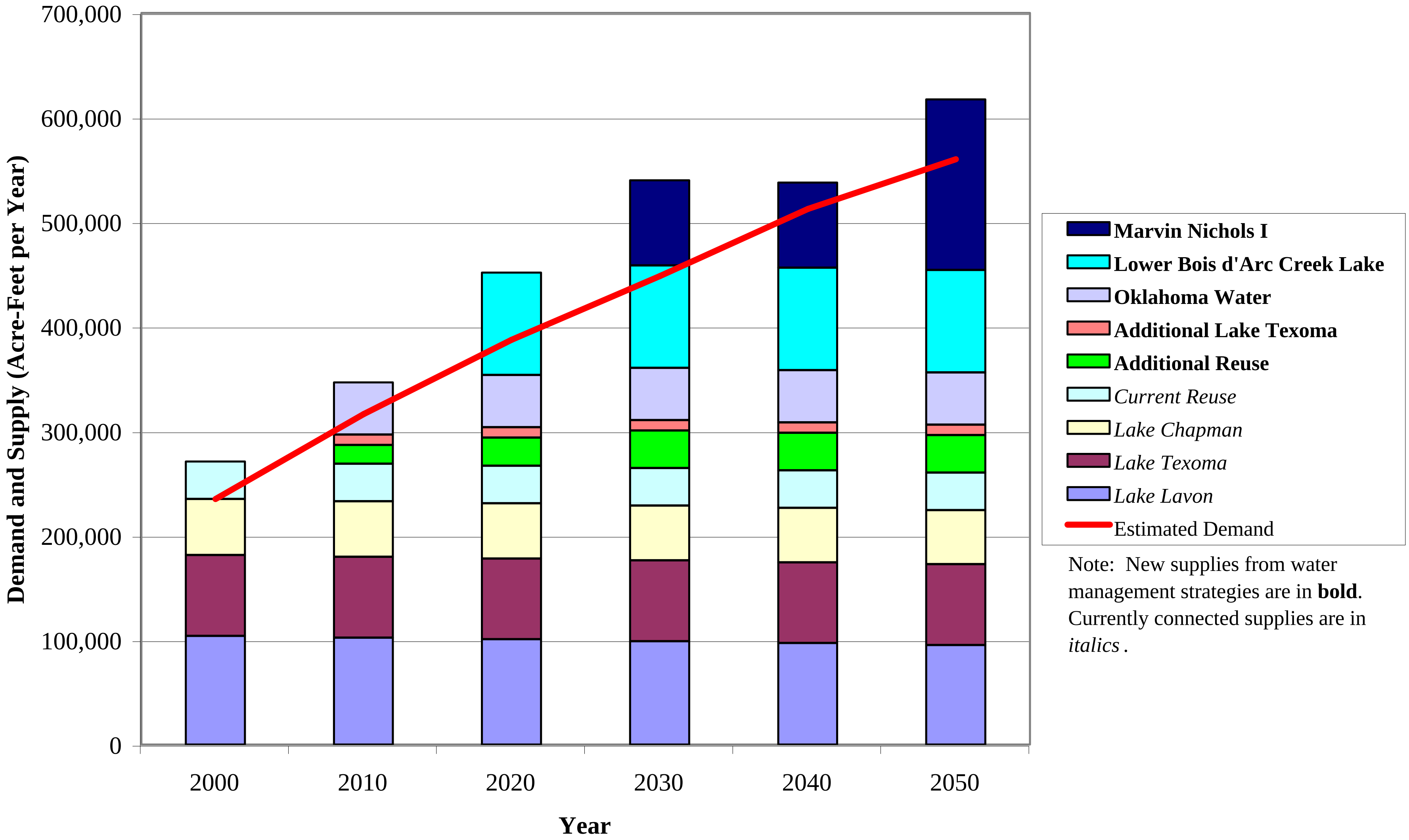
Note: New supplies from water management strategies are in **bold**. Currently connected supplies are in *italics* .

Figure ES-7
Tarrant Regional Water District Supply and Demand



Note: New supplies from water management strategies are in **bold**. Currently connected supplies are in *italics*.

Figure ES-8
North Texas Municipal Water District Supply and Demand



Note: New supplies from water management strategies are in **bold**. Currently connected supplies are in *italics*.

Introduction

In 1997, the 75th Texas Legislature passed Senate Bill One, legislation designed to address Texas water issues. With the passage of Senate Bill One, the legislature put in place a grass-roots regional planning process to plan for the water needs of all Texans in the next century. To implement this planning process, the Texas Water Development Board has created 16 regional water planning groups across the state and established regulations governing regional planning efforts.

This report gives the results of the planning process for Region C, one of the regions created to implement Senate Bill One. Figure I-1 is a map of Region C, which covers all or part of 16 counties in North Central Texas. As Figure I-1 shows, Region C includes all of Cooke, Grayson, Fannin, Jack, Wise, Denton, Collin, Parker, Tarrant, Dallas, Rockwall, Kaufman, Ellis, Navarro, and Freestone Counties and the part of Henderson County that is in the Trinity Basin.

The regional water planning groups created pursuant to Senate Bill One are in charge of the regional planning process(1). TWDB regulations require each regional planning group to include representatives of 11 designated interest groups. Table I-1 shows the members of the Region C water planning group and the interests they represent. The Region C water planning group hired a team of consultants to conduct technical analyses and prepare the regional water plan under the supervision of the planning group. The consulting team included Freese and Nichols, Inc., Alan Plummer Associates, Inc., Chiang, Patel, and Yerby, Inc., and Cooksey Communications, Inc.

Texas Water Development Board planning guidelines require each regional water plan to include seven tasks, which are addressed in the seven sections of this report. The tasks are:

1. Description of Region C
2. Population and Water Demand Projections
3. Analysis of Water Supply Currently Available to Region C

(1)Numbers in parentheses match references listed in Appendix A.

4. Comparison of Current Water Supply and Projected Water Demand
5. Evaluation and Selection of Water Management Strategies
6. Regulatory, Legislative, Administrative, and Other Recommendations
7. Plan Approval Process and Public Participation

The report also includes a number of appendices providing more detailed information on the planning efforts.

Table I-1
Members of the Region C Water Planning Group

Member	Affiliation	Interest
Terrace W. Stewart, Chairman	Dallas Water Utilities	Municipalities
James Parks, Vice-Chairman	North Texas Municipal Water District	Water Districts
Roy F. Eaton, Secretary	Wise County Messenger	Small Business
Brad Barnes	Rancher	Agricultural
A. Leroy Burch	Retired	Industries
Jerry W. Chapman	Greater Texoma Utility Authority	Water Districts
Dale Fisseler	City of Fort Worth	Municipalities
Howard Martin	City of Denton	Municipalities
Jim McCarter	Navarro Mills WSC	Water Utilities
Elaine Petrus	Streams and Valleys	Environmental
Paul Phillips	City of Weatherford	Municipalities
Irvin M. Rice	Retired	Public
Robert O. Scott	Tarrant Coalition for Environmental Awareness	Environmental
George Shannon	Tarrant Regional Water District	Water Districts
Connie Standridge	Winkler WSC	Water Utilities
Danny Vance	Trinity River Authority	River Authorities
Judge Tom Vandergriff	Tarrant County	Counties
Mary E. Vogelson	League of Women Voters	Public
Paul Zweiacker	Texas Utilities	Electric Generating Utilities

1. Description of Region C

Table 1.1 shows historical populations from 1900 through 1998 for the counties in Region C[2, 3]. Table 1.1 also shows the estimated total population for the region for the same period, including only the portion of Henderson County in Region C. Figure 1.1 is a plot of the historical population for Region C. During the 1900s, the population of Region C has grown from 588,706 in 1900 to an estimated 4,779,210 in 1998. Since 1940, the region's population has increased at a compounded rate of 2.6 percent per year. The increase of 700,920 people (17.2 percent) from 1990 through 1998 indicates that the area is still growing rapidly.

As of 1998, Region C included 24.4 percent of Texas' total population. The two most populous counties in Region C, Dallas and Tarrant, have 70.6 percent of the region's population. Collin, Denton, Grayson, and Ellis Counties also have 1998 populations over 100,000 people. Table 1.2 lists the 38 cities in Region C with an estimated 1998 population of more than 20,000. These cities include 80.5 percent of the 1998 population of the region.

1.1 Economic Activity in Region C

Region C includes most of the Dallas and Fort Worth-Arlington metropolitan statistical areas (MSAs). The largest employment sector in the Dallas MSA is the service industry, followed by trade, manufacturing and government. The Fort Worth-Arlington MSA's largest employment sectors are service, trade, and manufacturing. The Dallas and Fort Worth-Arlington MSAs have experienced strong economic growth in the 1990s [2].

Table 1.3 lists 1995 payrolls for Region C by county and economic sector [4]. (1995 is the most recent year for which data were available when this report was written). Payroll and employment in Region C are concentrated in the central urban counties of Dallas and Tarrant, which have 86.6 percent of the region's total payroll and 84.7 percent of the employment. (Economic activity is more concentrated than population because many workers commute from outlying counties to work in Dallas and Tarrant Counties.) The largest business sectors in Region C in terms of payroll are services and manufacturing, which account for a combined 51.3 percent of the region's total payroll.

Table 1.1
Historical Population for Region C Counties

County	Historical Population [a]										
	1900	**1910**	**1920**	**1930**	**1940**	**1950**	**1960**	**1970**	**1980**	**1990**	**1998**
Collin	50,587	49,021	49,609	46,180	47,190	41,692	41,247	66,920	144,490	264,036	416,620
Cooke	27,494	26,603	25,667	24,136	24,909	22,146	22,560	23,471	27,656	30,777	34,200
Dallas	82,726	135,748	210,551	325,691	398,564	614,799	951,527	1,327,321	1,556,549	1,852,810	2,032,171
Denton	28,318	31,258	35,355	32,822	33,658	41,365	47,432	75,633	143,126	273,525	382,389
Ellis	50,059	53,629	55,700	53,936	47,733	45,645	43,395	46,638	59,743	85,167	102,200
Fannin	51,793	44,801	48,186	41,163	41,064	31,253	23,880	22,705	24,285	24,804	28,015
Freestone	18,910	20,557	23,264	22,589	21,138	15,696	12,525	11,116	14,830	15,818	17,872
Grayson	63,661	65,996	74,165	65,843	69,499	70,467	73,043	83,225	89,796	95,021	104,202
Henderson [b]	14,338	14,454	20,339	21,959	22,848	16,807	15,642	19,003	30,591	42,034	49,515
Jack	10,224	11,817	9,863	9,046	10,206	7,755	7,418	6,711	7,408	6,981	7,730
Kaufman	33,376	35,323	41,276	40,905	38,308	31,170	29,931	32,392	39,015	52,220	63,583
Navarro	43,374	47,070	50,624	60,507	51,308	39,916	34,423	31,150	35,323	39,926	43,082
Parker	25,823	26,331	23,382	18,759	20,482	24,528	22,880	33,888	44,609	64,785	77,525
Rockwall	8,531	8,072	8,591	7,658	7,051	6,156	5,878	7,046	14,528	25,604	37,863
Tarrant	52,376	108,572	152,800	197,553	225,521	361,253	538,495	716,317	860,880	1,170,103	1,340,037
Wise	27,116	26,450	23,363	19,178	19,074	16,141	17,021	19,687	26,575	34,679	42,206
Region C Total	**588,706**	**705,702**	**852,735**	**987,925**	**1,078,553**	**1,386,789**	**1,887,297**	**2,523,223**	**3,119,404**	**4,078,290**	**4,779,210**
% Increase		19.9%	20.8%	15.9%	9.2%	28.6%	36.1%	33.7%	23.6%	30.7%	17.2%
Henderson (Total)	19,970	20,131	28,327	30,583	31,822	23,408	21,786	26,466	42,606	58,543	68,962

Notes: a. Population data through 1990 are from *The Texas Almanac* (2). Data for 1998 are from the Texas State Data Center (3).

b. The Henderson County population in Region C is assumed to be 71.8% of the total Henderson County population based on the ratio of TWDB's Region C Henderson County population to total Henderson County population in 1990.

Figure 1.1
Historical Population for Region C

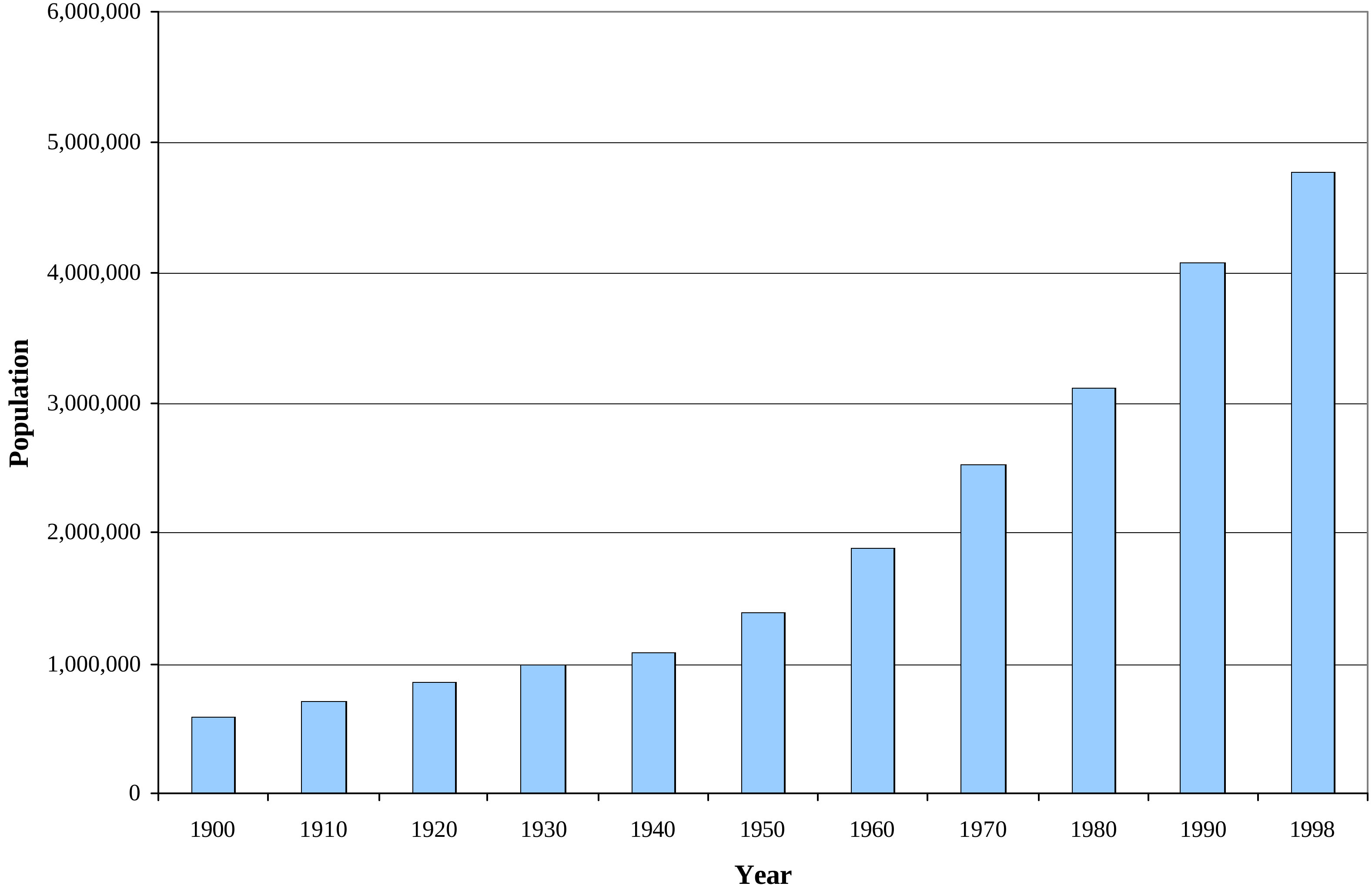


Table 1.2
Cities in Region C with Estimated 1998 Population Greater than 20,000

City	Estimated 1998 Population	County(ies)
Dallas	1,085,614	Dallas, Collin, Denton, Kaufman, Rockwall
Fort Worth	489,277	Tarrant, Denton, Johnson
Arlington	301,991	Tarrant
Plano	198,186	Collin, Denton
Garland	193,475	Dallas, Collin
Irving	175,983	Dallas
Mesquite	114,699	Dallas
Grand Prairie	113,672	Dallas, Tarrant, Ellis
Carrollton	100,950	Dallas, Denton
Richardson	90,798	Dallas, Collin
Denton	78,028	Denton
Lewisville	67,180	Denton, Dallas
North Richland Hills	54,688	Tarrant
Bedford	48,813	Tarrant
Euless	46,632	Tarrant
Flower Mound	40,291	Denton
Hurst	39,274	Tarrant
Grapevine	38,528	Tarrant, Dallas
Rowlett	38,203	Dallas, Rockwall
Duncanville	36,364	Dallas
Haltom City	36,177	Tarrant
DeSoto	35,615	Dallas
McKinney	34,979	Collin
Sherman	34,395	Grayson
Allen	32,501	Collin
The Colony	28,956	Denton
Cedar Hill	28,100	Dallas, Ellis
Coppell	27,625	Dallas
Lancaster	27,147	Dallas
Farmers Branch	26,227	Dallas
Corsicana	24,450	Navarro
Benbrook	22,902	Tarrant
University Park	22,872	Dallas
Watauga	22,682	Tarrant
Mansfield	22,679	Tarrant, Johnson, Ellis
Denison	22,425	Grayson
Keller	21,580	Tarrant
Waxahachie	20,961	Ellis
Total	3,844,919	

Note: Data are from the Texas State Data Center [3].

Table 1.3
1995 County Payroll by Category ($1,000)

	Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson
Agriculture	$20,043	$390	$119,995	$17,010	$1,358	$445	$0	$2,183
Mining	$123,084	$4,246	$781,095	$3,099	$0	$0	$0	$2,763
Construction	$117,637	$3,390	$1,592,815	$117,294	$23,278	$2,481	$0	$37,813
Manufacturing	$969,379	$67,564	$6,493,130	$421,954	$249,571	$31,169	$4,511	$328,743
Transportation & Public Utilities	$126,670	$8,190	$4,384,175	$114,607	$34,217	$5,802	$38,253	$30,825
Wholesale Trade	$254,111	$8,531	$4,775,360	$221,180	$23,175	$7,864	$1,619	$27,759
Retail Trade	$414,326	$29,546	$3,576,408	$527,094	$51,335	$12,216	$9,727	$113,583
Financial, Insurance, & Real Estate	$181,856	$6,548	$4,721,015	$80,983	$17,742	$9,493	$2,419	$42,944
Services	$1,147,326	$32,914	$12,678,321	$438,972	$106,978	$29,771	$7,080	$196,521
Unclassified	$1,063	$119	$12,914	$1,283	$0	$57	$0	$236
Not Categorized	$0	$0	$0	$0	$1,786	$0	$18,510	$0
Total Payroll	$3,355,495	$161,438	$39,135,228	$1,943,476	$509,440	$99,298	$82,119	$783,370
Total Employees	104,583	8,896	1,256,339	79,040	22,722	5,100	3,007	33,597

	Henderson [b]	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant	Wise	Total
Agriculture	$1,465	$469	$818	$946	$1,914	$1,261	$48,888	$813	$217,998
Mining	$5,093	$2,513	$1,345	$6,029	$2,625	$450	$207,609	$21,286	$1,161,237
Construction	$11,107	$740	$18,237	$5,964	$18,867	$10,010	$684,065	$5,233	$2,648,931
Manufacturing	$32,720	$0	$97,018	$50,426	$49,888	$28,744	$3,516,851	$27,688	$12,369,356
Transportation & Public Utilities	$14,262	$2,166	$9,788	$11,953	$8,207	$12,503	$1,323,903	$15,369	$6,140,890
Wholesale Trade	$7,469	$2,384	$16,130	$18,640	$17,771	$10,239	$1,149,130	$6,846	$6,548,208
Retail Trade	$38,943	$2,419	$38,929	$53,116	$49,935	$22,148	$1,772,518	$29,736	$6,741,979
Financial, Insurance, & Real Estate	$12,405	$1,653	$12,387	$13,150	$12,255	$8,657	$811,814	$6,807	$5,942,128
Services	$50,393	$3,388	$89,897	$60,270	$68,573	$31,618	$3,685,348	$26,926	$18,654,296
Unclassified	$74	$0	$218	$219	$282	$103	$5,532	$128	$22,228
Not Categorized	$0	$279	$0	$0	$0	$0	$0	$0	$20,575
Total Payroll	$173,931	$16,011	$284,767	$220,713	$230,317	$125,733	$13,205,658	$140,832	$60,467,826
Total Employees	10,318	945	14,024	11,711	12,091	6,510	514,017	6,848	2,089,748

Notes: a. Data are from U.S. Census 1995 economic data [4].
b. Data for Henderson County include the entire county.

1.2 *Water-Related Physical Features in Region C*

Most of Region C is in the upper portion of the Trinity Basin, with smaller parts in the Red, Brazos, Sulphur, and Sabine Basins. With the exception of the Red River Basin, the predominant flow of the streams is from northwest to southeast, as is true for most of Texas. The Red River itself flows west to east, forming the north border of Region C, and its major tributaries in Region C flow southwest to northeast. Figure 1-1 shows the major streams in Region C, which include the Brazos River, Clear Fork Trinity River, West Fork Trinity River, Elm Fork Trinity River, East Fork Trinity River, Trinity River, Red River, and numerous tributaries of the Trinity River. According to the Texas Parks and Wildlife Department, there are 324 streams of various sizes in Region C.

Figure 1.2 shows the average annual precipitation for Region C. Precipitation increases west to east from slightly more than 30 inches per year in western Jack County to more than 44 inches per year in the northeast corner of Fannin County [(5)]. Figure 1.3 shows average annual runoff, which follows a similar pattern of increasing from the west to the east [(5)]. (It is interesting to note that the percentage of rainfall that becomes runoff increases dramatically from west to east across Region C. While the average rainfall is about 1.5 times as great in the east as in the west, the runoff is almost 5 times as great in the east as in the west.) Figure 1.4 shows gross reservoir evaporation in Region C, which is higher to the west [(6)]. (Gross reservoir evaporation indicates the amount lost to evaporation from the surface of a reservoir.) The rate of evaporation from a reservoir surface exceeds rainfall throughout Region C, but the margin is much greater in the western part of the region than in the east. The patterns of rainfall, runoff, and evaporation result in more abundant water supplies in the eastern part of Region C than in the west.

Figure 1.5 shows the variations in annual streamflow for five U.S. Geological Survey (USGS) streamflow gages in Region C [(7)]. The four gages on tributaries have watersheds with limited development and show the natural variation of streamflows in this region. The Trinity River near Rosser gage is on the main stem of the Trinity River downstream from the Dallas-Fort Worth area. At this location, natural flow patterns have been substantially altered by reservoir development and by return flows of treated wastewater. Figure 1.6 shows seasonal patterns of median streamflows for the same five gages [(7)]. Return flows from the Dallas-Fort Worth area

Figure 1.2
Average Annual Precipitation

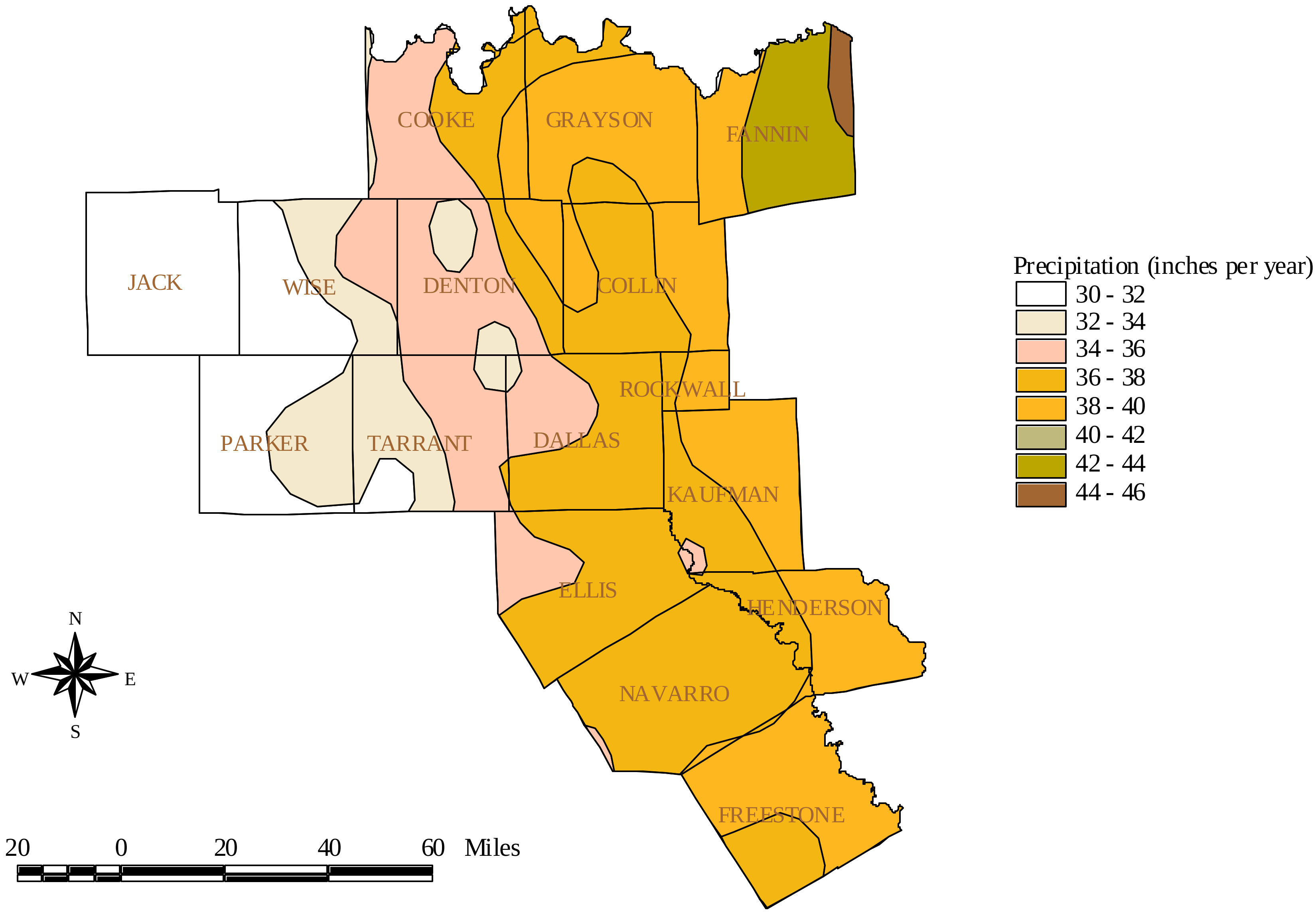


Figure 1.3
Average Annual Runoff

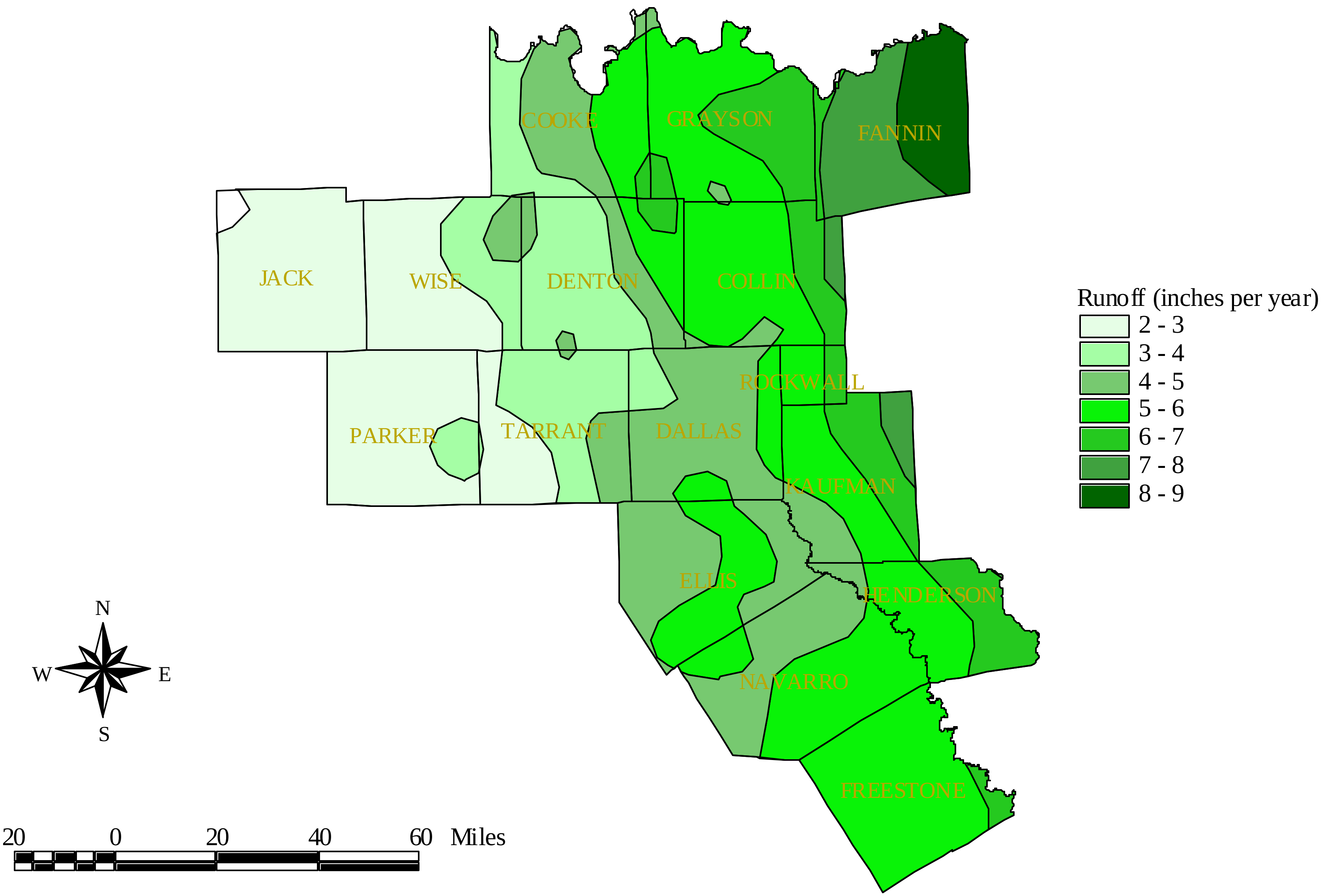
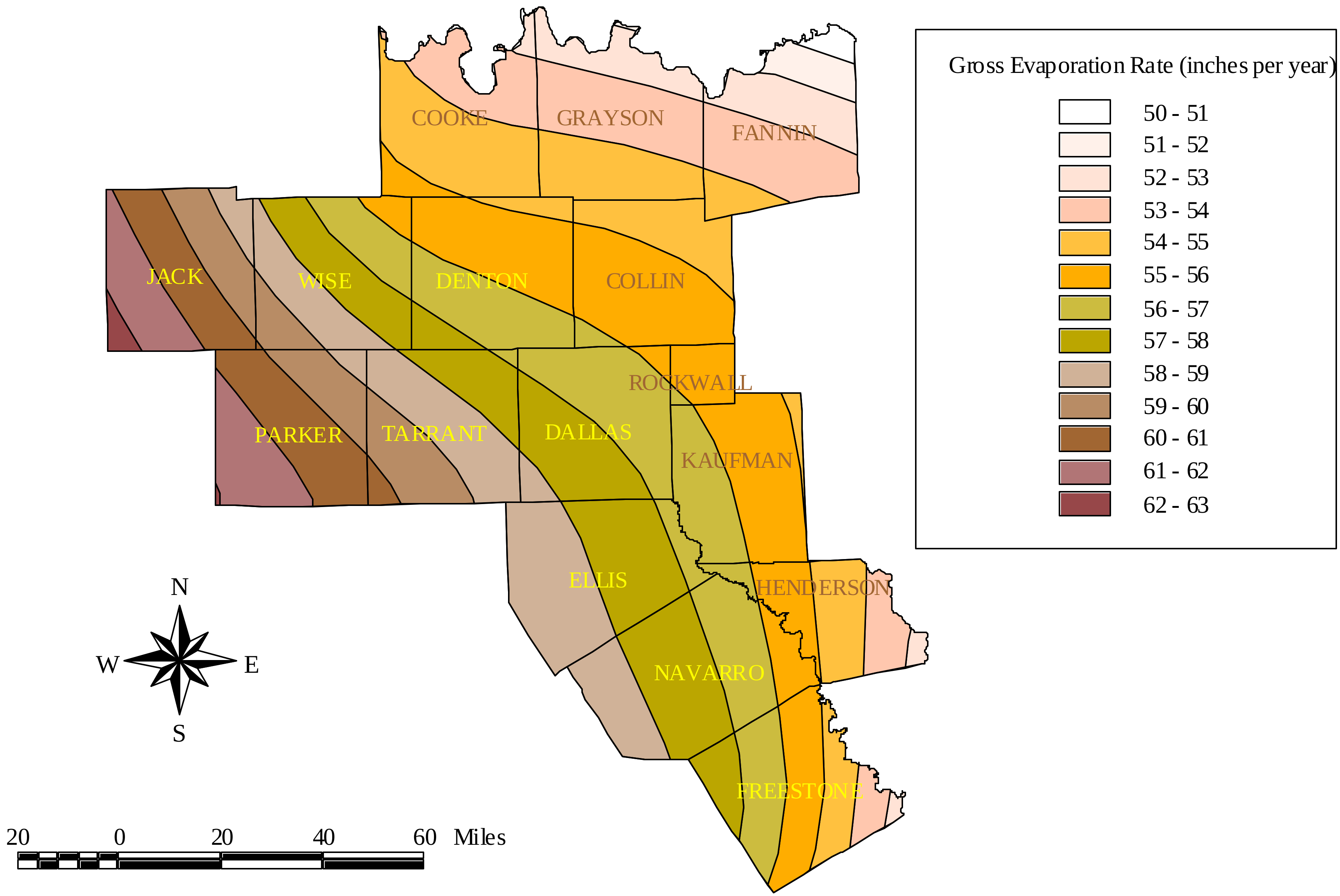


Figure 1.4
Average Annual Gross Evaporation



reduce seasonal variations in flow at the Rosser gage by significantly increasing summer flows compared to natural conditions.

Table 1.4 lists the 34 reservoirs in Region C with conservation storage over 5,000 acre-feet, all of which are shown in Figure I-1. These reservoirs and others outside of Region C provide most of the region's water supply. Reservoirs are necessary to provide a reliable surface water supply in this part of the state because of the wide variations in natural streamflow. Reservoir storage serves to capture high flows when they are available and save them for use during times of normal or low flow.

Figure 1.7 shows major aquifers in Region C, and Figure 1.8 shows minor aquifers [(8)]. The most heavily used aquifer in Region C is the Trinity aquifer, which supplies most of the groundwater used in the region. The Carrizo-Wilcox aquifer also outcrops in Region C in Navarro, Freestone, and Henderson Counties. Minor aquifers in Region C include the Woodbine aquifer, the Nacatoch aquifer, and a small part of the Queen City aquifer.

1.3 Current Water Uses and Demand Centers in Region C

Table 1.5 shows the total water use by county in Region C from 1980 through 1997, the most recent year for which data are available [(9)]. Water use in Region C has increased significantly since 1980, primarily in response to increasing population and municipal use. The historical record shows years of high use, including 1988 and 1996. 1998 and 2000 are not included in Table 1.5 because data have not yet been finalized, but preliminary figures show that 1998 and 2000 were also high use years. High use years are associated with dry weather, which causes higher municipal use due to increased outdoor water use (lawn watering). Table 1.6 shows water use for the same period by Texas Water Development Board use category. Figure 1.9 is a graph of the historical water use for Region C by category. Table 1.6 also shows statewide water use by category for 1997 and Region C use as a percent of statewide use. It is interesting to note that Region C, with 24.4 percent of Texas' population, had only 7.2 percent of the state's water use in 1997. This is primarily because Region C has very limited water use for irrigation, while irrigation use is more than 60 percent of total use for the state as a whole.

Table 1.7 shows the use by category by county in 1997, the most recent year for which water use data are available. About 85 percent of the current water use in Region C is for municipal supply, with manufacturing use as the second largest category, followed by steam electric power generation. Irrigation, mining, and livestock are relatively minor uses of water in Region C. The

Table 1.4
Major Reservoirs in Region C (Over 5,000 Acre-Feet of Conservation Storage)

Reservoir	Basin	Stream	County(ies)	Permitted Conservation Storage (Acre-Feet)	Owner	Water Right Holder(s)
Moss	Red	Fish Creek	Cooke	23,210	Gainesville	Gainesville
Texoma	Red	Red River	Grayson, Cooke	2,733,000	Corps of Engineers	Red River Authority, Greater Texoma UA, Denison, North Texas MWD, TXU Electric
Randell	Red	Unnamed Trib. Shawnee Creek	Grayson	5,400	Denison	Denison
Valley	Red	Sand Creek	Fannin, Grayson	15,000	TXU Electric	TXU Electric
Bonham	Red	Timber Creek	Fannin	13,000	Bonham MWA	Bonham
Coffee Mill	Red	Coffee Mill Creek	Fannin	8,000	USDA	U.S. Department of Agriculture
Kiowa	Trinity	Indian Creek	Cooke	7,000	Lake Kiowa POA Inc.	Lake Kiowa Property Owners Association, Inc.
Ray Roberts	Trinity	Elm Fork Trinity River	Denton, Cooke, Grayson	799,600	Corps of Engineers	Dallas and Denton
Lost Creek	Trinity	Lost Creek	Jack	11,961	Jacksboro	Jacksboro
Bridgeport	Trinity	West Fork Trinity River	Wise, Jack	387,000	TRWD	Tarrant Regional Water District
Lewisville	Trinity	Elm Fork Trinity River	Denton	618,400	Corps of Engineers	Dallas and Denton
Lavon	Trinity	East Fork Trinity River	Collin	380,000	Corps of Engineers	North Texas MWD
Weatherford	Trinity	Clear Fork Trinity River	Parker	19,470	Weatherford	Weatherford
Grapevine	Trinity	Denton Creek	Tarrant, Denton	161,250	Corps of Engineers	Park Cities MUD, Dallas, Grapevine
Eagle Mountain	Trinity	West Fork Trinity River	Tarrant, Wise	210,000	TRWD	Tarrant Regional Water District
Worth	Trinity	West Fork Trinity River	Tarrant	38,124	Fort Worth	Fort Worth
Benbrook	Trinity	Clear Fork Trinity River	Tarrant	88,250	Corps of Engineers	Tarrant Regional Water District, Benbrook WSA
Arlington	Trinity	Village Creek	Tarrant	45,710	Arlington	Arlington and TXU Electric
Joe Pool	Trinity	Mountain Creek	Dallas, Tarrant	176,900	Corps of Engineers	Trinity River Authority
Mountain Creek	Trinity	Mountain Creek	Dallas	22,840	TXU Electric	TXU Electric
North	Trinity	South Fork Grapevine Creek	Dallas	17,100	TXU Electric	TXU Electric
White Rock	Trinity	White Rock Creek	Dallas	21,345	Dallas	Dallas

Table 1.4, Continued

Reservoir	Basin	Stream	County(ies)	Permitted Conservation Storage (Acre-Feet)	Owner	Water Right Holder(s)
Ray Hubbard	Trinity	Elm Fork Trinity River	Dallas, Kaufman, Rockwall	490,000	Dallas	Dallas
Terrell	Trinity	Muddy Cedar Creek	Kaufman	8,712	Terrell	Terrell
Bardwell	Trinity	Waxahachie Creek	Ellis	54,900	Corps of Engineers	Trinity River Authority
Waxahachie	Trinity	Waxahachie Creek	Ellis	13,500	Ellis Co. WCID#1	Ellis Co. WCID#1
Cedar Creek	Trinity	Cedar Creek	Henderson, Kaufman	678,900	TRWD	Tarrant Regional Water District
Forest Grove	Trinity	Caney Creek	Henderson	20,038	TXU Electric	TXU Electric
Trinidad	Trinity	Off-channel	Henderson	6,200	TXU Electric	TXU Electric
Navarro Mills	Trinity	Richland Creek	Navarro	63,300	Corps of Engineers	Trinity River Authority
Halbert	Trinity	Elm Creek	Navarro	7,357	Corsicana	Corsicana
Richland-Chambers	Trinity	Richland Creek	Freestone, Navarro	1,135,000	TRWD	Tarrant Regional Water District
Fairfield	Trinity	Big Brown Creek	Freestone	50,600	TXU Electric	TXU Electric
Mineral Wells	Brazos	Rock Creek	Parker	7,065	Mineral Wells	Mineral Wells

Note: Data are from TNRCC water rights list [10] and other sources.

Figure 1.7
Major Aquifers in Region C Counties

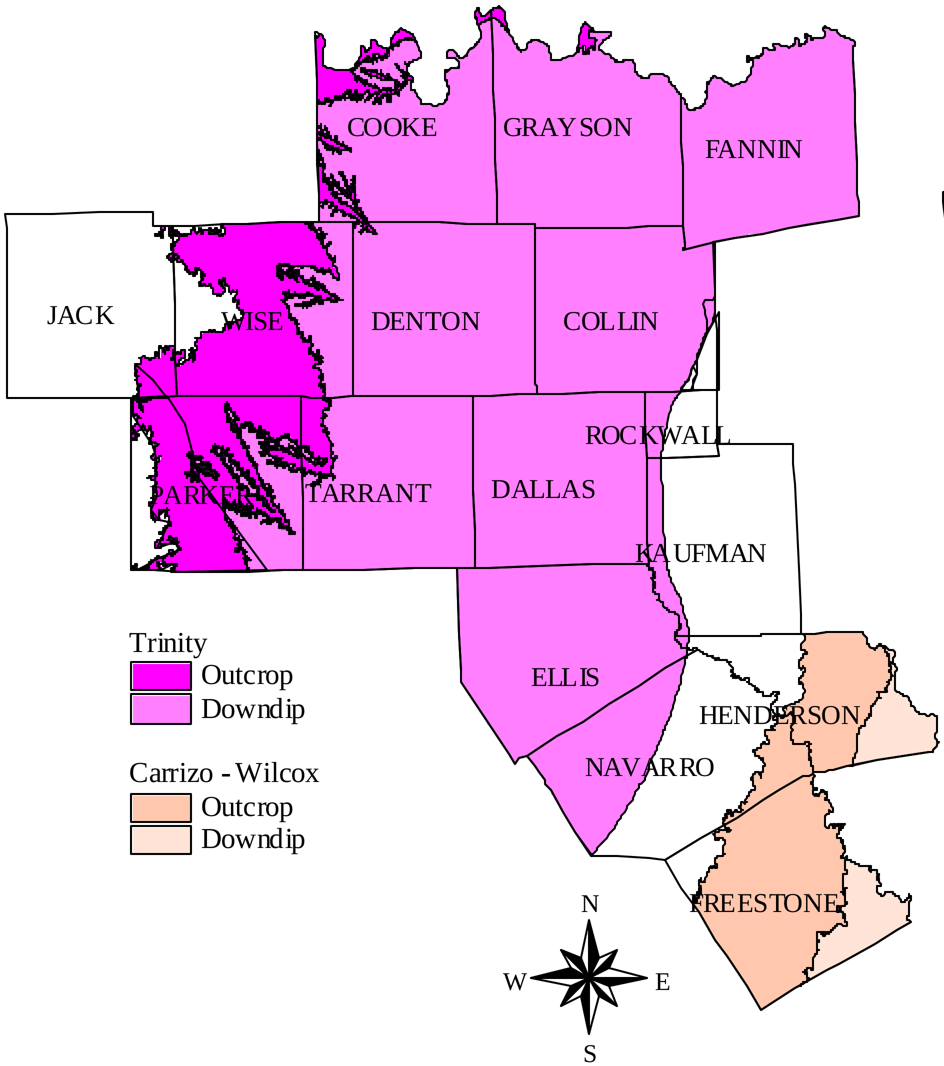
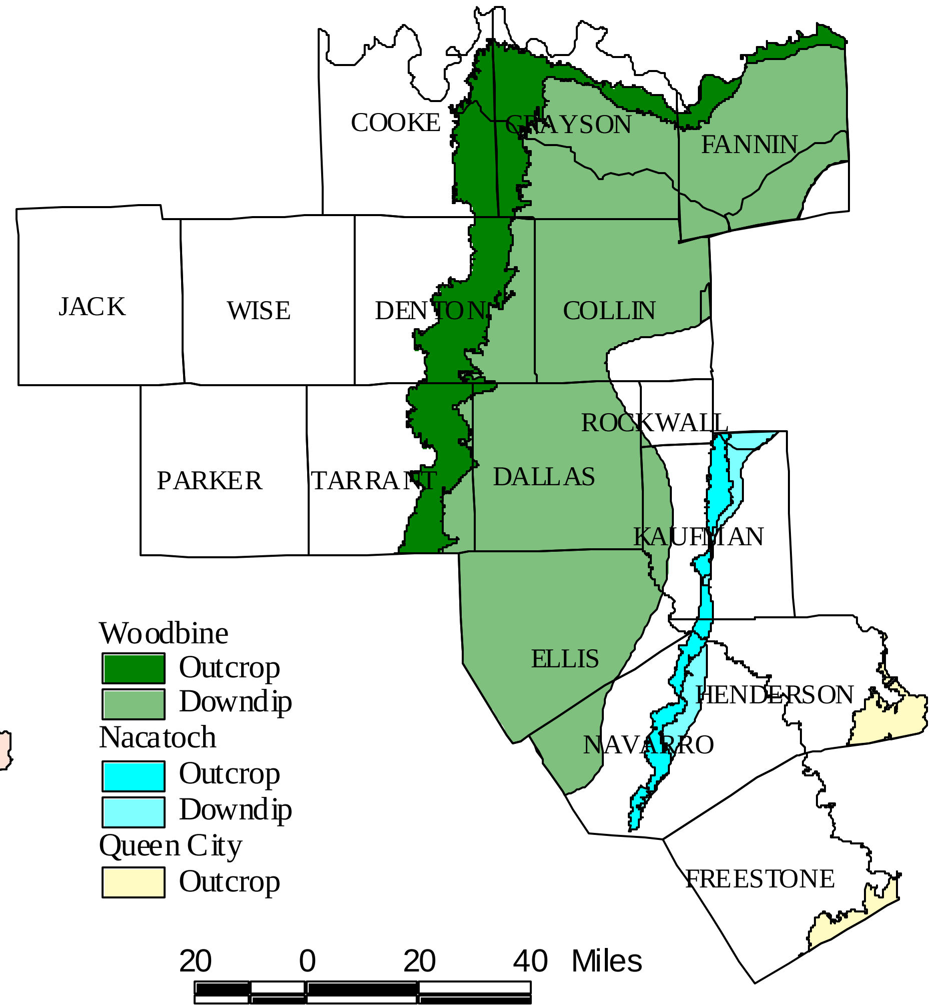


Figure 1.8
Minor Aquifers in Region C Counties



Note:
Outcrop is the area of the formation at the surface.
Downdip is the area of the formation below the surface.

Table 1.5
Historical Total Water Use by County in Region C (Acre-Feet)

County	Year							
	1980	1984	1985	1986	1987	1988	1989	1990
Collin	31,259	38,801	44,704	43,392	50,732	54,679	59,709	62,349
Cooke	7,286	7,673	7,623	7,857	7,057	7,600	6,841	7,406
Dallas	421,283	459,725	483,660	468,569	473,595	514,423	466,565	483,283
Denton	27,761	35,925	38,172	40,176	43,089	44,753	46,826	49,876
Ellis	12,452	17,493	18,444	14,843	15,543	18,540	18,683	18,967
Fannin	25,080	14,209	15,115	12,184	14,202	15,532	11,633	13,133
Freestone	18,846	21,447	18,120	19,962	18,317	22,028	18,729	17,155
Grayson	27,877	22,534	26,110	23,215	22,431	24,370	24,020	23,150
Henderson [b]	9,307	11,800	11,832	10,427	10,416	11,858	10,077	9,615
Jack	2,007	2,125	2,291	2,286	2,156	2,090	2,063	2,071
Kaufman	8,234	9,815	9,642	9,302	9,604	9,162	9,857	10,008
Navarro	9,152	9,790	8,811	8,051	8,289	8,801	7,968	9,234
Parker	11,179	8,732	10,729	10,733	10,500	10,698	10,854	11,236
Rockwall	2,696	4,418	4,588	4,751	4,362	5,089	4,319	5,273
Tarrant	241,850	239,252	248,695	252,954	261,305	277,871	267,645	285,033
Wise	15,895	12,402	12,149	15,032	15,930	16,323	12,355	15,219
Total	872,164	916,141	960,685	943,734	967,528	1,043,817	978,144	1,023,008

County	Year						
	1991	1992	1993	1994	1995	1996	1997
Collin	60,461	62,689	72,759	71,803	82,827	89,230	94,231
Cooke	7,781	8,047	8,643	9,044	8,330	8,429	8,534
Dallas	450,134	463,009	492,243	449,483	492,531	505,423	495,381
Denton	48,647	49,303	54,527	52,063	58,738	65,075	66,880
Ellis	17,218	16,726	18,567	17,650	17,799	19,721	20,368
Fannin	9,175	9,339	13,353	12,664	14,965	17,515	13,760
Freestone	18,278	16,569	17,659	18,477	17,262	20,608	15,446
Grayson	22,379	21,274	23,892	23,943	26,958	29,152	27,810
Henderson [b]	7,920	7,583	8,875	7,915	9,217	10,653	9,791
Jack	2,407	2,380	2,434	2,624	2,319	3,337	2,399
Kaufman	9,741	9,530	11,657	10,819	10,770	10,653	10,245
Navarro	8,714	8,372	9,107	8,838	8,598	10,558	10,540
Parker	11,839	10,231	11,268	11,505	11,231	12,372	12,600

Table 1.5, Continued

County	Year						
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Rockwall	5,076	4,718	5,462	5,495	6,212	6,566	6,437
Tarrant	264,569	248,053	274,763	264,769	273,657	291,406	283,626
Wise	15,094	14,605	20,869	23,594	24,396	25,688	30,608
Total	959,433	952,428	1,046,078	990,686	1,065,810	1,126,518	1,108,656

Notes: a. Data are from the Texas Water Development Board [9].
b. Data for Henderson County include only the part of the county in Region C.

Table 1.6
Historical Water Use by Category in Region C (Acre -Feet)

Year	Municipal	Manu-facturing	Steam Ele ctric	Irrigation	Mining	Livestock	Total
1980	666,010	100,657	53,009	23,993	10,114	18,381	872,164
1984	747,532	83,337	53,403	7,716	4,149	20,004	916,141
1985	789,077	81,998	51,661	12,404	6,386	19,159	960,685
1986	777,798	84,946	45,210	7,918	10,508	17,354	943,734
1987	801,530	79,017	48,503	7,817	13,437	17,224	967,528
1988	856,896	89,916	57,809	7,841	13,107	18,248	1,043,817
1989	801,595	97,859	47,433	6,640	7,153	17,464	978,144
1990	844,430	100,062	46,959	5,434	7,153	18,970	1,023,008
1991	798,811	89,141	36,951	4,441	10,948	19,141	959,433
1992	804,145	81,776	33,393	5,117	9,522	18,475	952,428
1993	879,038	81,043	39,175	10,749	17,478	18,595	1,046,078
1994	825,076	78,619	36,252	9,514	20,449	20,776	990,686
1995	897,591	76,036	40,321	11,693	20,324	19,845	1,065,810
1996	946,454	71,366	52,103	9,689	22,576	24,330	1,126,518
1997	942,004	79,048	35,673	10,451	23,283	18,197	1,108,656
State Total in 1997	3,429,392	1,521,336	325,890	9,529,808	246,673	338,004	15,391,103
% in Region C	27.5%	5.2%	10.9%	0.1%	9.4%	5.4%	7.2%

Note: Data are from the Texas Water Development Board [9].

Figure 1.9
Historical Water Use by Category in Region C

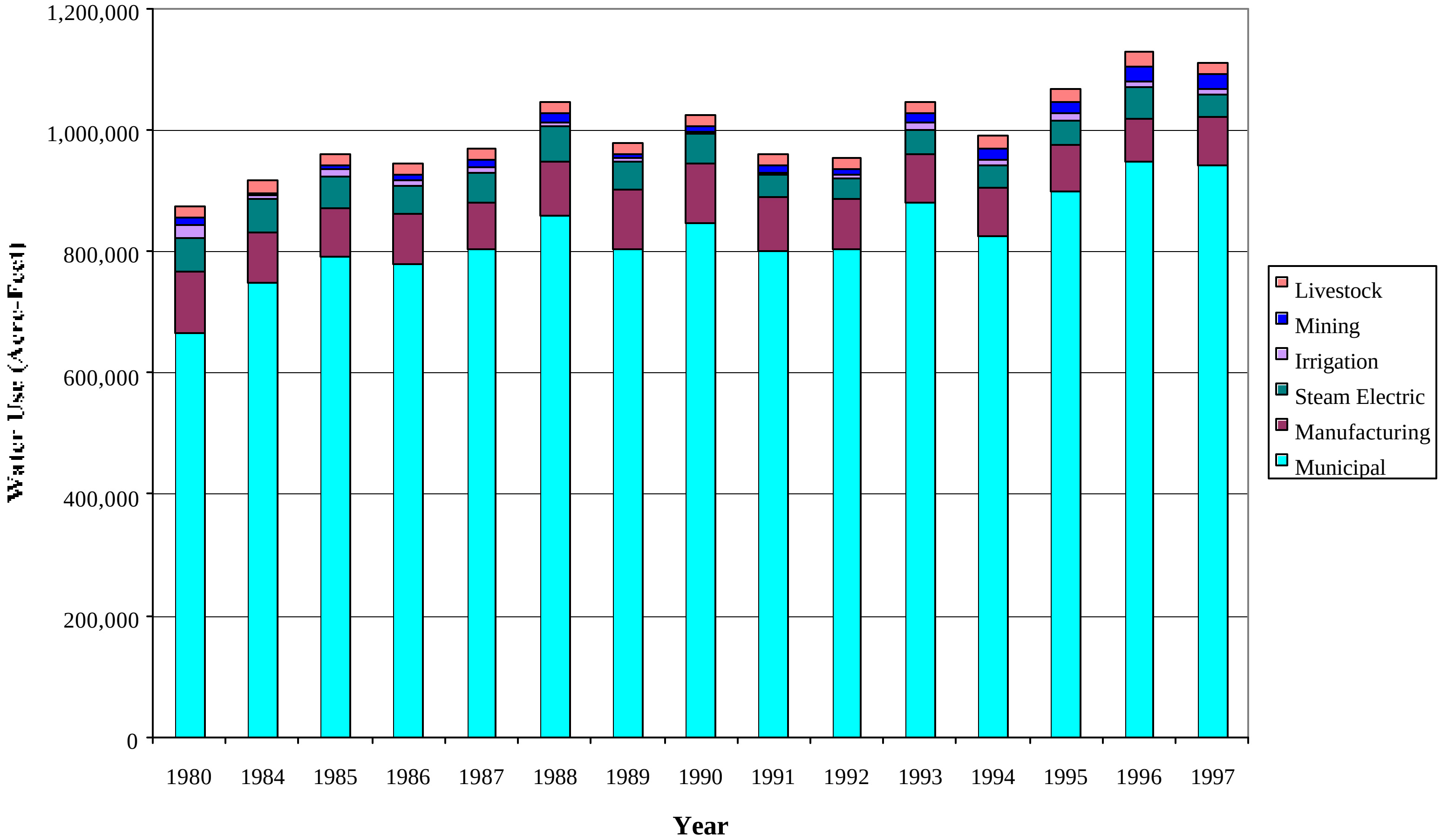


Table 1.7
1997 Water Use by Category by County (Acre-Feet)

County	Municipal	Manu-facturing	Steam Electric	Irrigation	Mining	Livestock	Total
Collin	89,214	1,832	1,661	93	341	1,090	94,231
Cooke	5,660	159	0	444	289	1,982	8,534
Dallas	450,099	28,575	11,802 [b]	1,317	2,990	598	495,381
Denton	63,525	886	122	472	139	1,736	66,880
Ellis	15,145	3,596	0	230	90	1,307	20,368
Fannin	4,060	345	4,967	3,038	161	1,189	13,760
Freestone	2,372	0	11,547	17	207	1,303	15,446
Grayson	15,670	6,547	0	3,512	1,058	1,023	27,810
Henderson [b]	7,413	93	797	29	631	828	9,791
Jack	1,048	0	0	4	433	914	2,399
Kaufman	8,282	641	0	135	75	1,112	10,245
Navarro	8,092	1,166	0	0	89	1,193	10,540
Parker	10,132	570	126	388	75	1,309	12,600
Rockwall	6,286	17	0	0	33	101	6,437
Tarrant	249,177	28,709	4,651	140	103	846	283,626
Wise	5,829	5,912	0	632	16,569	1,666	30,608
Total	942,004	79,048	35,673	10,451	23,283	18,197	1,108,656

Notes: a. Data are from the Texas Water Development Board [(9)].
b. Data for Henderson County include only the part of the county in Region C.

1997 water use in Tarrant and Dallas Counties was 70.3 percent of the total Region C use, and these two counties had 70.6 percent of the region's population in 1998.

In addition to the consumptive water uses discussed above, water is used for recreation and other purposes in Region C. Reservoirs for which records of visitors are maintained (primarily Corps of Engineers lakes with recreational facilities) draw millions of visitors each year in Region C. In addition, smaller lakes and streams in the region draw many visitors for fishing, boating, swimming, and other water-related recreational activities. Water in streams and lakes is also important to fish and wildlife in the region.

Table 1.8
Historical Sources of Water Supply in Region C

Year	Supply in Acre-Feet		
	Surface Water	Ground-water	Total
1980	779,799	92,365	872,164
1984	818,762	97,379	916,141
1985	858,607	102,078	960,685
1986	848,838	94,896	943,734
1987	871,038	96,490	967,528
1988	942,863	100,954	1,043,817
1989	884,663	93,481	978,144
1990	932,298	90,710	1,023,008
1991	874,846	84,587	959,433
1992	869,064	83,364	952,428
1993	959,840	86,238	1,046,078
1994	908,770	81,916	990,686
1995	981,168	84,642	1,065,810
1996	1,038,508	88,010	1,126,518
1997	1,020,639	88,017	1,108,656

Note: Data are from Texas Water Development Board (9).

1.4 Current Sources of Water Supply

Table 1.8 summarizes the total surface water and groundwater use in Region C from 1980 through 1997 (9), and Figure 1.10 shows the division of total water use between surface water and groundwater. Total water use has increased significantly since 1980, but groundwater use has actually decreased, with an increasing portion of the total supply coming from surface water. Since 1990, over 90 percent of the water use in Region C has been supplied by surface water. Table 1.9 shows the groundwater and surface water use by county and category for 1997, which is the most recent year for which data are available (9). Table 1.9 demonstrates some interesting points about water use in Region C:

- Although groundwater provides only 8 percent of the overall water use in Region C, it provides 63 percent of the irrigation use.
- Groundwater provides the majority of the total water use in Cooke and Grayson Counties and over 30 percent in Ellis, Fannin, Henderson, and Parker Counties.
- Groundwater provides all municipal water use in Cooke County and the majority of the municipal use in Fannin, Freestone, Grayson, Parker, and Wise Counties.

Figure 1.10
Historical Source of Supply in Region C

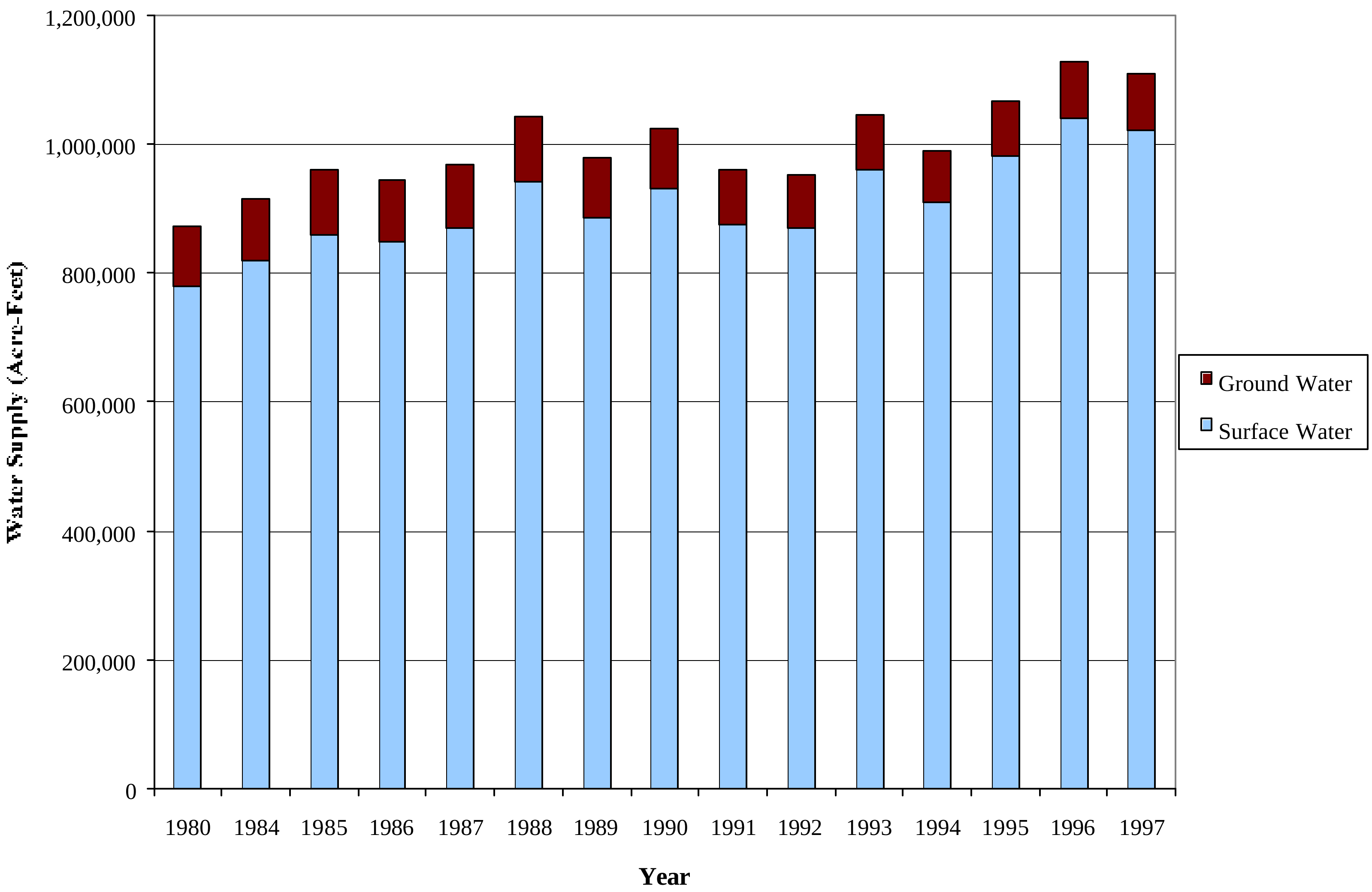


Table 1.9
Sources of Water Supply by County by Category in 1997 for Region C
- Values in Acre-Feet -

County	Water Type	Munic-ipal	Manu-facturing	Steam Electric	Irriga-tion	Mining	Live-stock	Total
Collin	Ground	2,756	228	2	0	0	109	3,095
	Surface	86,458	1,604	1,659	93	341	981	91,136
	Total	89,214	1,832	1,661	93	341	1,090	94,231
Cooke	Ground	5,660	159	0	288	52	991	7,150
	Surface	0	0	0	156	237	991	1,384
	Total	5,660	159	0	444	289	1,982	8,534
Dallas	Ground	2,058	730	0	474	1,385	60	4,707
	Surface	448,041	27,845	11,802	843	1,605	538	490,674
	Total	450,099	28,575	11,802	1,317	2,990	598	495,381
Denton	Ground	10,054	65	0	472	49	868	11,508
	Surface	53,471	821	122	0	90	868	55,372
	Total	63,525	886	122	472	139	1,736	66,880
Ellis	Ground	4,260	2,175	0	23	90	131	6,679
	Surface	10,885	1,421	0	207	0	1,176	13,689
	Total	15,145	3,596	0	230	90	1,307	20,368
Fannin	Ground	2,161	295	282	2,096	0	120	4,954
	Surface	1,899	50	4,685	942	161	1,069	8,806
	Total	4,060	345	4,967	3,038	161	1,189	13,760
Freestone	Ground	2,226	0	95	17	37	521	2,896
	Surface	146	0	11,452	0	170	782	12,550
	Total	2,372	0	11,547	17	207	1,303	15,446
Grayson	Ground	8,945	3,472	0	2,810	815	103	16,145
	Surface	6,725	3,075	0	702	243	920	11,665
	Total	15,670	6,547	0	3,512	1,058	1,023	27,810
Henderson [b]	Ground	2,194	22	0	20	466	497	3,199
	Surface	5,219	71	797	9	165	331	6,592
	Total	7,413	93	797	29	631	828	9,791
Jack	Ground	406	0	0	4	63	92	565
	Surface	642	0	0	0	370	822	1,834
	Total	1,048	0	0	4	433	914	2,399
Kaufman	Ground	199	0	0	1	0	111	311
	Surface	8,083	641	0	134	75	1,001	9,934
	Total	8,282	641	0	135	75	1,112	10,245

Table 1.9, Continued

County	Water Type	Munic-ipal	Manu-facturing	Steam Electric	Irriga-tion	Mining	Live-stock	Total
Navarro	Ground	143	1	0	0	89	119	352
	Surface	7,949	1,165	0	0	0	1,074	10,188
	Total	8,092	1,166	0	0	89	1,193	10,540
Parker	Ground	5,609	22	0	82	55	131	5,899
	Surface	4,523	548	126	306	20	1,178	6,701
	Total	10,132	570	126	388	75	1,309	12,600
Rockwall	Ground	146	0	0	0	0	10	156
	Surface	6,140	17	0	0	33	91	6,281
	Total	6,286	17	0	0	33	101	6,437
Tarrant	Ground	14,461	839	3	21	0	423	15,747
	Surface	234,716	27,870	4,648	119	103	423	267,879
	Total	249,177	28,709	4,651	140	103	846	283,626
Wise	Ground	3,278	12	0	272	259	833	4,654
	Surface	2,551	5,900	0	360	16,310	833	25,954
	Total	5,829	5,912	0	632	16,569	1,666	30,608
Region C	Ground	64,556	8,020	382	6,580	3,360	5,119	88,017
	Surface	877,448	71,028	35,291	3,871	19,923	13,078	1,020,639
	Total	942,004	79,048	35,673	10,451	23,283	18,197	1,108,656

Notes: a. Data are from the Texas Water Development Board [9].
b. Data for Henderson County include only the part of the county in Region C.

- Dallas and Tarrant Counties have 74 percent of the municipal water use in the region.
- Tarrant and Dallas Counties have 72 percent of the industrial water use in the region.
- Dallas and Freestone Counties have 65 percent of the steam electric power water use in the region.
- Fannin and Grayson Counties have 63 percent of the irrigation use in the region.
- Wise County has 71 percent of the mining use in the region.
- Livestock use is widely spread throughout the region.

Surface Water Sources

Table 1.10 lists the amount of surface water rights by TNRCC water rights category for each county in Region C[10]. Most of the surface water supply in Region C comes from major

Table 1.10

Surface Water Rights by County

County	Permitted Surface Water Diversions (Acre-Feet per Year)					
	Municipal	Industrial	Irrigation	Mining	Other	Total
Collin	100,000	4,000	3,920		23	107,943
Cooke	5,000		203			5,203
Dallas	171,085	19,806	12,260	100	1,531	204,782
Denton	1,392,700	10,300	6,416	3	391	1,409,810
Ellis	17,316	226	1,087		1	18,630
Fannin	5,462	10,140	15,626			31,228
Freestone	205,675	16,787	2,868	115	116	225,561
Grayson	130,580	14,004	1,990	100		146,674
Henderson [b]	172,700	21,178	5,074			198,952
Jack	1,487		341			1,828
Kaufman	6,000		807			6,807
Navarro	36,880	1,460	2,966		70	41,376
Parker	7,625	60,045	2,388			70,058
Rockwall			250			250
Tarrant	302,700	24,830	8,325	1,105	1,874	338,834
Wise	5,000		3,715	10,062		18,777
Total	2,560,210	182,776	68,236	11,485	4,006	2,826,713

Notes:
a. Data are from TNRCC water rights list [(10)].
b. Data for Henderson County include only the part of the county in Region C.
c. TNRCC does not have a separate category for steam electric rights. They are included in the industrial category.

reservoirs. Table 1.11 lists the permitted diversions, the actual 1996 diversions, and the estimated reliable supply from major reservoirs (over 5,000 acre-feet of conservation storage) in the region. For many of the reservoirs in the region, permitted diversions are significantly greater than the reliable supply. In planning to meet future needs, it is important to limit assumed availability to the reliable supply. Reliable supply is the supply that would be available in a drought of record condition. The reliable supplies shown in Table 1.11 are the lesser amount of the firm yield or the existing water rights.

Another major source of supply in Region C is surface water imported from other regions. Table 1.12 lists currently permitted imports of water to Region C from other regions. (No

Table 1.11

Water Rights, Diversion and Yield for Major Reservoirs

Reservoir	County(ies)	Water Right Number(s)[t]	Permitted Conservation Storage [n] (Acre-Feet)	Permitted Diversion[n] (Acre-Feet/Year)	1996 Use[o] (Acre-Feet)	Reliable Supply [q] (Acre-Feet/Year)
Moss	Cooke	4881	23,210	4,500	0	4,500 [a]
Texoma	Grayson, Cooke	4898, 2006, 4900, 4901, 5003	2,733,000	145,400	44,752	145,400 [j]
Randell	Grayson	4901	5,400	5,280	5,350 [r]	5,280 [a]
Valley	Fannin, Grayson	4900	15,000	10,000	9,996	N/A [m]
Bonham	Fannin	4925	13,000	5,340	1,577	5,340
Coffee Mill	Fannin	4915	8,000	0	0	0[j] (Recreation)
Kiowa	Cooke	2334A	7,000	0	0	0[j] (Recreation)
Ray Roberts	Denton, Cooke, Grayson	2335A, 2455A	799,600	799,600	90,155	110,000 [a]
Lost Creek	Jack	3313A	11,961	1,397	589	1,397 [p]
Bridgeport	Wise, Jack	3808A	387,000	15,000 [e]	3,019	15,000[w]
Lewisville	Denton	2348, 2456	618,400	598,900	148,612	110,800 [a]
Lavon	Collin	2410C	380,000	130,957 [h]	179,108	104,000 [a,l]
Weatherford	Parker	3356	19,470	5,220 [b]	2,845	2,000 [a]
Grapevine	Tarrant, Denton	2362, 2363, 2458B	161,250	161,250	47,024	23,100 [c]
Eagle Mountain	Tarrant, Wise	3809	210,000	159,600 [f]	75,150 [r]	86,600 [c,k]
Worth	Tarrant	3340	38,124	13,298	0 [s]	0 [k]
Benbrook	Tarrant	5157A	72,500	72,000	4,650	9,800 [a]
Arlington	Tarrant	3391	45,710	23,120	13,000	7,050 [a]
Joe Pool	Dallas, Tarrant	3404B	176,900	17,000	6,860	16,900 [a]
Mountain Creek	Dallas	3408	22,840	6,400	4,577 [u]	N/A [m]
North	Dallas	2365	17,100	1,000 [v]	1,796 [u]	0 [d]
White Rock	Dallas	2461	21,345	8,703	1,738	N/A [m]
Ray Hubbard	Dallas, Kaufman, Rockwall	2462C 2462D 2462E	490,000	89,700	80,525	63,100 [a]
Terrell	Kaufman	4972	8,712	6,000	3,594	1,650 [a]
Bardwell	Ellis	5021A	54,900	14,729 [l]	4,976	9,600
Waxahachie	Ellis	5018	13,500	3,570	1,757	2,400 [a]
Cedar Creek	Henderson, Kaufman	4976A	678,900	175,000	45,251	175,000 [c]

Table 1.11, Continued

Reservoir	County(ies)	Water Right Number(s)[t]	Permitted Conservation Storage [n] (Acre-Feet)	Permitted Diversion[n] (Acre-Feet/Year)	1996 Use[o] (Acre-Feet)	Reliable Supply [q] (Acre-Feet/Year)
Forest Grove	Henderson	4983	20,038	9,500 [g]	805 [u]	N/A [m]
Trinidad	Henderson	4970	6,200	4,000	4,000	4,000 [c]
Navarro Mills	Navarro	4992	63,300	19,400	6,236	19,400 [j]
Halbert	Navarro	5030	7,357	4,003	2,238	600 [a]
Richland-Chambers	Freestone, Navarro	5030, 5035A	1,135,000	223,650	119,594	223,650 [c]
Fairfield	Freestone	5040	50,600	14,150	0	N/A [m]
Mineral Wells	Parker	4039	7,065	2,520	0	1,500 [a]
Total				2,735,187	980,167	1,161,137

Notes:
a. Reliable supply for these reservoirs is from 1997 *Water for Texas* (11).
b. Diversion does not include 59,400 acre-feet per year of non-consumptive industrial use.
c. Reliable supply is from computations by Freese and Nichols.
d. Reliable supply depends on water purchased from Dallas.
e. Release of 78,000 acre-feet per year for diversion and use from Eagle Mountain Lake is also authorized.
f. Permitted diversion includes water released from Lake Bridgeport.
g. Permitted diversion does not include non-consumptive use.
h. Permitted diversion includes reuse of up to 26,957 acre-feet per year of return flows.
i. Permitted diversion includes reuse of up to 5,129 acre-feet per year of return flows.
j. Reliable supply is limited to permitted diversion.
k. Eagle Mountain Lake reliable supply is the total for Lake Bridgeport, Eagle Mountain Lake, and Lake Worth.
l. Reliable supply does not include reuse.
m. Reliable supplies are not readily available for these projects.
n. Permitted conservation storage and permitted diversions are from TNRCC permits (12).
o. 1996 use is from TNRCC (13) and TWDB records (9). Tarrant Regional Water District records show somewhat different diversions for Bridgeport, Eagle Mountain, Benbrook, Cedar Creek and Richland-Chambers.
p. Reliable supply is from HDR (14).
q. Reliable supply is the lesser of firm yield and permitted diversion.
r. Includes Eagle Mountain Lake Bridgeport (non-local), and Lake Worth.
s. Included in Eagle Mountain.
t. Water right numbers are Certificate of Adjudication numbers. For permits issued since adjudication, they are the application number.
u. 1996 use is according to TXU Electric records as reported to TNRCC.
v. Additional use (beyond the water right) is based on purchased water.
w. Bridgeport local use only.

Table 1.12

Permitted Importation of Water to Region C

Destination	Source	Source Region	Source Basin	Destination Basin	Permitted Amount (Acre-Feet/Year)	Raw or Treated	Status
North Texas MWD	Lake Chapman [b]	D	Sulphur	Trinity	54,000	Raw	Operating
Irving	Lake Chapman [b]	D	Sulphur	Trinity	54,000	Raw	Partially Developed
Upper Trinity RWD	Lake Chapman [b]	D	Sulphur	Trinity	16,106	Raw	Partially Developed
Dallas	Lake Tawakoni	D	Sabine	Trinity	190,480	Raw	Operating
Dallas	Lake Fork	D	Sabine	Trinity	120,000	Raw	Not Yet Developed
Dallas	Lake Palestine	I	Neches	Trinity	114,337	Raw	Not Yet Developed
Athens [c]	Lake Athens	I	Neches	Trinity	8,500	Treated	Operating
Terrell	Lake Tawakoni	D	Sabine	Trinity	10,090	Raw	Operating
TXU Big Brown Plant	Lake Livingston[d.]	H	Trinity	Trinity	16,000	Raw	Operating

Notes: a. Information is from previous work by Freese and Nichols.
b. Lake Chapman was formerly Cooper Lake.
c. Most of Athens is in the Trinity Basin.
d. Use is an upstream diversion based on Lake Livingston water right. Contract allows 20,000 acre per year, with a maximum of 48,000 acre-feet over 3 years.

special permit is required if importation from another region does not involve interbasin transfers, but all significant imports to Region C except TRA's upstream sale from Lake Livingston currently involve interbasin transfers and thus require interbasin transfer permits.) Figure I-1 shows the surface water reservoirs that provide these imports. There is also small-scale importation of treated water in parts of the region, where small suppliers purchase water that originates in other regions.

Groundwater Sources

Table 1.13 lists historical groundwater pumping by aquifer for Region C [(9)]. Table 1.14 shows the 1997 pumping by county and aquifer [(9)]. (Note that the pumping totals do not match use totals given in Tables 9 and 10. The Texas Water Development Board supplied both of these sets of data. The discrepancy is probably due to water that is pumped in one county and used in

Table 1.13
Historical Groundwater Pumping by Aquifer in Region C

Year	Pumping by Aquifer (Acre-Feet)						
	Trinity	Woodbine	Carrizo-Wilcox	Nacatoch	Queen City	Undifferent-iated/Other	Total
1980	65,200	12,898	4,745	424	56	1,734	85,057
1984	74,768	13,210	6,470	283	66	1,686	96,483
1985	77,760	16,324	6,579	325	59	1,501	102,548
1986	73,464	13,654	6,317	269	66	1,485	95,255
1987	74,728	14,861	5,716	253	49	1,444	97,051
1988	78,344	13,979	6,697	277	65	1,434	100,796
1989	71,443	14,332	5,328	278	63	1,211	92,655
1990	69,295	13,486	5,305	256	63	1,212	89,617
1991	63,484	13,256	4,998	311	64	1,447	83,560
1992	61,322	14,009	5,266	238	62	1,391	82,288
1993	61,089	16,330	5,526	241	58	1,881	85,125
1994	57,110	13,408	5,808	244	60	4,134	80,764
1995	57,241	15,349	6,117	285	62	4,677	83,731
1996	60,589	14,849	6,464	316	76	4,452	86,746
1997	60,032	15,423	5,873	285	58	3,938	85,609

Note: Data are from the Texas Water Development Board [9].

Table 1.14
1997 Groundwater Pumping by County and Aquifer

County	1997 Pumping by Aquifer (Acre-Feet)						
	Trinity	Woodbine	Carrizo-Wilcox	Nacatoch	Queen City	Undifferent-iated/Other	Total
Collin	946	1,190				309	2,445
Cooke	7,096						7,096
Dallas	4,018	589				479	5,086
Denton	9,423	1,681					11,104
Ellis	3,871	2,493					6,364
Fannin	526	2,452				2,096	5,074
Freestone			2,872		28	34	2,934
Grayson	9,650	6,866				32	16,548
Henderson[b]			2,933		30	132	3,095
Jack	5					560	565
Kaufman		70		228			298
Navarro		82	68	57		104	311

Table 1.14, Continued

County	1997 Pumping by Aquifer (Acre-Feet)						
	Trinity	**Woodbine**	**Carrizo-Wilcox**	**Nacatoch**	**Queen City**	**Undifferent-iated/Other**	**Total**
Parker	5,629					24	5,653
Rockwall						156	156
Tarrant	14,419						14,419
Wise	4,449					12	4,461
Total	60,032	15,423	5,873	285	58	3,938	85,609

Notes: a. Data are from the Texas Water Development Board [9].

b. Data for Henderson County include only the part in Region C.

another.) The Trinity aquifer is by far the largest source of groundwater in Region C, providing 70 percent of the total groundwater pumped in 1997. (The Trinity aquifer is sometimes called the Trinity Sands and includes the Antlers, Twin Mountain, Glen Rose, and Paluxy formations[15].) The Woodbine and Carrizo-Wilcox aquifers provided 18 and 7 percent of the 1997 totals, with the Nacatoch and Queen City aquifers providing less than one percent and 5 percent from other and undifferentiated aquifers. Groundwater pumping is highest in Grayson, Tarrant, and Denton Counties. These three counties have 49 percent of the region's total groundwater pumping.

Water Reclamation

Over half of the water used for municipal supply in Region C is discharged as treated effluent from wastewater treatment plants, making wastewater reclamation and reuse a potentially significant source of additional water supply. At present, only a fraction of the region's treated wastewater is actually reclaimed and reused in the region. There are currently a number of water reclamation projects in Region C that reuse treated wastewater as a water source for non-potable uses such as irrigation of golf courses. In addition, there are sizable return flows of treated wastewater upstream from many Region C reservoirs. If the reservoir's water rights exceed its firm yield without return flows, as is the case for many Region C reservoirs, return flows will increase the reliable supply from the reservoir. If the reservoir's water rights do not exceed its firm yield, a water right must be obtained to allow indirect reuse of return flows. Current permits for indirect reuse in Region C include the following:

- Trinity River Authority sells treated wastewater from its Central Wastewater Treatment Plant in Dallas County to the Dallas County Utility and Reclamation District.
- North Texas Municipal Water District has a permit to reuse treated wastewater from its Wilson Creek Wastewater Treatment Plant through rediversion from Lake Lavon.
- The Trinity River Authority has permits for future reuse of wastewater returned to the Lake Bardwell watershed from the City of Ennis and the City of Waxahachie.

The largest wastewater treatment plants in Region C discharge into the Trinity River and its tributaries downstream from all Region C reservoirs. Tarrant Regional Water District is currently pursuing a major reuse project that will use a portion of this return flow, the Trinity River Authority has a reuse permit pending before TNRCC for the return flows from its wastewater treatment plants, and Dallas and other Region C suppliers have also considered future reclamation projects. Additional discussion on the reuse of treated wastewater is included below in Section 1.6.

Springs in Region C

There are no springs in Region C that are currently used as a significant source of water supply. Springs were important sources of water supply to Indians and in the initial settlement of the area and had great influence on the initial patterns of settlement. Groundwater development and the resulting water level declines have caused many springs to disappear and greatly diminished the flow from those that remain[16].

The TPWD has identified a number of small to medium-sized springs in Region C[17]. Table 1.15 shows the distribution and number of these springs as of 1980. Former springs are springs that have run dry due to groundwater pumping, sedimentation caused by surface erosion, or other causes.

1.5 Water Providers in Region C

Water providers in Region C include regional wholesale suppliers such as river authorities and some water districts, and retail suppliers (cities and towns, water supply corporations, special utility districts, and private water companies.) Cities and towns provide most of the retail water service in Region C, with significant contributions from other types of suppliers.

Table 1.15
Distribution and Estimated Size of Springs and Seeps

County	Medium (2.8 – 28 cfs)	Small (0.28 – 2.8 cfs)	Very Small (0.028 – 0.28 cfs)	Seep (Less than 0.028 cfs)	Former
Collin	0	3	10	1	4
Cooke	0	3	9	3	1
Dallas	2	6	2	0	4
Denton	0	3	8	1	1
Ellis	0	0	0	0	1
Fannin	0	3	6	3	1
Grayson	0	2	12	1	1
Parker	0	8	3	2	6
Rockwall	0	0	1	0	2
Tarrant	3	6	1	3	5
Wise	0	7	4	3	2

Note: Data are from Texas Parks and Wildlife Department [(17)].

Regional Wholesale Water Suppliers

There are six entities which provide regional water service in Region C and do not serve as retail suppliers: Tarrant Regional Water District, North Texas Municipal Water District, the Trinity River Authority, Upper Trinity Regional Water District, Greater Texoma Utility Authority, and the Dallas County Park Cities Municipal Utility District.

Tarrant Regional Water District (TRWD). Table 1.16 is a list of 1997 sales by the Tarrant Regional Water District, which totaled 258,448 acre-feet. TRWD supplies raw water to customers in Tarrant County and in the vicinity of its reservoirs. TRWD owns and operates Lake Bridgeport, Eagle Mountain Lake, Cedar Creek Lake, and Richland-Chambers Lake. The district's water supply system also includes Lake Arlington (owned by Arlington), Lake Worth (owned by Fort Worth), and Lake Benbrook (owned by the Corps of Engineers, with TRWD holding water rights), as well as a substantial water transmission system. The TRWD system has a current firm yield of slightly less than 500,000 acre-feet per year. In addition to its current customers, the district has commitments for long-term water supply to Weatherford and

Table 1.16

1997 Sales by Tarrant Regional Water District

Customer	Source(s)	1997 Raw Water Sales (Acre -Feet)
Fort Worth	Cedar Creek/Richland-Chambers	78,844
Fort Worth	Eagle Mountain	73,620
Fort Worth	Benbrook	884
Arlington	Cedar Creek/Richland-Chambers	56,337
TRA	Cedar Creek/Richland-Chambers	25,402
TXU Electric	Eagle Mountain	4,073
TXU Electric	Arlington	1,270
Mansfield	Cedar Creek/Richland-Chambers	3,699
Benbrook Water and Sewer Authority	Benbrook	2,601
Azle	Eagle Mountain	1,390
Bridgeport	Bridgeport	1,282
West Cedar Creek MUD	Cedar Creek/Richland-Chambers	1,226
Mabank	Cedar Creek/Richland-Chambers	1,061
East Cedar Creek FWSD	Cedar Creek/Richland-Chambers	1,058
Wise County WSD	Bridgeport	1,046
River Oaks	Eagle Mountain	799
Ridglea Country Club	Benbrook	695
Southwest Water Co.	Cedar Creek/Richland-Chambers	497
Walnut Creek SUD	Bridgeport	467
West County Rural WSC	Bridgeport	339
Community WSC	Eagle Mountain	307
Kemp	Cedar Creek/Richland-Chambers	300
Runaway Bay	Bridgeport	229
Springtown	Eagle Mountain	183
Star Harbor	Cedar Creek	153
Mira Vista Country Club	Benbrook	148
Pinnacle Club	Cedar Creek	130
Cedar Creek Country Club	Cedar Creek	102
Bay Golf Holdings	Bridgeport	101
Trident (Warren Petroleum)	Cedar Creek	72
Texas Industries	Bridgeport	60
Country Day School	Benbrook	46
Shady Oaks Country Club	Eagle Mountain	14
Bill Sisul	Cedar Creek	8
Golf Driving Range	Cedar Creek	2
Trinity Materials	Bridgeport	2
Golf Driving Range	Arlington	1
Total		258,448

Note: Data were provided by the Tarrant Regional Water District.

Benbrook, as well a commitment to supply water for users in Ellis County through the Trinity River Authority.

North Texas Municipal Water District (NTMWD). Table 1.17 is a list of 1997 sales by the North Texas Municipal Water District, which totaled 168,247 acre-feet. NTMWD supplies treated water to customers in suburban communities north and east of Dallas. The district obtains raw water from water rights in Lake Lavon, Lake Texoma, and Chapman Lake, all of which are owned and operated by the Corps of Engineers. The district has a water treatment plant on Lake Lavon, and water from all three reservoirs is blended in Lake Lavon before it is withdrawn and treated. NTMWD's current permitted raw water supply is 270,700 acre-feet per year. In addition to providing treated water, the district also owns and/or operates a number of wastewater treatment plants in Region C.

Trinity River Authority (TRA). The Trinity River Authority serves as a regional supplier through a number of projects in Region C:

- TRA holds water rights in Joe Pool Lake, Navarro Mills Lake, and Bardwell Lake, all owned and operated by the Corps of Engineers. TRA sells raw water from these lakes for use in Region C. (TRA has contracts to sell Joe Pool Lake water to Midlothian, Duncanville, Cedar Hill, and Grand Prairie. Midlothian and Grand Prairie are currently using water from the lake.)
- TRA sells raw water to TXU Electric for use in the Big Brown Steam Electric Station on Lake Fairfield. This water is diverted from the Trinity River under water rights held by TRA in Lake Livingston downstream, in Region H.
- TRA has a regional treated water system in northeast Tarrant County, which uses raw water delivered by the Tarrant Regional Water District system through Lake Arlington.
- TRA has a commitment to sell raw water from the Tarrant Regional Water District to water suppliers in Ellis County in the future and is now selling water to some Ellis County entities.

Table 1.18 lists the 1997 sales by Trinity River Authority in Region C, which totaled 22,217 acre-feet of treated water from the Tarrant County Water Supply System and 15,220 acre-feet of raw water. In addition to its raw and treated water sales, TRA operates a number of regional wastewater treatment projects in Region C.

Upper Trinity Regional Water District (UTRWD). Table 1.19 lists the 1997 water sales by the Upper Trinity Regional Water District, which totaled 3,421 acre-feet. UTRWD operates a regional water supply system in Denton County. The district, which has purchased and resold treated water from other suppliers in the past, began operation of its own water treatment plant

Table 1.17
1997 Sales by North Texas Municipal Water District

Customer	Total Treated Water Sales (Acre-Feet)
Plano	47,141
Garland	33,836
Richardson	24,895
Mesquite	17,616
McKinney	9,176
Allen	6,278
Rowlett	5,642
Frisco	4,282
Rockwall	4,057
Wylie	1,709
Forney	1,484
Sachse	1,076
Kaufman	907
Farmersville	821
Princeton	813
North Collin WSC	724
Kaufman 4-1	708
Fairview	662
Royse City	647
Sunnyvale	625
Lucas	532
Cash WSC	510
Caddo Basin SUD	478
East Fork WSC	463
Murphy	425
Parker	397
Milligan WSC	313
Forney Lake WSC	310
Lavon WSC	307

Table 1.17, Continued

Customer	Total Treated Water Sales (Acre-Feet)
Wylie NE WSC	290
Mt. Zion WSC	263
Gastonia-Scurry WSC	240
Seis Lagos MUD	138
College Mound WSC	132
Nevada WSC	121
Rose Hill WSC	94
Fate	85
Josephine	47
Total	168,247

Notes:
a. Data were provided by the North Texas Municipal Water District.
b. All sales are from the NTMWD system, which draws water from Lake Lavon, Lake Texoma, and Lake Chapman.

Table 1.18
1997 Sales by Trinity River Authority

Customer	1997 Water Sales (Acre-Feet)			Source
	Treated	Raw	Total	
Bedford	6,784		6,784	Tarrant County System (TRWD)
Corsicana		6,323	6,323	Navarro Mills
Euless	4,817		4,817	Tarrant County System (TRWD)
North Richland Hills	3,922		3,922	Tarrant County System (TRWD)
Midlothian		3,825	3,825	Joe Pool
Colleyville	3,562		3,562	Tarrant County System (TRWD)
Grapevine	3,132		3,132	Tarrant County System (TRWD)
Ennis		2,643	2,643	Bardwell
TXU Electric [b]		2,039	2,039	Livingston (Trinity River)
Post Oak WSC		257	257	Navarro Mills
Dawson		133	133	Navarro Mills
Total	22,217	15,220	37,437	

Notes: a. Data are from the Texas Water Development Board [(9)].
b. Water use would be greater in dry years. For example, 1996 water use was 12,682 acre-feet.

Table 1.19
1997 Sales by the Upper Trinity Regional Water District

Customer	1997 Treated Water Sales (Acre-Feet)
Flower Mound	1,173
Corinth	827
Lake Cities MUA	593
Highland Village	511
Bartonville WSC	196
Argyle WSC	109
Denton County FWSD	12
Total	3,421

on Lake Lewisville in 1998, and 1998 sales were more than double the 1997 level, at 7,684 acre-feet. UTRWD has a contract with the City of Commerce to divert up to 16,106 acre-feet per year of raw water from Lake Chapman in the Sulphur River Basin and is currently working with the City of Irving to develop a delivery system to bring that water to Lake Lewisville. UTRWD also has contracts to buy raw water from Dallas and Denton. In addition to its water supply activities, UTRWD provides regional wastewater treatment services in Denton County.

Dallas County Park Cities Municipal Utility District (PCMUD). Table 1.20 shows the 1997 treated water sales by Dallas County Park Cities Municipal Utility District, which totaled 9,244 acre-feet. PCMUD has a water right to divert 50,000 acre-feet per year from Lake Grapevine, but its share of the firm yield from Lake Grapevine is considerably less than 50,000 acre-feet per year. The district operates a water treatment plant and sells treated water from Lake Grapevine to Highland Park and University Park.

Table 1.20
1997 Sales by Dallas County Park Cities Municipal Utility District

Customer	1997 Treated Water Sales (Acre-Feet)	Source
University Park	5,842	Lake Grapevine
Highland Park	3,402	Lake Grapevine
Total	9,244	

Note: Data are from the Texas Water development Board [9]

Greater Texoma Utility Authority (GTUA). In 1997, the Greater Texoma Utility Authority provided 7,184 acre-feet of raw water from Lake Texoma to Sherman. GTUA has water rights for 25,000 acre-feet per year from Lake Texoma and sells raw water to Sherman, which operates a desalination and treatment plant. GTUA has water available to sell to other customers. The authority also operated wastewater treatment plants for several communities in the Red River Basin.

Retail Water Suppliers

Cities and towns provide most of the retail water service in Region C, and some cities also serve as wholesale suppliers by selling treated water to other water suppliers. Table 1.21 lists the cities in Region C with over 500 acre-feet of wholesale water sales in 1997. Among cities, Dallas and Fort Worth are by far the largest wholesale water suppliers. Table 1.22 lists all retail suppliers in Region D with over 500 acre-feet of municipal retail sales in 1997.

Major Water Providers

TWDB Senate Bill One regulations require additional data development for "major providers of water for municipal and manufacturing purposes." TWDB rules state that "the definition of a major water provider will be determined by the RWPG based on the characteristics and needs of the region." The rules also provide this suggested definition: "A major water provider is an entity which delivers and sells a significant amount of raw or treated water for municipal and/or manufacturing use on a wholesale and/or retail basis. The entity can be public or private (non-profit or for-profit). Examples include municipalities with wholesale customers, river authorities, and water districts."

There are no implications of designation as a "major water provider" except for the additional data tables required by TWDB. The major water provider data is a different way of grouping water supply information. An entity that is not designated as a major water provider will still be included in the regional water plan. TWDB gave a list of "samples of entities that a RWPG might select as MWPs" for each region. In Region C, the sample entities listed were North Texas Municipal Water District, Tarrant Regional Water District, Trinity River Authority, and Dallas Water Utilities.

Table 1.21
1997 Wholesale Sales by Cities

City	1997 Wholesale Sales to Other Suppliers (Acre-Feet)	Major Customers (Over 500 Acre-Feet)
Dallas	148,281	Irving, Carrollton, Grand Prairie, Lewisville, Farmers Branch, De Soto, Flower Mound, Duncanville, Coppell, Addison, Cedar Hill, Lancaster, TXU Electric (North Lake Plant and Lake Hubbard Plant), The Colony, Dallas Co. WCID#6, D/FW Airport, Seagoville, Hutchins, City of Denton
Fort Worth	39,521	North Richland Hills, Hurst, Haltom City, Southlake, Keller, Burleson, Saginaw, Forest Hill, D/FW Airport, White Settlement, Trophy Club MUD#1, Tarrant Co. MUD#1, Richland Hills, Grand Prairie, Crowley, Westover Hills, Naval Air Station
North Richland Hills	3,125	Watauga
Midlothian	2,788	Rockett SUD
Corsicana	2,754	Rice Water Supply and Sewer Corp.
Denton	1,484	Upper Trinity Regional Water District
Rockwall	1,328	R-C-H WSC
McKinney	1,224	North Collin WSC
Mineral Wells	981	
Terrell	931	
Lewisville	905	
Cedar Hill	893	
Mabank	599	
Forney	538	
Keller	513	

Note: Data are from the Texas Water Development Board [9].

Table 1.22
Major Retail Water Suppliers in Region C (More than 500 Acre-Feet in 1997)

Supplier	Type	Primary County	Other County(ies)	1997 Sales in Acre-Feet				
				Municipal Wholesale	Manu-facturing	Municipal Retail	Other	Total
Dallas	Municipal	Dallas	Collin, Kaufman, Denton, Rockwall	148,281	15,473	274,559	5,563	443,876
Fort Worth	Municipal	Tarrant		39,521	8,639	106,668		154,828
Arlington	Municipal	Tarrant		180	1,918	54,223		56,321
Plano	Municipal	Collin	Denton	15	501	46,628		47,144
Irving	Municipal	Dallas			3,474	38,654		42,128
Garland	Municipal	Dallas		1	2,365	31,355	117	33,838
Richardson	Municipal	Dallas	Collin	133	1,628	23,136		24,897
Carrollton	Municipal	Dallas	Denton		2,026	17,771		19,797
Grand Prairie[(b)]	Municipal	Dallas	Tarrant	22	888	17,225		18,135
Mesquite	Municipal	Dallas			751	16,883		17,634
Denton	Municipal	Denton		1,484	517	14,849	122	16,972
Sherman	Municipal	Grayson		285	5,969	6,335		12,589
Lewisville	Municipal	Denton		905	365	10,610		11,880
North Richland Hills	Municipal	Tarrant		3,125	419	7,483		11,027
Farmers Branch	Municipal	Dallas			949	8,382	21	9,331
McKinney	Municipal	Collin		1,224	462	7,501		9,187
Corsicana	Municipal	Navarro		2,754	648	5,308		8,710
Bedford	Municipal	Tarrant			14	8,259		8,273
Grapevine	Municipal	Tarrant	Dallas	7	8	7,470		7,485
De Soto	Municipal	Dallas		11	48	6,828		6,887
Flower Mound	Municipal	Denton		16				6,720
Euless	Municipal	Tarrant			45	6,563		6,608
Duncanville	Municipal	Dallas		6	64	6,330		6,400
Allen	Municipal	Collin			16	6,274		6,290
Hurst	Municipal	Tarrant			32	6,058		6,090
Coppell	Municipal	Dallas				5,938		5,938
University Park	Municipal	Dallas		35		5,807		5,842
Rowlett	Municipal	Dallas	Rockwall	53	10	5,580		5,643
Addison	Municipal	Dallas			67	5,410		5,477
Haltom City	Municipal	Tarrant		9	62	4,950		5,021
Cedar Hill	Municipal	Dallas		893	118	3,711		4,722
Waxahachie	Municipal	Ellis		374	732	3,501		4,607
Southlake	Municipal	Tarrant	Denton			4,578		4,578
Frisco	Municipal	Collin	Denton	37	222	4,195		4,454
Colleyville	Municipal	Tarrant		82		4,201		4,283
Denison	Municipal	Grayson		405	550	3,224		4,179
Rockwall	Municipal	Rockwall		1,328	13	2,772		4,113
Mansfield	Municipal	Tarrant	Johnson	10	170	3,862		4,042
Benbrook	Municipal	Tarrant		2	2	3,916		3.920
Midlothian	Municipal	Ellis		2,788	206	913		3,907
Terrell	Municipal	Kaufman		931	302	2,577		3,810
Mineral Wells[(a)]	Municipal	Palo Pinto	Parker	981	22	2,753		3,756

Table 1.22, Continued

Supplier	Type	Primary County	Other County(ies)	1997 Sales in Acre-Feet				
				Municipal Wholesale	Manu-facturing	Municipal Retail	Other	Total
Keller	Municipal	Tarrant		513	31	3,155		3,698
Lancaster	Municipal	Dallas			154	3,297		3,451
Weatherford	Municipal	Parker		34	269	3,143		3,446
Highland Park	Municipal	Dallas				3,402		3,402
Gainesville	Municipal	Cooke		73	106	3,021		3,200
Watauga	Municipal	Tarrant				3,111		3,111
Rockett SUD	SUD	Ellis	Dallas	N/A	N/A	N/A	N/A	3,106
The Colony	Municipal	Denton				2,965		2,965
Ennis	Municipal	Ellis		N/A	N/A	N/A	N/A	2,643
Burleson[(a)]	Municipal	Johnson	Tarrant		10	2,539		2,549
Highland Village	Municipal	Denton				2,431		2,431
Athens	Municipal	Henderson		1	84	2,108		2,193
Balch Springs	Municipal	Dallas				2,111		2,111
White Settlement	Municipal	Tarrant				1,990		1,990
Dallas Co. WCID#6	District	Dallas		N/A	N/A	N/A	N/A	2,130
Bonham	Municipal	Fannin	Rockwall	241	50	1,631		1,922
Wylie	Municipal	Collin		37	143	1,570		1,750
Saginaw	Municipal	Tarrant		4	120	1,455		1,579
Seagoville	Municipal	Dallas		482		1,059		1,541
Forney	Municipal	Kaufman		538	327	619		1,484
Azle	Municipal	Tarrant		133		1,260		1,393
Trophy Club	Municipal	Denton	Tarrant			1,381		1,381
Forest Hill	Municipal	Tarrant		1		1,353		1,354
Bridgeport	Municipal	Wise		55	319	968		1,342
West Cedar Creek MUD	District	Henderson		N/A	N/A	N/A	N/A	1,241
Richland Hills	Municipal	Tarrant		2	6	1,209		1,217
East Cedar Creek FWSD	District	Henderson		N/A	N/A	N/A	N/A	1,111
Sachse	Municipal	Dallas	Rockwall			1,049		1,049
Corinth	Municipal	Denton		1		1,047		1,048
Mabank	Municipal	Kaufman	Henderson	599		372		971
Decatur	Municipal	Wise			23	940		963
Gun Barrel City	Municipal	Henderson				944		944
Kaufman	Municipal	Kaufman		318	12	577		907
Crowley	Municipal	Tarrant		4	27	862		893
Trophy Club MUD #1	District	Denton	Tarrant	N/A	N/A	N/A	N/A	846
Lake Worth	Municipal	Tarrant		24		800		824
Farmersville	Municipal	Collin		470		352		822
R-C-H WSC	WSC	Rockwall		N/A	N/A	N/A	N/A	819
Princeton	Municipal	Collin		492		316		808
River Oaks	Municipal	Tarrant		21		778		799
Kennedale	Municipal	Tarrant		14	22	762		798
Tarrant Co. MUD #1	Authority	Tarrant		N/A	N/A	N/A	N/A	743
Glenn Heights	Municipal	Dallas	Ellis	123		614		737
Royse City	Municipal	Rockwall	Collin	226	5	492		723
Briar	Municipal	Wise	Tarrant, Parker			663		663
Fairview	Municipal	Collin		23		639		662

Table 1.22, Continued

Supplier	Type	Primary County	Other County(ies)	1997 Sales in Acre-Feet				
				Municipal Wholesale	Manu-facturing	Municipal Retail	Other	Total
Lake Dallas	Municipal	Denton				662		662
Whitesboro	Municipal	Grayson		14		640		654
Rice Water Supply and Sewer Corp.	WSC	Navarro	Ellis	N/A	N/A	N/A	N/A	651
Sunnyvale	Municipal	Dallas			79	546		625
Hutchins	Municipal	Dallas			13	607		620
Heath	Municipal	Rockwall				616		616
Westover Hills	Municipal	Tarrant		N/A	N/A	N/A	N/A	615
Fairfield	Municipal	Freestone		13		599		612
Everman	Municipal	Tarrant				595		595
Lake Cities MUA	Authority	Denton		N/A	N/A	N/A	N/A	593
Jacksboro	Municipal	Jack		1		567		568
Pantego	Municipal	Tarrant		4		557		561
Naval Air Station	Federal	Dallas	Tarrant	N/A	N/A	N/A	N/A	1,074
College Mound WSC	WSC	Kaufman		N/A	N/A	N/A	N/A	530
Ovilla	Municipal	Ellis	Dallas	3		524		527
Red Oak	Municipal	Ellis		23		478		501

(a) TWDB lists Mineral Wells and Burleson in Region C, but most of their water use is in Region G.
(b) Data for Grand Prairie were adjusted based on discussions with the city.

Criteria that might be considered in designating suppliers as major water providers include:

- Amount of wholesale sales
- Number of wholesale customers
- Population served through wholesale sales
- Size of service area
- Percentage of total water demands for an area supplied
- Other

The Region C Water Planning Group has decided to designate all entities with wholesale sales in excess of 20,000 acre-feet per year in Region C as major water providers. The major water providers in Region C are Dallas Water Utilities, Tarrant Regional Water District, North Texas Municipal Water District, Fort Worth, and the Trinity River Authority. As other suppliers reach 20,000 acre-feet per year in wholesale sales, they can be added to the list of major water providers. Table 1.23 gives some basic data on the suppliers designated as major water providers in Region C.

Table 1.23

Major Water Providers in Region C

Wholesale Provider	1997 Wholesale Sales (Acre-Feet)			Number of Wholesale Customers		
	Raw	Treated	Total	Cities	Water Suppliers	Others
Tarrant Regional WD	258,448	0	258,448	12	11	16
North Texas MWD	0	168,247	168,247	23	14	1
Dallas	13,324	148,281	161,605	17	4	2
Fort Worth	427	39,521	39,948	18	2	4
Trinity RA	15,220	22,217	37,437	8	2	1

1.6 Pre-Existing Plans for Water Supply Development

Previous Water Supply Planning in Region C

Appendix B is a list of previous water-related plans and reports for Region C. The region has a long history of successful local water supply planning and development. When the Senate Bill One planning process began, pre-existing plans for future water supply in Region C included the following:

- Dallas planned to connect its currently unused supplies in Lake Fork Reservoir and Lake Palestine to its system.
- Dallas was engaged in an update of its long-range water supply plan.
- Irving and Upper Trinity Regional Water District were engaged in development of transmission facilities to bring their water supplies from Lake Chapman to Lake Lewisville.
- Tarrant Regional Water District was planning to divert return flows of treated wastewater from the Trinity River into Cedar Creek and Richland-Chambers Lakes to increase the yield of its system.
- Tarrant Regional Water District was planning to develop Lake Tehuacana on Tehuacana Creek or participate in Marvin Nichols I Reservoir on the Sulphur River.
- Several Region C water suppliers were considering the development of water supplies in the Sulphur Basin to the east. Alternatives included George Parkhouse Reservoirs I and II and Marvin Nichols Reservoirs I and II. Development of any of these sites would require a cooperative effort with water suppliers in the vicinity of the reservoirs, which are located in Senate Bill One Region D.

- Other Region C suppliers were planning and developing smaller water supply projects to meet local needs. Examples included Muenster (new reservoir), Wortham (contract with Mexia), and many entities developing additional wells or seeking water supplies from the major water suppliers in the region.

As discussed in Section 1.4, there has been an increasing interest in the reuse of treated wastewater in Region C in recent years. There are several permits for significant indirect reuse projects in the region. In addition to these permitted indirect reuse projects, many of the reservoirs in Region C make indirect reuse of treated wastewater return flows in their watersheds, which increase reservoir yields. Many water suppliers in the area are considering reuse projects. Several applications for indirect reuse are pending with the Texas Natural Resource Conservation Commission, and TNRCC policy on future indirect reuse projects is not yet firmly established. If TNRCC does not allow the development of additional indirect reuse in Region C, current local water supply planning will be disrupted and other sources must be sought. Direct reuse, often for irrigation of golf courses, is also increasing in the region. It is clear that reuse of treated wastewater will remain a significant part of future water planning for Region C.

Most Recent State Water Plan

The most recent state water plan, *Water for Texas,* published in 1997, proposed several water supply projects for Region C [11]:

- Diversion of Trinity River wastewater return flows from the Fort Worth area into Cedar Creek and Richland-Chambers Lakes to serve Tarrant Regional Water District by 2025.
- Construction of Tehuacana Reservoir on Tehuacana Creek to serve Tarrant Regional Water District by 2050.
- Development of George Parkhouse II Reservoir in the Sulphur River Basin to serve North Texas Municipal Water District by 2015. (This project might also serve Upper Trinity Regional Water District.)
- Reallocation and permitting of the unappropriated share of Texas' portion of Lake Texoma to serve the North Texas Municipal Water District <u>if</u> the Red River Chloride Control Project improves the amount of usable supply from Lake Texoma by 2050.
- Construction of transmission facilities from Lake Fork Reservoir to serve Dallas by 2005.
- Construction of transmission facilities from Lake Palestine to serve Dallas by 2015.

- Construction of the Marvin Nichols I Reservoir to serve Dallas by 2040. (This project might also serve North Texas Municipal Water District, Tarrant Regional Water District, and Upper Trinity Regional Water District).
- Possible reuse by Dallas Water Utilities to supplement existing supplies.
- Development of transmission facilities from Lake Chapman in the Sulphur Basin to serve Irving and Upper Trinity Regional Water District.
- Possible use of Lake Joe Pool to supply additional water to Waxahachie.

Conservation Planning in Region C

For the last several years, the Texas Water Development Board and the Texas Natural Resource Conservation Commission have required the development of conservation plans as a condition for TWDB financing of projects and for TNRCC permitting. Primarily as a result of these requirements, many entities in Region C and around the state have developed conservation and drought contingency plans. These plans have significantly improved the awareness of water conservation in Texas. In projections of water use made in the 1990s, the Texas Water Development Board has assumed significant reductions in per capita municipal use due to the implementation of conservation measures. The biggest assumed reduction is due to the use of low flow plumbing fixtures in all new development and renovation, as currently required by federal and state law. Additional reductions in per capita use were assumed due to reduced outdoor water use, reduced leakage in distribution systems, and other measures. Texas Water Development Board rules for Senate Bill One require that water use projections include savings from conservation.

In addition to its regional planning provisions, Senate Bill One includes a requirement that all holders of existing water rights for more than 10,000 acre-feet per year for irrigation or more than 1,000 acre-feet per year for any other purpose develop and implement a water conservation plan. This will increase the number of water users preparing conservation plans.

Preliminary Assessment of Current Preparations for Drought in Region C

The recent dry summers in 1996 and 1998 placed considerable stress on water suppliers throughout Texas, including Region C. The larger systems in Region C did not have a shortage of supply, but several had problems with delivery of raw water to points of need and with treated water distribution. Many Region C water suppliers have already made or are currently making improvements to increase delivery of raw and treated water under drought conditions. Some smaller suppliers in Region C faced a shortage of supplies in the recent drought. Most of those entities have moved to address this problem by connecting to a larger supplier or by developing additional supplies on their own.

Most of the conservation plans developed in response to TNRCC and TWDB requirements include a drought contingency plan. In addition to its regional planning provisions, Senate Bill One included a requirement that all public water suppliers and irrigation districts develop and implement a drought contingency plan.

Other Water-Related Programs

In addition to the Senate Bill One regional planning efforts, there are a number of other significant water-related programs that will affect water supply efforts in Region C. Perhaps the most important are Texas Natural Resource Conservation Commission water rights permitting, the Clean Rivers Program, the Clean Water Act, and the Safe Drinking Water Act.

Texas Natural Resource Conservation Commission (TNRCC) Water Rights Permitting. Surface water in Texas is a public resource, and the TNRCC is empowered to grant water rights that allow beneficial use of that resource. Any new surface water supply source will require a water right permit. In recent years, TNRCC has increased its scrutiny of the environmental impacts of water supply projects, and permitting has become more difficult and complex. Among its many other provisions, Senate Bill One set out formal criteria for the permitting of interbasin transfers for water supply. Since many of the major sources of supply that have been considered for Region C involve interbasin transfers, these criteria will be important in Region C planning.

Clean Rivers Program. The Clean Rivers Program is a Texas program, funded and overseen by TNRCC, designed to provide information on water quality issues and to develop plans to resolve water quality problems. The Clean Rivers Program is carried out by local entities. In Region C, the program is carried out by river authorities: the Trinity River Authority in the Trinity Basin, the Red River Authority in the Red Basin, the Brazos River Authority in the Brazos Basin, the Sulphur River Basin Authority in the Sulphur Basin, and the Sabine River Authority in the Sabine Basin.

Clean Water Act. The Clean Water Act is a federal law designed to protect water quality. The parts of the act which have the greatest impact on water supplies are the NPDES permitting process, which covers wastewater treatment plant discharges, and the Section 404 permitting process for dredging and filling in the waters of the United States, which affects reservoir construction. In Texas, the state has recently taken over the NPDES permitting system, which sets the discharge requirements for wastewater treatment plants. The Section 404 permitting process is handled by the Corps of Engineers, and Section 404 permitting is an important step in the development of a new reservoir and is also required for most pipelines and pump stations.

Safe Drinking Water Act (SDWA). The Safe Drinking Water Act is a federal program that regulates drinking water supplies. In recent years, new requirements introduced under the SDWA have required significant changes to water treatment. On-going SDWA initiatives will continue to impact water treatment requirements. Some of the initiatives that may have significant impacts in Region C are the reduction in allowable levels of trihalomethanes in treated water, the requirement for reduction of total organic carbon levels in raw water, and the possible reduced allowable level of arsenic in drinking water.

1.7 Agricultural and Natural Resources in Region C

Wetlands

According to the regulatory definition of the U.S. Army Corps of Engineers [18], wetlands are ". . . areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Areas classified as wetlands are often dependent on water from streams and reservoirs. Wetlands provide food and habitat for fish and wildlife, water quality improvement, flood protection, shoreline erosion control, and groundwater exchange, in addition to opportunities for human recreation, education and research.

The Natural Resources Conservation Service (NRCS) has mapped and quantified areas of hydric soils for all but five of the counties in Region C. The agency makes these data available through its local county offices and, in some cases, publishes the acreages of soil series in the soil survey report for the county. Hydric soil is defined as ". . . soil that in its undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation" [19]. Thus, the area of hydric soils mapped in a county provides an indication of the potential extent of wetlands in that county. However, as implied in the definition, some areas mapped as hydric soils may not occur as wetlands because the hydrology has been altered to preclude saturation or inundation.

Table 1.24 is a list of acreages of hydric soils for the counties in Region C for which the data are available. The hydric soil areas range from just over one percent of the county area in Collin, Cooke, and Tarrant counties to approximately 24 percent in Henderson County. The acreages of hydric soils listed in Table 1.24 should be considered as an indicator of the relative abundance of wetlands in the counties and not as an absolute quantity. It should also be noted that wetlands are likely to occur in other areas throughout the region as "atypical" or "problem area" wetlands, as defined in the Corps of Engineers' Wetland Delineation Manual [18].

Endangered or Threatened Species

Table 1.25 lists "species of special concern" identified in Region C counties by the Texas Parks and Wildlife Department (TPWD) [21] and U.S. Fish and Wildlife Service [22]. Species of special concern include species listed as threatened or endangered at the state level and species that have limited range within the state. The TPWD maintains a list of species of special concern in the Texas Biological and Conservation Data System.

Stream Segments with Significant Natural Resources

In each river basin in Texas, the TPWD has identified stream segments classified as having significant natural resources [20]. Stream segments have been placed on this list because they have been identified by TPWD as having one or more of the following: high water quality, exceptional aquatic life, high aesthetic value, fisheries, spawning areas, unique state holdings, endangered or threatened species, priority bottomland hardwood habitat, wetlands, springs, and pristine areas.

Stream segments that have been classified as having significant natural resources in Region C in the Trinity River Basin include the following [20]:

Table 1.24

Hydric Soils Mapped by the Natural Resources Conservation Service for the Counties in Region C

County	Total County Acreage (Acres)	Hydric Soil Acreage within County (Acres)	Percent of County (%)
Collin	565,760	8,620	1.52
Cooke	568,320	7,100	1.25
Dallas	577,920	53,570	9.27
Denton	611,200	10,460	1.71
Ellis	608,000	Not Available	
Fannin	574,080	Not Available	
Freestone	574,720	85,855	14.94
Grayson	627,840	29,240	4.66
Henderson*	604,800	142,540	23.57
Jack	588,800	Not Available	
Kaufman	517,760	Not Available	
Navarro	695,680	86,100	12.38
Parker	581,760	35,350	6.08
Rockwall	94,080	Not Available	
Tarrant	574,080	9,410	1.64
Wise	592,000	13,100	2.21

*Note that the values for Henderson County include all of Henderson County, not just the Region C portion.

- High water quality, exceptional aquatic life, and high aesthetic value - Elm Fork of the Trinity River (headwaters to Lake Ray Roberts), West Fork of the Trinity River (Lake Bridgeport tailrace to Eagle Mountain Lake), Big Sandy Creek (Lake Amon G. Carter tailrace to West Fork of the Trinity River), Spring Creek (Dallas County near Garland), and Tenmile Creek (Dallas County).
- Diverse fishery - Tenmile Creek (Dallas County)
- Unique state holdings - Segment 0804 of the Trinity River (below Cedar Creek Lake spillway; significant holding in Region C is Richland Creek Wildlife Management Area).
- Paddlefish stocking area - Trinity River (Lake Ray Hubbard to Lake Livingston).
- Priority bottomland hardwood habitat - Confluence of Buffalo and Linn Creeks in Freestone County.

Stream segments in the Red River Basin in Region C classified as having significant natural resources include the following [20]:

Table 1.25
Species of Special Concern[a]

Species	Federal Status[b]	State Status[c]	Riparian or Wetland Dependent	County: Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson	Henderson	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant	Wise
Bachman's sparrow		T			x														
Henslow's sparrow						x				x		x		x				x	
Western burrowing owl						x								x				x	
Piping plover	LT		X			x	x				x								
Cerulean warbler					x														
Golden-cheeked warbler	LE	E														x			
American peregrine falcon		E		x	x		x	x	x		x		x		x	x	x		x
Arctic peregrine falcon				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
White-faced ibis		T	X											x					
Whooping crane	LE	E	X	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
Bald eagle	LT	T	X	x	x	x	x	x	x	x	x	x		x	x	x		x	
Migrant loggerhead shrike						x		x				x		x				x	
Wood stork	E	T	X		x	x	x			x	x	x		x					
Eskimo curlew	LE	E			x										x				x
Interior least tern	LE	E	X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Black-capped vireo	LE	E				x							x			x			x
Blue sucker		T	X						x		x								
Western sand darter			X		x						x								
Blackside darter		T	X						x										
Paddlefish		T	X								x								
Shovelnose sturgeon		T	X								x								
Red wolf	LE	E						x					x			x			
Gray wolf	LE	E											x						
Black-footed ferret	LE	E			x														
Plains spotted skunk						x				x		x		x				x	
Black bear	T/SA	T							x										
Rafinesque's big-eared bat		T								x									
Southeastern myotis			X							x									
Timber/canebrake rattlesnake		T			x	x	x	x		x	x	x		x	x			x	x
Brazos water snake		T	X													x			
Texas horned lizard		T			x	x	x	x	x	x	x	x	x	x	x	x		x	x
Houston toad	LE	E	X							x									

Table 1.25, Continued

Species	Federal Status[b]	State Status[c]	Riparian or Wetland Dependent	County															
				Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson	Henderson	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant	Wise
Texas garter snake				x		x	x	x		x		x		x	x	x		x	x
Northern scarlet snake		T										x							
Alligator snapping turtle		T	X									x							
Comanche Peak prairie-clover																x			x
Large-fruited sand verbena	LE	E								x									
Navasota ladies' -tresses	LE	E	X							x									
Warnock's coral root						x													
Rough-stem aster			X									x							
Auriculate false foxglove																		x	

Notes: a. Information obtained from the Texas Parks and Wildlife Department [21] and from the U.S. Fish and Wildlife Service[22].

b. LE is federally listed endangered, LT is federally listed threatened, and T/SA is federally threatened by similarity of appearance.

c. E is state listed endangered, T is state listed threatened, and "blank" is rare, but with no regulatory listing status

- Pristine area, spring fed, intermittent pools and ripples - North Fish Creek and South Fish Creek in Cooke County.
- Striped bass spawning and migration and unique saltwater springs - Segment 0204 of the Red River (above Lake Texoma).
- Unique community, wetlands - Rock Creek in Cooke County.
- Unique state holdings - Bois d'Arc Creek in Fannin County (Caddo Wildlife Management Area).
- Paddlefish - Segment 0202 of the Red River (below Lake Texoma) and Shawnee Creek in Grayson County.
- Blue Sucker - Segment 0202 of the Red River (below Lake Texoma).

Stream segments in the Brazos River Basin in Region C classified as having significant natural resources include the following:[20]

- Recreation - Brazos River, Possum Kingdom Dam to Lake Granbury, including the reach in Parker County which is in Region C.
- Striped bass spawning migration and small mouth bass fishery - Brazos River, Possum Kingdom Dam to Granbury, including the reach in Parker County which is in Region C.
- Pristine and historic area - Sanchez Creek in Parker County.

As discussed in Section 6.5, the Texas Parks and Wildlife Department has recommended certain stream segments in Region C for designation as "ecologically unique stream segments."

Agriculture and Prime Farmland

Table 1.26 gives some basic data on agricultural production in Region C, based on the most recent data available from the U.S. Department of Agriculture (USDA) [(23)]. Region C includes almost 6,000,000 acres in farms and over 2,500,000 acres of cropland. Irrigated agriculture does not play a significant role in Region C, with less than 1 percent of the cropland irrigated. The market value of agricultural products is significant in all Region C counties, with a total value for 1997 of almost $500,000,000. (Separate data are not available for the portion of Henderson County in Region C, so the USDA data include the entire county.) For the region as a whole, the market value of livestock is almost twice that of crops.

The Natural Resources Conservation Service (NRCS) defines prime farmland as "land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses [(24)]." As part of the National Resources Inventory, the NRCS has identified prime farmland throughout the country. Figure 1.11 shows the distribution of prime farmland in Region C. Each color in Figure 1.11 represents the percentage of the total acreage that is prime farmland of any kind. (There are four categories of prime farmland in the NRCS STATSGO database for Texas: prime farmland, prime farmland if drained, prime farmland if protected from flooding or not frequently flooded during the growing season, and prime farmland if irrigated.) There are large areas of prime farmland in Cooke, Denton, Collin, Tarrant, Dallas, and Ellis Counties. It is evident from Figure 1.11 that prime farmland in Region C tends to be distributed along streams.

Table 1.26
1997 U.S. Department of Agriculture County Data

	Collin	Cooke	Dallas	Denton	Ellis	Fannin	Freestone	Grayson
Farms	1,407	1,487	768	1,782	1,713	1,604	1,205	2,080
Land in Farms (acres)	270,434	478,860	148,862	362,712	425,717	444,661	422,548	417,356
Crop Land (acres)	190,161	188,496	75,289	197,573	255,083	263,906	133,394	244,589
Harvested Crop Land (acres)	122,000	93,816	38,635	114,788	148,012	143,820	35,469	134,852
Irrigated Crop Land (acres)	403	1,520	1,407	773	817	2,020	331	1,953
Market Value ($1,000)								
Crops	$22,432	$6,223	$16,276	$12,885	$24,695	$17,057	$1,437	$15,697
Livestock	$11,564	$31,064	$6,003	$40,662	$15,735	$22,163	$18,211	$19,779
Total	$33,996	$37,287	$22,279	$53,547	$40,430	$39,220	$19,648	$35,476

	Henderson[b]	Jack	Kaufman	Navarro	Parker	Rockwall	Tarrant	Wise	Total
Farms	1,630	730	1,883	1,513	2,301	265	1,048	2,075	23,491
Land in Farms (acres)	367,096	531,787	388,830	516,395	479,807	46,015	184,081	411,737	5,896,898
Crop Land (acres)	155,335	70,778	181,244	236,567	169,855	31,566	70,233	176,755	2,640,824
Harvested Crop Land (acres)	58,000	14,069	75,801	97,192	52,260	18,978	35,278	59,784	1,242,754
Irrigated Crop Land (acres)	846	212	1,261	346	1,200	27	673	795	14,584
Market Value ($1,000)									
Crops	$10,105	$1,022	$5,239	$12,526	$10,779	$2,009	$10,547	$4,351	$173,280
Livestock	$19,391	$15,897	$23,783	$21,048	$33,058	$1,726	$10,323	$29,925	$320,332
Total	$29,496	$16,919	$29,022	$33,574	$43,837	$3,735	$20,870	$34,276	$493,612

Notes: a. Data are from the U.S. Department of Agriculture [(23)].

b. Data for Henderson County are for the entire county.

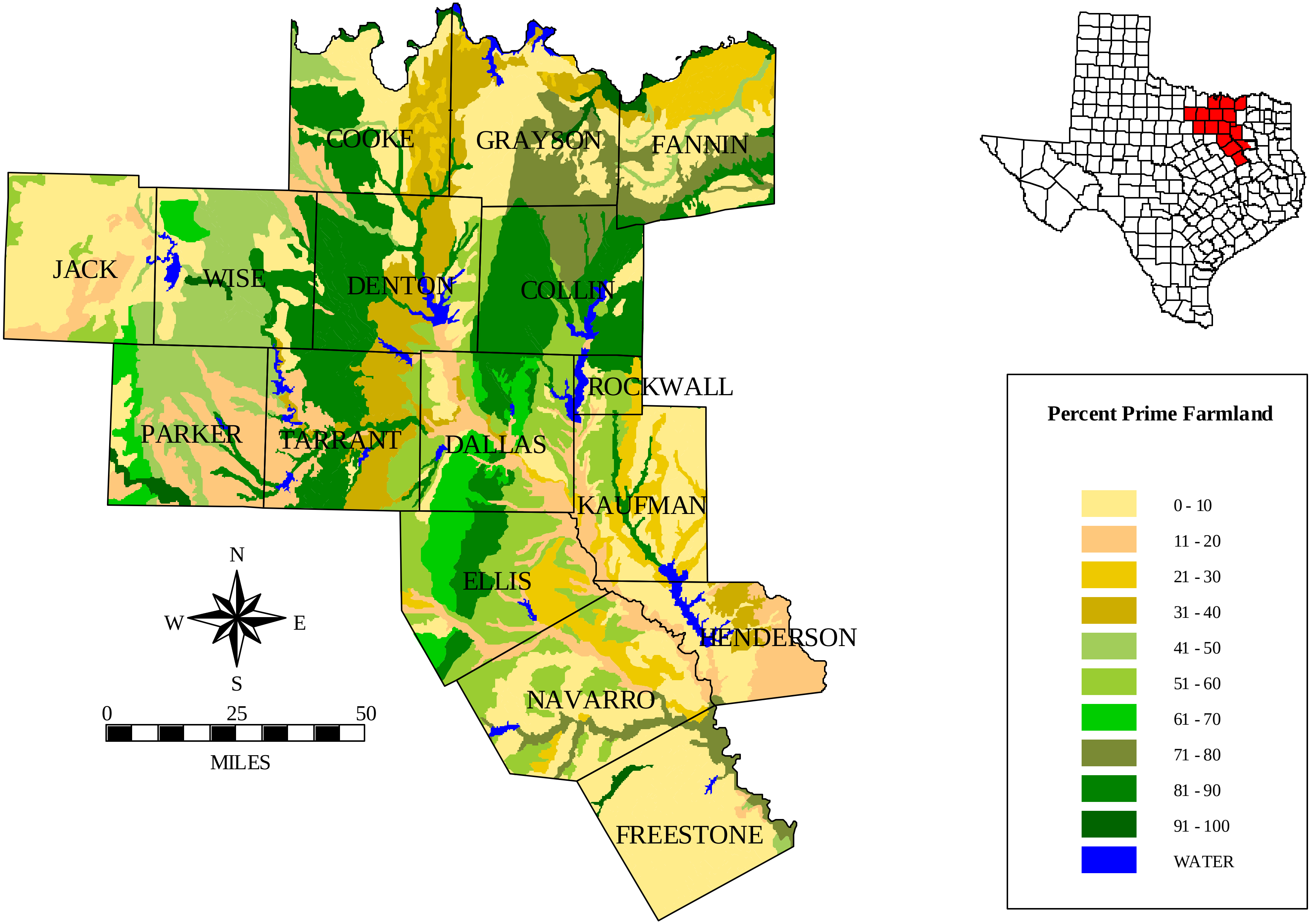


Figure 1.11
Percent Prime Farmland
Region C

There are localized areas of irrigated agriculture in Region C. Table 1.9 shows that 63 percent of the 1997 water use for irrigation in Region C came from groundwater (compared to only 8 percent of total water use from groundwater.) Texas Water Development Board Report 269 [15] studied the groundwater in most of Region C (except for Jack and Henderson Counties and part of Navarro County). Most irrigation wells in the study area were scattered over the outcrop areas of the Trinity and the Woodbine aquifers with only a few areas of concentrated activity. The largest concentration of irrigation wells is located on the Woodbine outcrop in an area bounded by western Grayson County, the eastern edge of Cooke County, and the northeastern corner of Denton County. Approximately 80 irrigation wells operated in this region (as of 1982), and several produced as much as 900 gpm. Several smaller irrigation well developments were located in Parker County and Wise County in the Trinity aquifer. There were also irrigation wells in Fannin County producing from the alluvium along the Red River[15].

State and Federal Natural Resource Holdings

The TPWD operates several state parks in Region C: Bonham State Park in Fannin County, Cedar Hill State Park in Dallas County, Eisenhower State Park in Grayson County, Fairfield Lake State Park in Freestone County, Lake Lewisville State Park in Denton County, Lake Mineral Wells State Park in Parker County, Lake Ray Roberts State Park in Denton and Cooke Counties, and Purtis Creek State Park partially in Henderson County. TPWD also operates Caddo Wildlife Management Area in Fannin County, Ray Roberts Wildlife Management Area in Cooke, Denton, and Grayson Counties, Richland Creek Wildlife Management Area in Freestone and Navarro Counties, and Eisenhower State Historic Park in Grayson County.

Federal government natural resource holdings in Region C include the following:

- Parks and other land around all of the Corps of Engineers lakes in the region (Texoma, Ray Roberts, Lewisville, Lavon, Grapevine, Benbrook, Joe Pool, Bardwell, and Navarro Mills)
- Hagerman National Wildlife Refuge on the shore of Lake Texoma in Grayson County
- Caddo National Grasslands in Fannin County
- Lyndon B. Johnson National Grasslands in Wise County.

Oil and Gas Resources

Oil and natural gas fields are significant natural resources in portions of Region C. There is a high density of oil wells in Jack, Wise, Cooke, and Grayson Counties, with a lesser density in

Denton, Parker, Navarro, Henderson, and Kaufman Counties. There is a high density of producing natural gas wells in Freestone, Parker, Jack, and Wise Counties, with a lesser density in Navarro, Henderson, Denton, Cooke, and Grayson Counties. None of the 20 top-producing oil fields in Texas is located in Region C, but two of the 20 top-producing gas fields are in the region [(25)]. The Boonesville field ranked 13^{th} in Texas natural gas production, while the East Newark field ranked 19^{th}. Both gas fields are centered in Wise County.

Lignite Coal Fields

There are some lignite coal resources in Region C [(26)]. Paleozoic rocks with bituminous coal deposits underlie most of Jack County and small portions of Wise and Parker Counties. Near surface (to 200 feet in depth) lignite deposits in the Wilcox Group underlie significant portions of Freestone, Navarro, and Henderson Counties. Deposits of deep basin lignite (200 - 2,000 feet in depth) in rocks of the Wilcox Group underlie a significant portion of Freestone County. The most significant current lignite production in Region C is from the near surface Wilcox Group deposits in Freestone County to supply TU Electric's Big Brown Steam Electric Station on Lake Fairfield.

1.8 Summary of Threats and Constraints to Water Supply in Region C

The most significant potential threats to existing water supplies in Region C are surface water quality concerns, groundwater drawdown, and groundwater quality. Constraints on the development of new supplies include the availability of sites and unappropriated water for new water supply reservoirs and the challenges imposed by environmental concerns and permitting.

Need to Develop Additional Supplies

Most of the water suppliers in Region C will have to develop additional supplies before 2050. The major water suppliers have supplies well in excess of current needs, but they will require additional supplies to meet projected growth. Some smaller water suppliers face a more urgent need for water. Their needs can be addressed by local water supply projects or by purchasing water from a major water supplier.

Surface Water Quality Concerns

The Texas Natural Resource Conservation Commission (TNRCC) published *The State of Texas Water Quality Inventory* in 1996 and 1998 [27, 28]. The Water Quality inventories indicate that public water supply use is supported in the stream segments designated for public water supply in Region C. The TNRCC has also established a list of stream segments for which it intends to develop total maximum daily load (TMDL) evaluations to address water quality concerns [29]. Table 1.27 lists the stream segments in Region C for which TMDL evaluations are proposed and summarizes the water quality concerns to be addressed.

Only a few of the proposed TMDL studies in Region C are due to concerns related to public water supply. Most are due to concerns over aquatic life, contact recreation, and fish consumption. One public water supply concern is the detection of atrazine in treated drinking water originating from several reservoirs in Region C, including Lake Bardwell, Lake Waxahachie, Lake Lavon, Richland-Chambers Lake, and Joe Pool Lake. Atrazine was also found in treated drinking water originating from Lake Tawakoni, which is not in Region C but does provide water for Region C. In each case, the level of atrazine detected was much less than the maximum contaminant level for drinking water. In its Clean Water Act Section 303(d) list, the TNRCC stated as follows for each of these reservoirs: "All water quality measurements currently support use as a public drinking water supply; however, atrazine concentrations in finished drinking water indicate contamination of source water and represent a threat to future use [29]." To address this concern, TNRCC has assigned a high priority to development of total maximum daily load (TMDL) evaluations for these watersheds.

Other potential water quality concerns that might affect public water supplies in Region C include nutrient levels in water supply reservoirs, excessive total organic carbon (TOC) levels in source waters, dissolved solids in some reaches, and arsenic. Most of the water supply reservoirs in Region C are experiencing increasing discharges of treated wastewater in their watersheds. To date, this has not presented a problem for public water supplies, but increased amounts of wastewater and greater nutrient loads may lead to concerns about eutrophication in some lakes. Figure 1.12 shows municipal wastewater treatment plants in Region C with over 1 mgd of permitted discharge. Most of the largest plants are on the Trinity River in the Dallas-Fort Worth Metroplex and do not discharge into the watershed of any Region C reservoir. However, there are significant permitted discharges upstream from many reservoirs in the region, and return flows are tending to increase with time.

Table 1.27
Total Maximum Daily Load (TMDL) Studies Proposed for Region C

Segment #	Segment Name	Basin	Priority	Concern is for: Public Supply	General	Aquatic Life	Contact Recreation	Fish Consump-tion	Description
507	Lake Tawakoni	Sabine	Medium	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
804	Trinity River- Cedar Creek Spillway to Lake Livingston	Trinity	Low/ Under-way			x	x		Average lead concentration exceeds aquatic life chronic exposure level (out of Region C). Bacteria sometimes exceed contact recreation level in upper 25 miles.
805	Trinity River- Elm Fork to Cedar Creek Spillway	Trinity	Low/ Under-way				x	x	Bacteria sometimes exceed contact recreation level. Fish consumption not supported in upper 19 miles due to chlordane in fish tissue.
806	West Fork Trinity River- Lake Worth Dam to Village Creek	Trinity	Low/ Under-way				x	x	Bacteria sometimes exceed contact recreation level in a 17 mile stretch. Fish consumption not supported in lower 12 miles due to chlordane in fish tissue.
806A	Fosdic Lake	Trinity	Medium					x	Fish consumption not supported due to chlordane, dieldrin, DDE, and PCBs in fish tissue.
806B	Echo Lake	Trinity	Medium					x	Fish consumption not supported due to PCBs in fish tissue.
810	West Fork Trinity River- Lake Bridgeport to Eagle Mountain Lake	Trinity	Low				x		Bacteria sometimes exceed contact recreation level in lower 25 miles.

Table 1.27, Continued

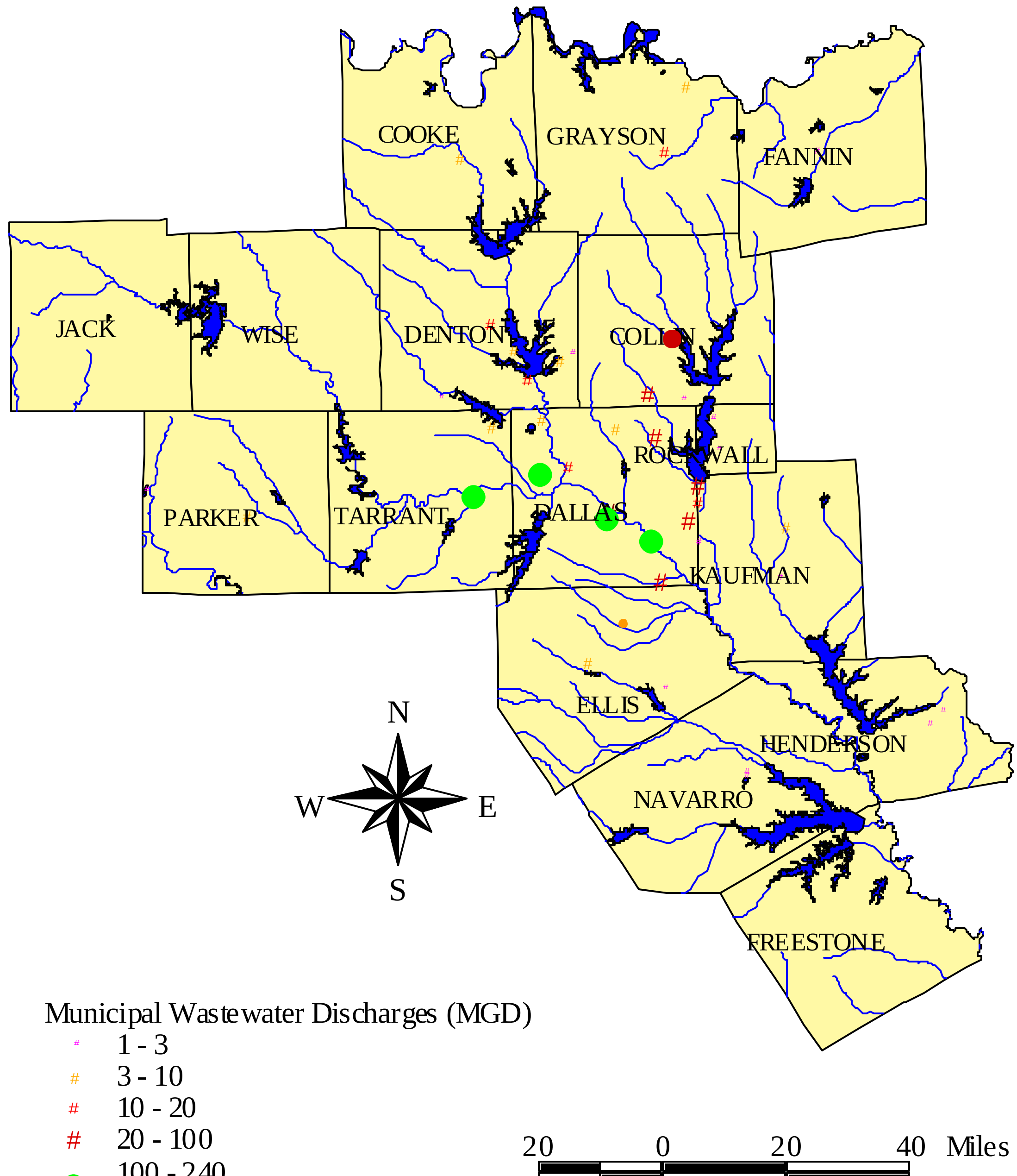
Segment #	Segment Name	Basin	Priority	Concern is for: Public Supply	General	Aquatic Life	Contact Recreation	Fish Consump-tion	Description
812	West Fork Trinity River above Lake Bridgeport	Trinity	Medium		x	x			In lower 25 miles, dissolved oxygen is sometimes lower than the standard to protect aquatic life. In lower 25 miles, average chlorides and total dissolved solids exceed general standard for segment (but not secondary drinking water standards).
815	Lake Bardwell	Trinity	High	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
816	Lake Waxahachie	Trinity	High	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
819	East Fork Trinity River below Lake Ray Hubbard	Trinity	Low				x		Bacteria sometimes exceed contact recreation levels in lower 14 miles.
821	Lake Lavon	Trinity	Medium	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
822	Elm Fork Trinity River below Lake Lewisville	Trinity	Medium			x	x	x	In upper 15 miles, dissolved oxygen is occasionally lower than aquatic life standard. Average lead concentration exceeds aquatic life chronic exposure level and level to protect fish consumption.
824	Elm Fork Trinity River above Ray Roberts Lake	Trinity	Medium			x			In lower 8 miles, average lead concentration exceeds aquatic life chronic exposure level.
829	Clear Fork Trinity River- Lake Benbrook to West Fork Trinity River	Trinity	Medium					x	Fish consumption not supported in lower mile due to chlordane in fish tissue.

Table 1.27, Continued

Segment		Basin	Priority	Concern is for					Description
#	Name			Public Supply	General	Aquatic Life	Contact Recreation	Fish Consump-tion	
829A	Lake Como	Trinity	Medium					x	Fish consumption not supported due to chlordane, dieldrin, DDE, and PCBs in fish tissue.
831	Clear Fork Trinity River- Lake Weatherford to Benbrook Lake	Trinity	Medium			x			Average lead concentration exceeds aquatic life chronic exposure level in lower 3.3 miles. Dissolved oxygen concentrations are occasionally lower than aquatic life standard in lower 15.7 miles.
833	Clear Fork Trinity River above Lake Weatherford	Trinity	Low			x			Dissolved oxygen standards are occasionally lower than aquatic life standard.
836	Richland-Chambers Lake	Trinity	Medium	x					All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
838	Joe Pool Lake	Trinity	High	x	x				Average sulfates and total dissolved solids exceed general standards for segment (but not secondary drinking water standards). All water quality measurements support use as public water supply, but atrazine has been detected at low levels in treated water.
841	West Fork Trinity River-Village Creek to Elm Fork	Trinity	Low/ Under-way			x	x	x	Bacteria sometimes exceed contact recreation levels in lower 21 miles. Fish consumption not supported in upper 19 miles due to chlordane in fish tissue. Toxicity occasionally exceeds aquatic life standard.
841A	Mountain Creek Lake	Trinity	Medium					x	Fish consumption not supported due to PCBs, chlordane, heptachlor epoxide, dieldrin, DDE, DDD, and DDT in fish tissues.

Notes: a. All information is from TNRCC Section 303(d) list [29].
b. Lake Tawakoni is outside of Region C, but provides water to Region C.

Figure 23
Wastewater Discharge Points



In December 1998, the U.S. EPA published the *Stage 1 Disinfectants and Disinfection Byproducts (D/DBP) Rule*[30], which applies to water systems that treat surface water with a chemical disinfectant. Under certain circumstances, the rule mandates the use of enhanced coagulation to remove total organic carbon (TOC), an indicator of potential disinfection byproduct formation. TRA has commissioned a study to determine the impact of this new rule on Trinity Basin water supplies [31]. Based on TNRCC's 1982-1992 water quality data, 20 Trinity Basin segments in Region C have an average TOC over 6 mg/l. Based on source water TOC and surface water alkalinity, this rule will require TOC reductions of 25 to 40 percent by enhanced coagulation for most Region C water supplies in the Trinity Basin [31].

Dissolved solids in the Red River and Lake Texoma along the northern boundary of Region C are generally high. Use of Lake Texoma water for public supply requires desalination (Sherman, Red River Authority Tanglewood Estates) or blending with higher quality water (North Texas MWD, Denison). This limits the use of water from the Red River and Lake Texoma for public water supply. The Red River Authority is serving as a local sponsor for the proposed Red River Chloride Control Project, which may serve to improve the quality of Lake Texoma water by diverting saline water before it reaches the lake. Two reaches in Region C – the West Fork of the Trinity River and Joe Pool Lake - show average levels of total dissolved solids and other salts in excess of the current stream standards. In both cases, the levels are below the TNRCC secondary standards for drinking water and should not present a problem for public water supply.

Arsenic is present in several Region C lakes at trace levels, well below the current Safe Drinking Water Act standard of 50 micrograms per liter. The EPA is currently considering adopting a lower standard for arsenic. If the standard is set very low, additional treatment may be required to remove trace levels of arsenic from some supplies.

The Texas Natural Resource Conservation Commission (TNRCC) has the primary responsibility for enforcing state laws against water pollution. Chapter 7 of the Texas Water Code also establishes laws to allow local governments to combat environmental crime, including water pollution. Local enforcement of these laws can supplement the enforcement activities of TNRCC and help protect Texas' water resources.

Groundwater Drawdown

Overdevelopment of aquifers and the resulting decline in water levels poses a threat to small water suppliers and to household water use in rural areas. As water levels decline, the cost of pumping water grows and water quality generally suffers. Wells that go dry must be redrilled to deeper portions of the aquifer. Water level declines have been reported in localized areas in each of the major and minor aquifers in Region C. In particular, the annual pumpage from the Trinity and the Nacatoch aquifers is estimated to be greater than the annual recharge [15]. Concern about groundwater drawdown is likely to prevent any substantial increase in groundwater use in Region C and may require conversion to surface water in some areas.

Groundwater Quality

Figure 1.7 shows the major aquifers in Region C, the Trinity aquifer and the Carrizo-Wilcox aquifer. Figure 1.8 shows the minor aquifers in Region C, which are the Woodbine aquifer, the Nacatoch aquifer, and the Queen City aquifer. Water quality in the Trinity aquifer is acceptable for most municipal and industrial purposes [15, 32]. However, in some areas, natural concentrations of arsenic, fluoride, nitrate, chloride, iron, manganese, sulfate, and total dissolved solids in excess of either primary or secondary drinking water standards can be found. Water on the outcrop tends to be harder with relatively high iron concentration. Downdip, water tends to be softer, with concentrations of TDS, chlorides, and sulfates higher than on the outcrop. Groundwater contamination from man-made sources is found in localized areas. Texas Water Development Board Report 269 reported contaminated water in wells located between Springtown in Parker County and Decatur in Wise County [15]. The apparent source of the contamination was improperly completed oil and gas wells. Other potential contaminant sources (agricultural practices, abandoned wells, septic systems, etc.) are known to exist on the Trinity outcrop, but existing data are insufficient to quantify their impact on the aquifer [32].

Water from the Carrizo-Wilcox aquifer is fresh to slightly saline. In the outcrop, the water is hard and low in TDS [33]. In the downdip, the water is softer, with a higher temperature and higher TDS concentrations [33]. Hydrogen sulfide and methane may be found in localized areas[33]. In much of the northeastern part of the aquifer, water is excessively corrosive and has a high iron content [33]. In this area, the groundwater may also have high concentrations of TDS, sulfate, and chloride. Some of these sites may be mineralized due to waters passing through lignite deposits, especially in the case of high sulfate [33]. Another cause may be the historic practice of storing oil field brines in unlined surface storage pits [33]. In Freestone County, excessive iron concentration may be a problem; a well recently completed by the City of Fairfield contained water with a high iron concentration[34]. Excessive iron concentrations can be removed by treatment.

Water quality in the layers of the Woodbine aquifer used for public water supply is good along the outcrop. Water quality decreases downdip (southeast), with increasing concentrations of sodium, chloride, TDS and bicarbonate. High sulfate and boron concentrations may be found in Tarrant, Dallas, Ellis, and Navarro Counties. Excessive iron concentrations also occur in parts of the Woodbine formation.

The Nacatoch and Queen City aquifers provide very little water in Region C. Available data indicate that the quality of the Nacatoch in this area is acceptable for most uses. Water quality data on the Queen City aquifer in Region C are very limited.

1.9 Water-Related Threats to Agricultural and Natural Resources in Region C

Water-related threats to agricultural and natural resources in Region C include changes to natural flow conditions, water quality concerns, and inundation of land due to reservoir development. In general, there are few significant water-related threats to agricultural resources in Region C due to the limited use of water for agricultural purposes. Water-related threats to natural resources are more significant.

Changes to Natural Flow Conditions

Reservoir development, groundwater drawdown, and return flows of treated wastewater have greatly altered natural flow patterns in Region C. Springflows in Region C have diminished, and many springs have dried up because of groundwater development and the resulting drawdown. This has reduced reliable flows for many tributary streams. Reservoir development also changes natural hydrology, diminishing flood flows and capturing low flows. (Some reservoirs provide steady flows in downstream reaches due to releases to empty flood control storage or meet permit requirements.) Downstream from the Dallas-Fort

Worth Metroplex, baseflows on the Trinity River have been greatly increased due to return flows of treated wastewater. It is unlikely that future changes to flow conditions in Region C will be as dramatic as those that have already occurred. If additional reservoirs are developed, they will be required to make low flow releases to maintain downstream stream conditions, which was often not required in the past. It is likely that return flows from the Dallas-Fort Worth area will continue to increase, thus increasing flows in the Trinity River. On balance, this will probably enhance habitat in this reach.

Water Quality Concerns

Table 1.27 lists a number of reaches in which TNRCC has documented concerns over water quality impacts to aquatic life or fish consumption. In general, these concerns are due to excessively low dissolved oxygen levels or to levels of lead, pesticides, or other pollutants that can harm aquatic life or present a threat to humans eating fish in which these compounds tend to accumulate. Two total maximum daily load (TMDL) studies are currently underway in the Trinity – one examining the effects of low levels of lead and the other examining the pesticide chlordane. TMDL studies on other concerns will follow over the next few years.

Inundation Due to Reservoir Development

At various times, a number of new reservoirs have been considered for development in Region C, including:

- Tehuacana Reservoir on Tehuacana Creek in Freestone County.
- Tennessee Colony Reservoir on the main stem of the Trinity River in Freestone, Navarro, Henderson, and Anderson Counties.
- Roanoke Reservoir on Denton Creek in Denton County.
- Italy Reservoir on Chambers Creek in Ellis and Navarro Counties.
- Emhouse Reservoir at the confluence of Chambers and Waxahachie Creeks in Ellis and Navarro Counties.
- Upper Red Oak Reservoir and Lower Red Oak Reservoir on Red Oak Creek in Ellis County.
- Bear Creek Reservoir on Bear Creek in Ellis County.
- New Bonham Reservoir on Bois d’Arc Creek in Fannin County.

At this time, Tehuacana Reservoir and New Bonham Reservoir seem to be the most promising of these projects. The impacts of a new reservoir on natural resources include the inundation of habitat, often including wetlands and bottomland hardwoods, and changes to downstream flow patterns. Depending on the location, a reservoir may also inundate prime farmland. The impacts of specific projects depend on the location, the mitigation, and the operation of the projects.

2. Population and Water Demand Projections

This section presents the population and water demand projections for Region C and describes the development of those projections. For the purposes of water supply planning, projections of dry year water demands are used. Demands are generally greater in dry years than in normal years, and it is important to develop a water supply system that is able to meet those greater demands when they occur.

2.1 Previous Texas Water Development Board Projections

The estimated 1996 population of Region C was 4,609,060. Table 2.1 shows TWDB's previous population projections for Region C counties developed for the 1997 Texas Water Plan(1), which projected a 2050 population of 8,843,253. Figure 2.1 shows the historical population for Region C from 1900 through 1990 and the TWDB projection from the 1997 water plan.

The estimated 1996 water use in Region C was 1,126,518 acre-feet. Table 2.2 shows the projected water demand for Region C counties from the 1997 Texas Water Plan, with a total region-wide demand of 1,967,916 acre-feet per year projected by 2050. Figure 2.2 shows TWDB's projected water demand for Region C from the 1997 water plan by type of use.

2.2 Region C Population and Water Use Patterns

The sixteen counties in Region C can be divided into four classifications from the standpoint of population and water use:

- Urbanized counties
- Partially urbanized counties
- Urban fringe counties
- Rural counties.

Figure 2.3 shows the classification of counties in Region C.

Urbanized counties are characterized by dense population and by residential, industrial, and commercial development covering most of the land area. Population growth will come from development of the remaining open land and from redevelopment. Increased water

Table 2.1
Texas Water Development Board
County Population Projections from the 1997 Texas Water Plan

County	Historical 1996	Projected Population					
		2000	2010	2020	2030	2040	2050
Collin	373,095	387,598	527,712	706,997	873,323	1,019,350	1,162,482
Cooke	33,196	32,139	33,714	35,241	36,360	37,142	37,821
Dallas	1,999,926	2,074,858	2,286,828	2,556,793	2,784,704	3,045,931	3,259,995
Denton	349,566	385,876	523,205	679,279	845,595	985,370	1,135,566
Ellis	94,097	106,921	130,867	156,521	181,711	194,893	205,487
Fannin	27,435	26,692	26,966	27,408	27,835	28,173	28,396
Freestone	17,757	17,291	17,854	18,382	18,848	19,164	19,433
Grayson	100,611	102,119	106,277	110,643	114,702	117,864	120,982
Henderson (Partial)	45,761	46,562	51,261	55,514	57,704	58,689	60,476
Jack	7,435	7,148	7,530	7,896	8,358	8,865	9,352
Kaufman	61,646	63,741	76,272	89,203	100,144	107,283	112,964
Navarro	42,875	42,441	45,665	48,265	50,691	51,563	53,312
Parker	73,897	80,436	99,095	118,287	139,094	156,023	171,216
Rockwall	34,287	41,174	61,392	88,135	121,288	160,588	203,530
Tarrant	1,306,457	1,415,759	1,594,218	1,798,893	1,915,375	2,111,193	2,205,610
Wise	41,019	39,743	45,428	50,540	55,596	56,476	56,631
Region C Total	4,609,060	4,870,498	5,634,284	6,547,997	7,331,328	8,158,567	8,843,253

Table 2.2
Texas Water Development Board
County Water Demand Projections from the 1997 Texas Water Plan

County	Historical 1996	Projected Water Demand (Acre-Feet per Year)					
		2000	2010	2020	2030	2040	2050
Collin	89,230	91,275	109,344	134,062	159,642	183,209	202,680
Cooke	8,429	8,266	8,113	8,073	8,075	8,079	8,147
Dallas	505,423	597,945	649,055	700,728	729,819	802,988	860,588
Denton	65,075	80,037	98,815	117,821	132,349	151,155	172,338
Ellis	19,721	24,756	27,812	30,050	33,422	35,127	36,857
Fannin	17,515	13,199	15,896	15,582	20,398	25,247	30,147
Freestone	20,608	17,939	17,857	17,738	17,717	17,674	17,691
Grayson	29,152	25,738	25,981	26,139	26,719	27,354	28,553
Henderson (Partial)	10,785	11,550	18,771	28,791	33,945	38,881	44,014
Jack	3,337	2,365	2,290	2,259	2,265	2,294	2,346
Kaufman	10,653	12,434	13,503	14,503	15,669	16,359	17,035
Navarro	10,558	9,405	9,585	9,675	9,875	9,917	10,159
Parker	12,372	13,603	15,147	16,304	18,362	20,125	21,858
Rockwall	6,566	8,375	10,929	14,562	19,709	25,952	32,219
Tarrant	291,406	346,372	375,680	379,846	401,915	437,950	462,745
Wise	25,688	16,845	17,493	18,276	19,287	19,863	20,539
Region C Total	1,126,518	1,280,104	1,416,271	1,534,409	1,649,168	1,822,174	1,967,916

Figure 2.1
Texas Water Development Board Historical and Projected Population for Region C from the 1997 Water Plan

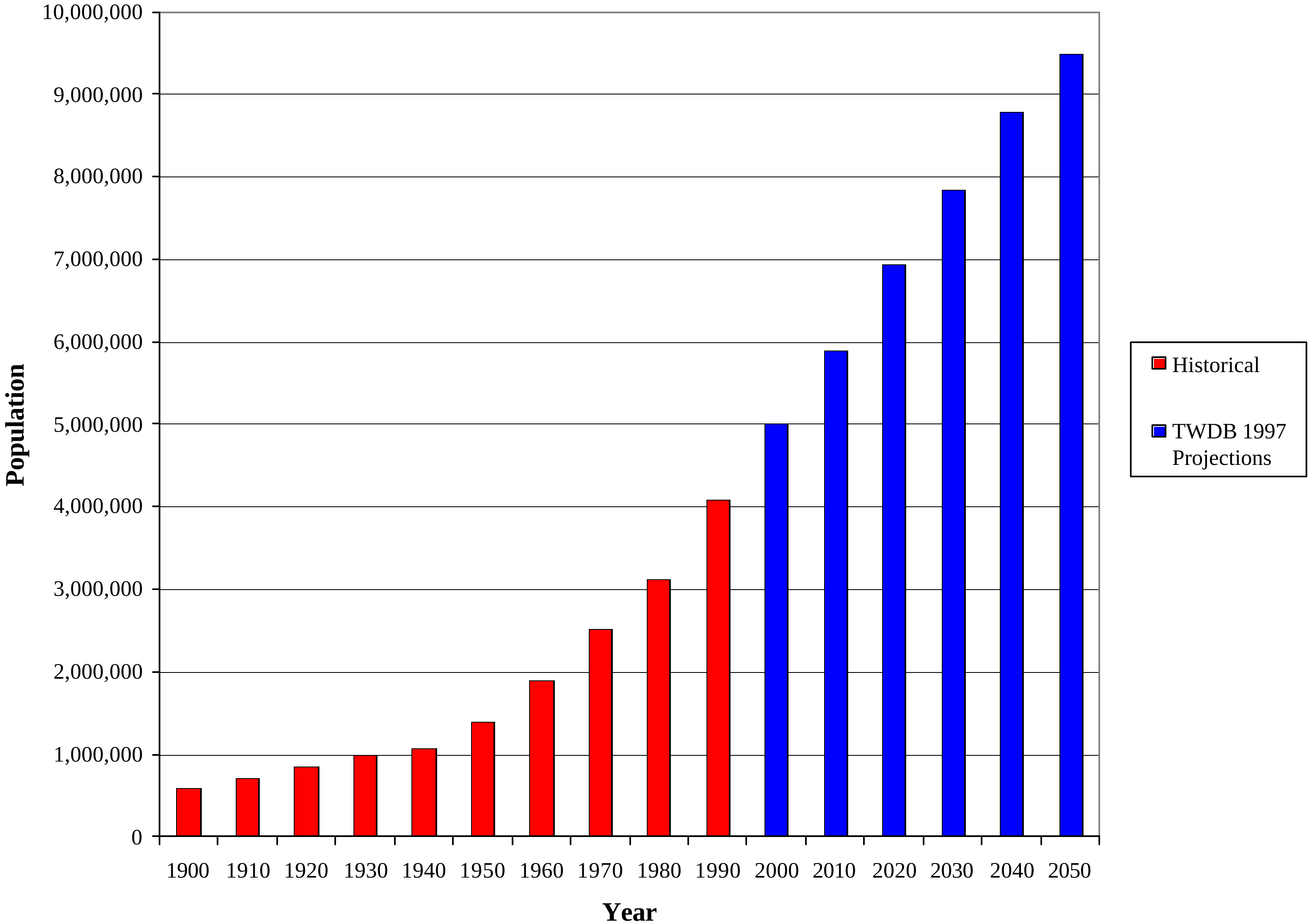


Figure 2.2
Texas Water Development Board 1997 Water Plan Projections
for Water Use by Category in Region C

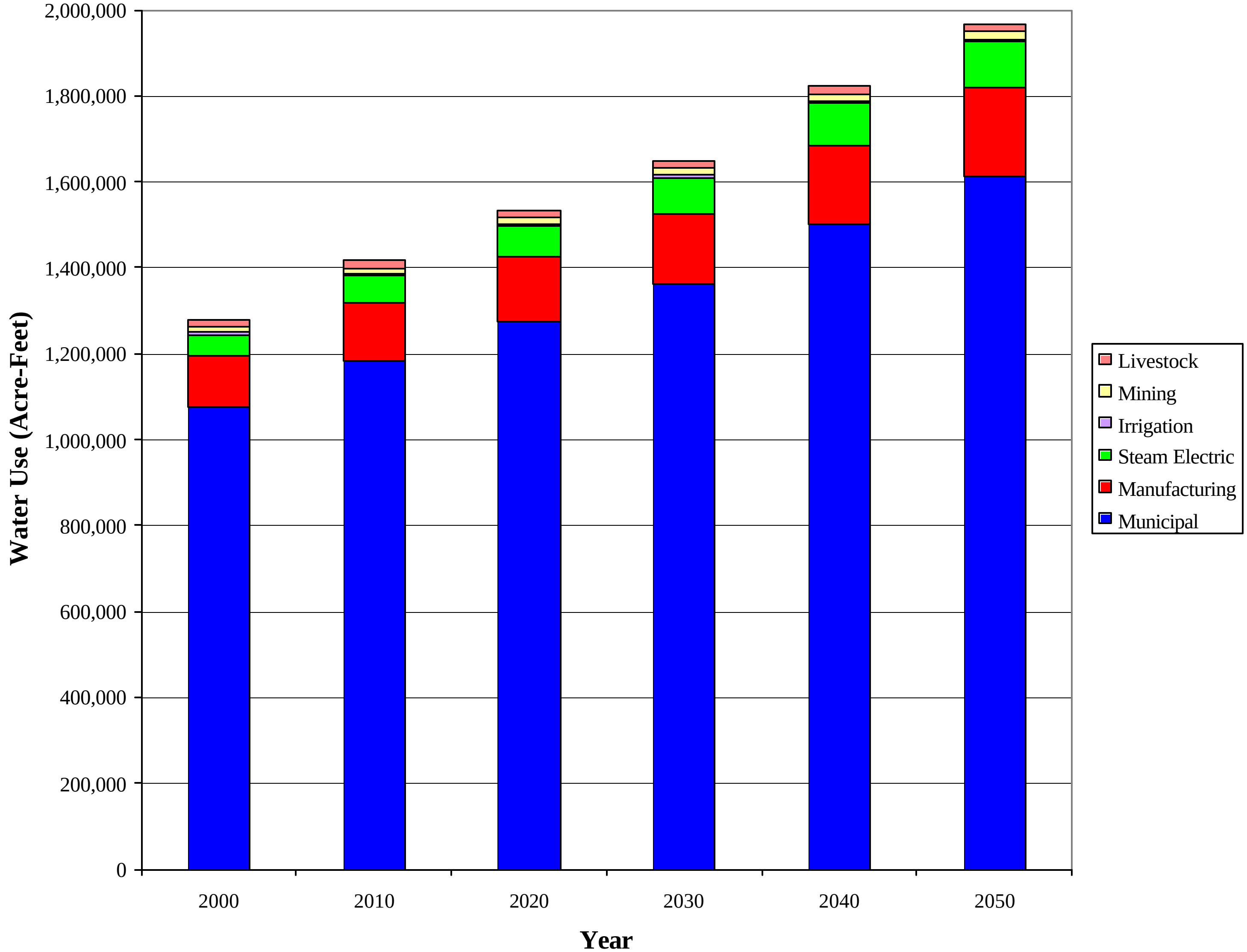
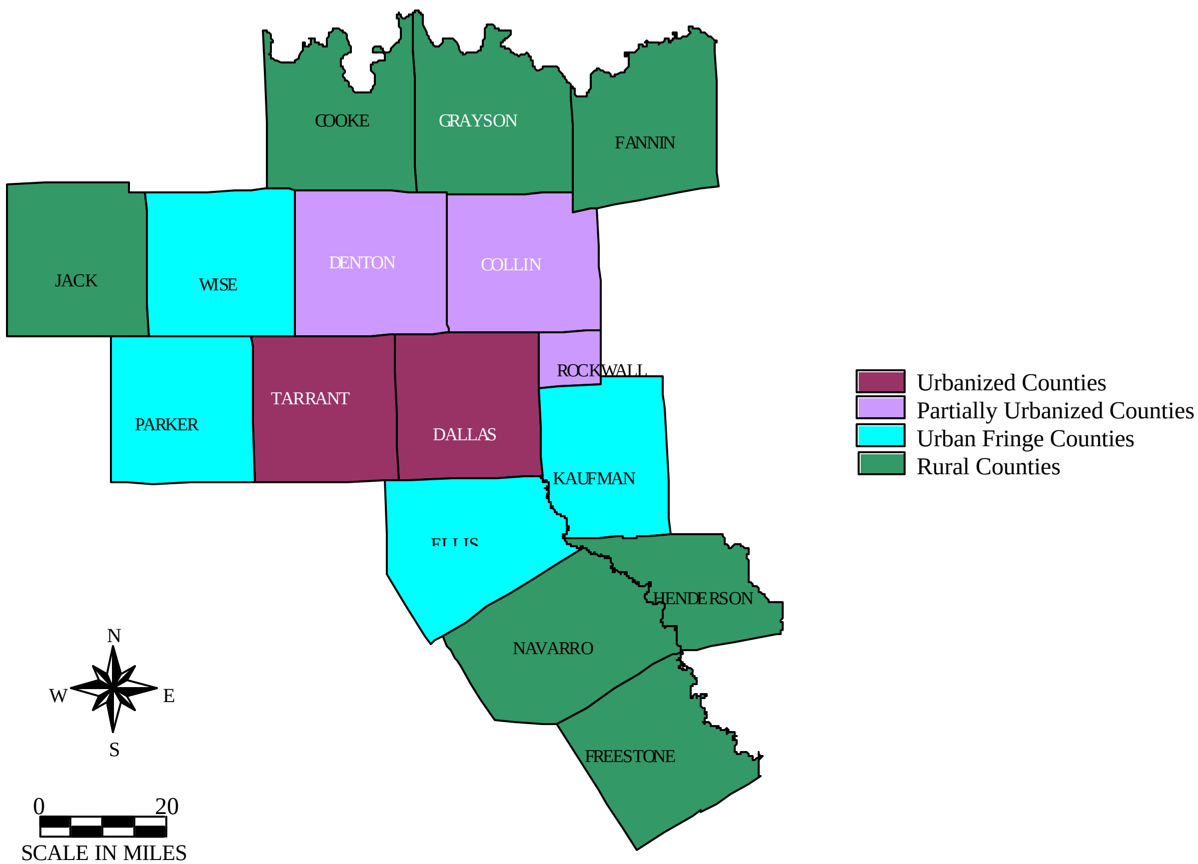


Figure 2.3
Region C County Classifications



demand will come primarily from population and employment growth (partially offset by water conservation). Dallas and Tarrant Counties are the urbanized counties in Region C.

Partially urbanized counties have a significant land area that is highly developed, with dense population and industrial and commercial development. These counties also have significant undeveloped areas. Population growth in these counties is expected to be significant and to be driven primarily by new development. Increased water demand will also come primarily from new development. Growth rates in these counties cannot be predicted from historical trends alone. Per capita municipal water demand is likely to increase with population in developing areas, even though conservation measures are implemented. The increase in per capita municipal demand occurs as a result of changes in the type of housing. Newly constructed homes in developing areas are likely to have higher per capita demand than existing development because of irrigation systems, swimming pools, and water-using appliances. Collin, Denton, and Rockwall Counties are partially urbanized counties in Region C.

Urban fringe counties are located adjacent to urban counties, but they currently have minimal urbanized development. They generally have higher population density than rural counties, but most of the land area is undeveloped. These counties are expected to experience relatively high growth in the next fifty years as urban development expands from the urbanized counties. Population growth in the urban fringe counties can be expected to be significant and will be derived primarily from new development. Water demand will grow with the growing population, and per capita municipal demand will generally increase even with water conservation measures because of changes in housing type. The urban fringe counties in Region C are Ellis, Kaufman, Parker, and Wise.

Rural counties are located beyond the immediate influence of the urban counties. Growth in these counties will generally be generated from local expansion and be dependent on local economic factors. In most cases, historical trends are a reasonable indication of future population growth. In some cases, recent economic or demographic changes, such as prison construction, have altered population growth trends. The rural counties in Region C are Cooke, Fannin, Freestone, Grayson, Henderson, Jack, and Navarro.

2.3 Methodology for Projections of Population and Water Demand

TWDB's Regional Water Planning Guidelines [1] require the regional water planning groups to use TWDB population and water demand projections from the 1997 Texas Water Plan [11] unless revisions are approved by TWDB. TWDB provided guidelines allowing for revisions based on changed conditions or new information[35].

TWDB projects water demand in several categories, including municipal, manufacturing, steam electric power generation, mining, irrigation, and livestock. Municipal demand is developed separately for each community with a population of over 500 and includes commercial, institutional, and residential demands but does not include manufacturing water use. A "county other" group for each county covers municipal use in rural areas and communities with less than 500 people. The other demand categories are developed on a countywide basis for each county.

The basic data provided by TWDB included historical population and water use data and the projections from the 1997 Texas Water Plan [9, 11]. For the Senate Bill One planning process, these data were assembled in tables and figures that could be reviewed by counties, cities, water suppliers, industries, and other interested entities. The TWDB data and a questionnaire were sent to all Region C counties, cities with a population over 1,000, regional water suppliers, retail water suppliers (supplying over 0.2 mgd), and large industries. The questionnaires sought information on population and water use projections and other water supply issues. Copies of the questionnaires are included in Appendix C. The response rate for all questionnaire recipients was 51 percent, and 61 percent of the cities, counties, and regional water suppliers responded. Many cities and counties responded with suggestions for revisions to the previous projections, as did several major water providers.

In addition to data provided by TWDB and replies from the surveys, population data were gathered from the State Data Center [3] and the North Central Texas Council of Governments (NCTCOG) [36]. The State Data Center provided historical population estimates for each city and county and a 1998 population projection by county based on 1990-1996 migration rates. NCTCOG provided historical population estimates for cities and counties in its service area and projected populations for 1999 and 2000.

Revisions to Population Projections

Figures showing historical and projected population were developed for each Region C county. The figures are included in Appendix D, which has back-up data for population and water demand projections. The figures show the following:

- Historical population estimates from the State Data Center
- TWDB population projections through 2050 developed for the 1997 water plan
- State Data Center population projections through 2030 based on 1990-96 migration rates
- Projections provided from responses to the surveys
- Projections adopted by the Region C committee and approved by TWDB.

The State Data Center and TWDB population projections are based on analysis of projected birth rates, death rates, and migration into and out of each county. In the 1997 water plan, the TWDB developed at least three different population projections for each county, based on different assumptions about future migration rates:

- Future migration rates equal to 100 percent of the rates that actually occurred in the 1980s
- Future migration rates equal to 50 percent of the rates in the 1980s
- No net future migration into or out of the county.

The TWDB then adopted one of these three population projections as the "most likely" for the county or ran a fourth projection as the most likely set. The State Data Center projection is a single projection showing future population if migration rates are the same as those from 1990 through 1996.

The existing population projections for each county were reviewed, and changes to projections were recommended where current populations deviate significantly from the previous TWDB projections. The 1998 State Data Center projections were considered carefully in this process since they are based on the most recent available migration information.

Once the county population projections were completed, city population projections were adjusted based on historical trends and knowledge of expected future development. The county population projections served as controls in this process, and all population not assigned to a particular city was included as "county other" for that county.

Revisions to Water Demand Projections

As discussed in Section 1, municipal use is over 85 percent of the total water use in Region C. TWDB estimates of municipal demand are based on projections of population and per capita municipal water demand. The projected population is multiplied by the projected per capita municipal demand to determine the projected municipal water use. TWDB's projections of per capita municipal water demand from the 1997 Texas Water Plan [11] were compared with per capita water demand in the 1990s from TWDB data [9]. In addition, data were developed on 1998 per capita water use for many Region C water providers. Previous TWDB projections in per capita water demand were adjusted to reflect actual use in the 1990s, trends in water use, water conservation, reasonable minimum demands for water, knowledge of future development that might affect per capita needs, and other factors. Tables and graphs were developed for each city in the region. They are not included in this report due to space limitations, but they were provided to the Region C Technical Review Committee and the TWDB to assist in the review of the recommended projections.

Projections of water demand for steam electric power generation were revised based on input from TXU Electric. The revised projections are higher than previous TWDB projections because of the surge in power plant development that is presently occurring. Previous TWDB projections for manufacturing, mining, irrigation, and livestock use were left unchanged after comparison with recent historical data.

Review of Initial Recommendations for Population and Water Use Projections

The Region C Water Planning Group formed a Technical Review Committee consisting of experienced water resource planners to review the recommendations of the consultants on population and water use and report to the planning group. The Technical Review Committee met with the Region C consultants five times for a total of 35 hours to review and finalize the population and water demand projections for the region. These meetings included a thorough review and discussion of the population and municipal demand projections for each water user group in the region. The report of the Technical Review Committee is included as Appendix E. The Region C Water Planning Group also held a public meeting to receive input on the water demand projections.

The TWDB staff conducted a thorough review of the revisions to projected population and water demand recommended by the Region C Water Planning Group. A number of additional changes were made as a result of TWDB input, and the TWDB board approved the revised projections in December of 1999.

2.4. Population Projections

Table 2.3 presents the population projections by county for Region C as recommended by the Region C water planning group and approved by TWDB. Figure 2.4 shows the historical and projected population for the region. Figure 2.5 is a map of the projected 2050 population and the projected change between 1996 and 2050 by county. All counties are projected to increase in population between now and 2050, and the new 2050 population projection for Region C is 9,481,157, which is 7.2 percent higher than the previous TWDB projection. The newly adopted 2050 population projections are higher than the previous TWDB projections for Collin, Cooke, Denton, Fannin, Freestone, Grayson, Kaufman, Navarro, and Wise Counties. They are lower than the previous projections for Ellis County, and they are the same for Dallas, Henderson, Jack, Parker, Rockwall, and Tarrant Counties. The reasons for the changes to county population projections are as follows:

Collin. The estimated 1998 population for Collin County exceeds TWDB's projected population for the year 2000. In the 1990s, population growth has been slightly above TWDB's highest projection and well above TWDB's most likely projection. The adopted projection follows TWDB's highest projection through 2020 and shows slower growth thereafter.

Cooke. The estimated 1998 population for Cooke County exceeds TWDB's projections for 2000 and 2010. The adopted projection follows the 1998 State Data Center projection through 2020 and continues slow growth thereafter.

Denton. Based on growth through 1998, the expected year 2000 population for Denton County will exceed TWDB's most likely projection. The adopted projection for 2000 is based on extending the 1990-98 growth trend. The adopted projection parallels the State Data Center projection for 2010 through 2030 and shows slower growth thereafter.

Table 2.3
Adopted County Population Projections for Region C

County	Historical 1996	2000	2010	2020	2030	2040	2050	Previous TWDB 2050	% Change from Previous
Collin	373,095	443,000	635,455	923,309	1,150,001	1,351,000	1,501,395	1,162,482	29.2%
Cooke	33,196	34,209	36,967	38,816	40,000	41,250	42,500	37,821	12.4%
Dallas	1,999,926	2,104,858	2,326,828	2,556,793	2,784,704	3,045,931	3,259,995	3,259,995	0.0%
Denton	349,566	423,327	591,350	802,461	1,033,731	1,200,000	1,349,999	1,135,566	18.9%
Ellis	94,097	103,070	123,854	144,054	162,273	175,403	185,364	205,487	-9.8%
Fannin	27,435	30,000	33,601	37,000	39,501	40,499	41,001	28,396	44.4%
Freestone	17,757	18,167	18,800	19,300	19,600	20,000	20,300	19,433	4.5%
Grayson	100,611	106,119	110,226	114,702	117,865	120,981	122,000	120,982	0.8%
Henderson (Partial)	45,761	46,562	51,261	55,515	57,704	58,690	60,476	60,476	0.0%
Jack	7,435	7,819	8,139	8,591	8,934	9,175	9,353	9,352	0.0%
Kaufman	61,646	68,368	87,106	108,291	129,359	147,108	162,417	112,964	43.8%
Navarro	42,875	45,191	49,207	53,031	57,015	59,200	61,000	53,312	14.4%
Parker	73,897	80,436	99,095	118,287	139,094	156,023	171,216	171,216	0.0%
Rockwall	34,287	41,175	61,392	88,136	122,000	160,588	203,529	203,530	0.0%
Tarrant	1,306,457	1,415,759	1,594,218	1,798,894	1,915,375	2,111,193	2,205,610	2,205,610	0.0%
Wise	41,019	44,800	54,674	64,363	73,641	81,000	85,002	56,631	50.1%
Region C Total	4,609,060	5,012,860	5,882,173	6,931,543	7,850,797	8,778,041	9,481,157	8,843,253	7.2%
Previous TWDB Total		4,870,498	5,634,284	6,547,997	7,331,328	8,158,567	8,843,253		
% Change from Previous		2.9%	4.4%	5.9%	7.1%	7.6%	7.2%		

Figure 2.4
Historical and Projected Population for Region C

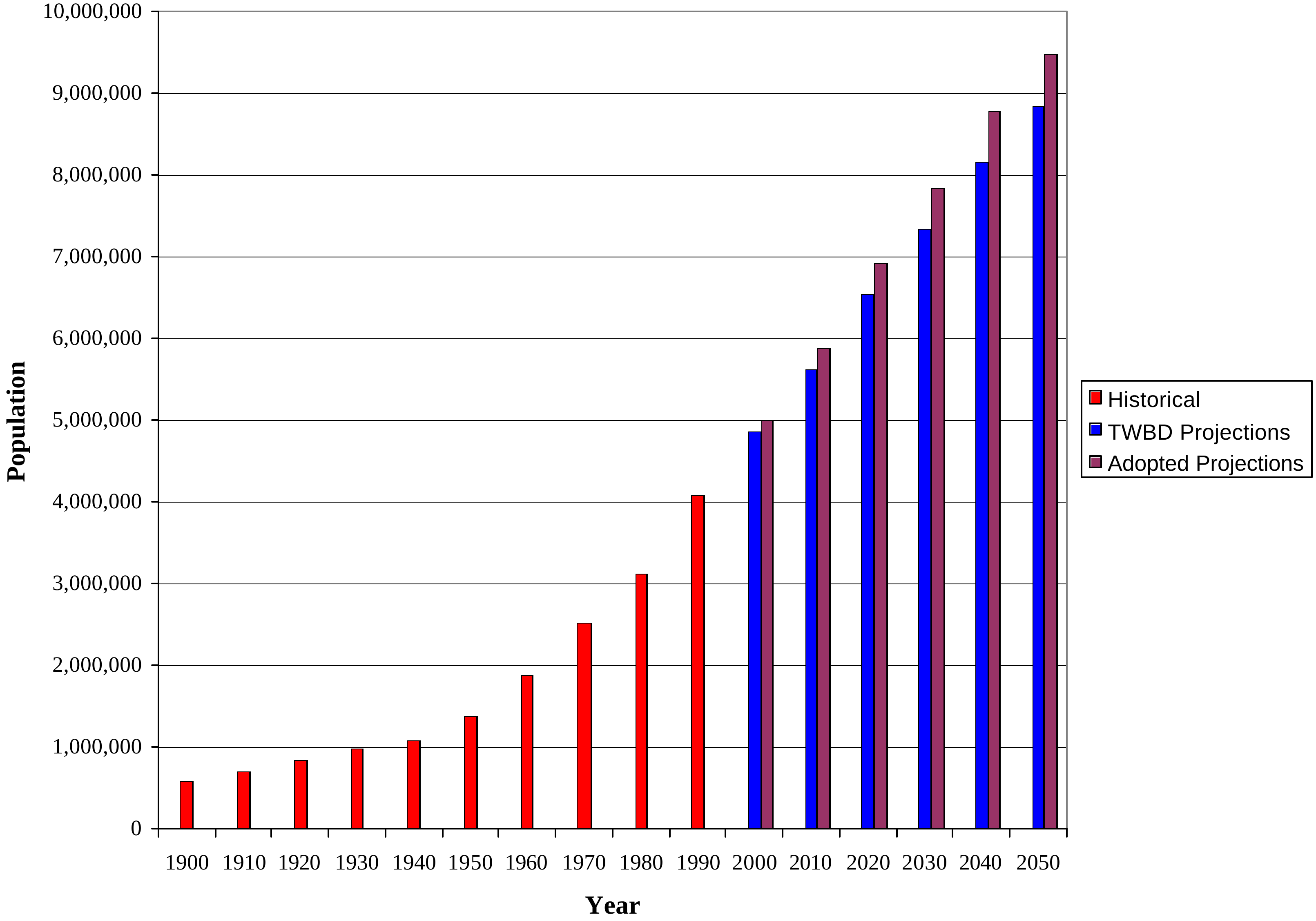
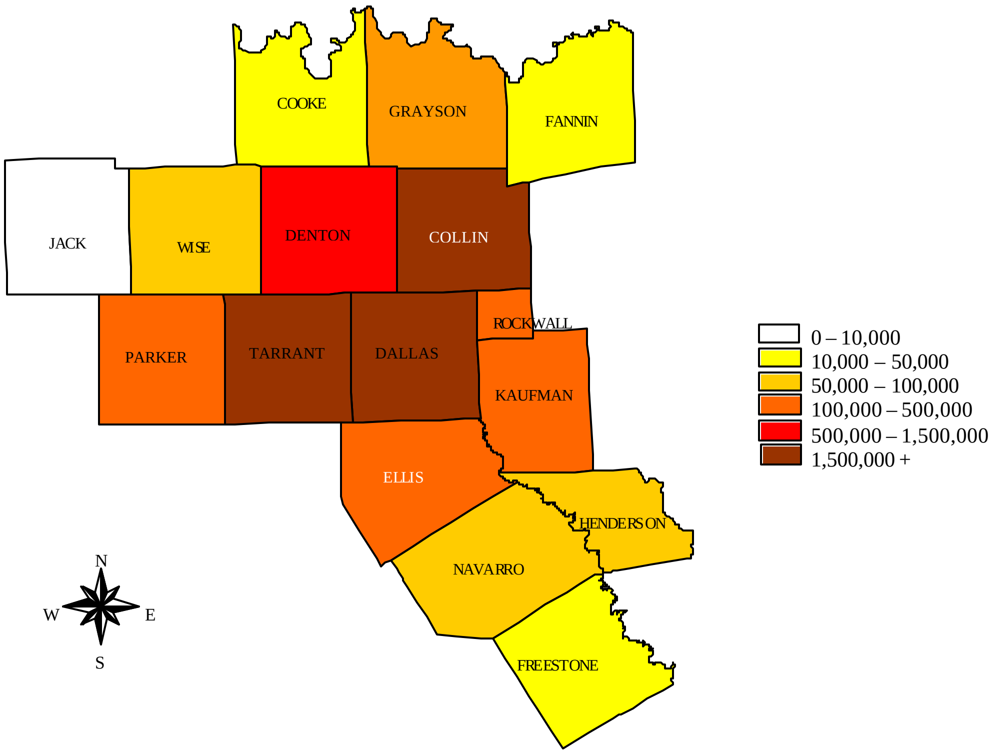
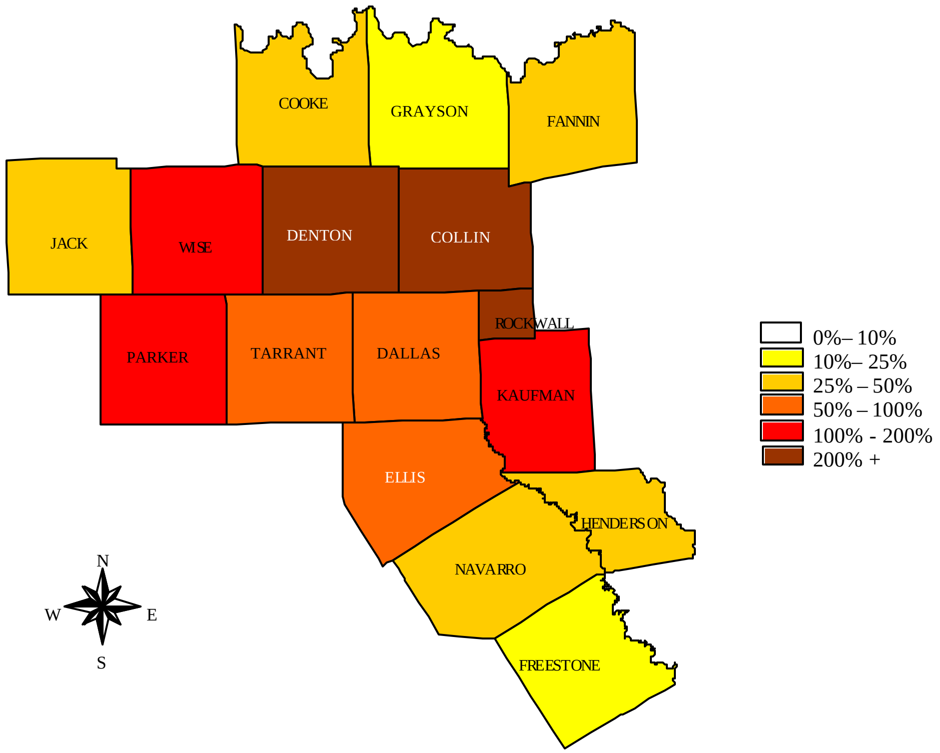


Figure 2.5
Adopted Population Projections for 2050



Approved Relative Population 2050



Approved % Increase 1996 - 2050

Ellis. Based on growth through 1998, the expected year 2000 population for Ellis County will be less than TWDB's most likely projection. The adopted projection follows the State Data Center projection, which is lower than TWDB's most likely projection, through 2030 and parallels TWDB's most likely projection from 2030 through 2050.

Fannin. The estimated 1998 population for Fannin County exceeds TWDB's projections for 2000, 2010, and 2020. The adopted projection follows information provided by the county through 2010 and shows slower growth thereafter.

Grayson. The estimated 1998 population projection for Grayson County exceeds TWDB's projection for 2000. The adopted population for 2000 is based on extending the 1990-98 growth trend. After 2000, the adopted projection shows slightly slower growth than TWDB's most likely scenario. The adopted projection for 2050 is almost the same as TWDB's previous most likely projection.

Kaufman. Based on growth through 1998, the expected year 2000 population for Kaufman will exceed the TWDB's most likely projection. The adopted projections through 2050 are the average of TWDB's 100 percent migration and most likely projections.

Navarro. The estimated 1998 population for Navarro County exceeds the TWDB's projection for 2000. The adopted projection follows a projection provided by the county (very close to the State Data Center projection) through 2030 and parallels TWDB's 100 percent migration projection thereafter.

Wise. Based on growth through 1998, the estimated 2000 population for Wise County will exceed TWDB's projection. The adopted projection follows a projection provided by the county (very close to the State Data Center projection) through 2030 and projects slower growth thereafter.

Although the adopted year 2050 population projections for Dallas and Jack Counties are the same as the previous TWDB projections, they are slightly different in the early decades. Dallas County requires a slight adjustment for 2000 and 2010 in order to balance the projections for the individual cities. Jack County's estimated 1998 population is greater than TWDB's projections for 2000 and 2010. The adopted projection uses 1990-98 growth to estimate 2000 population, uses the State Data Center projection for 2010-2030 and uses TWDB's most likely projection for 2050.

In summary, changes were made to the previous TWDB county population projections for the following reasons:

- Estimated 1998 population exceeds TWDB's projected population for 2000 (Collin, Cooke, Fannin, Freestone, Grayson, Jack, Navarro).
- Projected 2000 population based on 1990-98 growth rate exceeds TWDB's projected population for 2000 (Denton, Kaufman, Wise).
- Projected 2000 population based on the 1990-98 growth rate is less than TWDB's projected population for 2000 (Ellis).
- Small adjustments made to balance city populations (Dallas County, 2000 and 2010).

Table 2.4 presents a summary of the change in the projected 2050 population for each Region C county and the reasons for the changes.

Once the county population projections were completed, city population projections were adjusted based on historical trends and knowledge of expected future development. The county populations served as controls in this process, and all population not assigned to a particular city was included as county other. Appendix F includes the adopted Region C population projections by county, water user group, and basin. Table D-2 in Appendix D shows the reasons for the changes from previous TWDB population projections for each city. Population changes for cities are based on one or more of the following factors:

Current population exceeds TWDB year 2000 projection. In some cities, recent population estimates by the State Data Center indicate that the current population exceeds TWDB projections for 2000. This indicates that the city is growing faster than previously projected by TWDB.

Recent growth trends exceed TWDB's projected trends. Some cities have experienced a change in growth trends in recent years. These are often areas in partially urbanized or urban fringe counties. In these cases, growth trends in the 1990s support a higher growth rate than was used in the previous TWDB projections.

Urbanization. Some cities are in transition from undeveloped rural areas into more urban areas. Others are expected to make such a transition between now and 2050. In these

Table 2.4
Summary of Changes to Population Projections and Reasons for Changes by County

County	2050 Population		Change	Percent Change	Reasons (See key.)					
	Previous TWDB	Adopted			1	2	3	4	5	6
Collin	1,162,482	1,501,395	338,913	29.2%	X	X		X		
Cooke	37,821	42,500	4,679	12.4%	X	X				
Dallas	3,259,995	3,259,995	0	0.0%	No change from TWDB					
Denton	1,135,566	1,349,999	214,433	18.9%	X	X		X		
Ellis	205,487	185,364	-20,123	-9.8%						
Fannin	28,396	41,001	12,605	44.4%	X	X				X
Freestone	19,433	20,300	867	4.5%	X	X				
Grayson	120,982	122,000	1,018	0.8%	X	X				
Henderson (Partial)	60,476	60,476	0	0.0%	No change from TWDB					
Jack	9,352	9,353	1	0.0%	No change from TWDB					
Kaufman	112,964	162,417	49,453	43.8%	X	X		X		
Navarro	53,312	61,000	7,688	14.4%	X	X				
Parker	171,216	171,216	0	0.0%	No change from TWDB					
Rockwall	203,530	203,529	-1	0.0%	No change from TWDB					
Tarrant	2,205,610	2,205,610	0	0.0%	No change from TWDB					
Wise	56,631	85,002	28,371	50.1%	X	X				
Region C Total	8,843,253	9,481,157	637,904	7.2%						

Key to Reasons:

1 Estimated Current Population Exceeds TWDB Year 2000 Projections
2 Recent Growth Trends Exceed TWDB's Projected Trends
3 City Limit Growth Through Annexation
4 Urbanization
5 Buildout
6 Other (See Table D-2 in Appendix D)

situations, historical growth trends are not accurate indicators of future trends. The growth experienced by similar areas that have already gone through such urbanization is a better guide. For example, growth trends experienced by Plano from 1980 through 2000 can be used as a model for McKinney and Frisco. Growth trends experienced by Lewisville and Flower Mound can serve as models for adjacent communities in Denton County.

Build Out. For some cities, the expected build out population is less than the previous TWDB projection for 2050. The area available for development and the expected population density will limit population in these cities.

Other. Other reasons for changes in population projections are covered on a case-by-case basis in Table D-2.

2.5 Water Demand Projections

Table 2.5 shows adopted water demand projections for Region C by county. Table 2.6 and Figure 2.6 show the projected water demand for the region by type of use. Figure 2.7 is a map of the projected 2050 water demand and the projected change between 1996 and 2050 by county. The projected 2050 water demand for Region C is 2,536,902 acre-feet per year, which is 28.9 percent higher than the previous TWDB projection. The projected year 2050 demand is more than double the 1996 use in the region. The newly adopted projections are higher than the previous TWDB projections for all counties except Fannin and Henderson. For both Fannin and Henderson Counties, the reduction in projected 2050 water demand is due to a reduction in projected water demand for steam electric power generation. Most of the change from previous TWDB projections is in projected municipal demands, with a smaller change in steam electric power demands. No changes were made to TWDB's previous projections for manufacturing, mining, irrigation, or livestock demands.

Table 2.7 presents a summary of the specific reasons for changes to projected water demand for each county. Specific reasons for the increases include the following:

Population change. As set forth in TWDB guidelines [(35)], a change in projected population requires a change in projected water use. The adopted 2050 population projection for Region C is 7.2 percent higher than the previous TWDB guidelines, which

Table 2.5
Adopted County Water Demand Projections for Region C

County	Historical 1996 (Acre-Feet per Year)	Projected Water Demand (Acre-Feet per Year)						Previous TWDB 2050 (Acre-Feet per Year)	% Change from Previous
		2000	2010	2020	2030	2040	2050		
Collin	89,230	129,015	199,964	262,520	312,307	363,821	401,007	202,680	97.9%
Cooke	8,429	9,054	9,133	9,238	9,304	9,581	9,879	8,147	21.3%
Dallas	505,423	594,937	683,097	751,767	810,356	883,850	940,289	860,588	9.3%
Denton	65,075	90,209	135,740	185,725	230,286	257,410	281,989	172,338	63.6%
Ellis	19,721	24,372	43,204	46,030	49,309	53,991	55,575	36,857	50.8%
Fannin	17,515	12,100	13,330	14,500	15,597	16,572	17,515	30,147	-41.9%
Freestone	20,608	20,074	31,058	33,000	33,036	37,260	37,290	17,691	110.8%
Grayson	29,152	29,060	29,760	30,242	31,347	32,508	33,688	28,553	18.0%
Henderson (Partial)	10,785	12,697	13,169	13,478	13,697	13,737	13,908	44,014	-68.4%
Jack	3,337	2,644	2,589	2,574	2,591	2,615	2,652	2,346	13.0%
Kaufman	10,653	21,219	24,401	27,392	32,361	34,832	42,017	17,035	146.7%
Navarro	10,558	10,301	10,845	11,210	11,850	12,303	12,735	10,159	25.4%
Parker	12,372	14,120	24,528	28,455	37,697	42,853	45,725	21,858	109.2%
Rockwall	6,566	9,160	19,805	26,027	33,061	41,320	50,249	32,219	56.0%
Tarrant	291,406	379,205	423,578	468,728	490,960	527,716	553,302	462,745	19.6%
Wise	25,688	18,206	31,460	34,007	36,067	37,819	39,082	20,539	90.3%
Region C Total	1,126,518	1,376,373	1,695,661	1,944,893	2,149,826	2,368,188	2,536,902	1,967,916	28.9%
Previous TWDB Total		1,280,104	1,416,271	1,534,409	1,649,168	1,822,174	1,967,916		
% Change from Previous		7.5%	19.7%	26.8%	30.4%	30.0%	28.9%		

Table 2.6
Adopted Water Demand Projections for Region C by Type of Use
- Values in Acre-Feet per Year -

Use	Historical 1996	Projected Water Demand 2000	2010	2020	2030	2040	2050
Municipal	946,454	1,162,093	1,401,197	1,625,412	1,808,337	1,988,513	2,125,330
Manufacturing	71,366	117,577	135,114	148,798	162,714	183,188	207,637
Steam Electric Power	52,103	59,800	122,300	132,700	139,700	156,192	162,192
Mining	22,576	13,046	13,231	14,190	15,294	16,515	17,950
Irrigation	9,689	5,382	5,344	5,318	5,306	5,305	5,318
Livestock	24,330	18,475	18,475	18,475	18,475	18,475	18,475
Total	1,126,518	1,376,373	1,695,661	1,944,893	2,149,826	2,368,188	2,536,902

causes a 5.1 percent increase in water demand. (The increase in demand is less than the increase in population because the increased population affects only municipal demand. Manufacturing, steam electric, mining, irrigation, and livestock demands are not directly dependent on population.) The increase in water demand due to higher population projections is most significant in Collin, Denton, Kaufman, Navarro, and Wise Counties.

Actual per capita use. As set forth in TWDB guidelines[(35)], actual per capita municipal use in excess of projections is a reason to revise municipal demand projections. The dry years in 1996 and 1998 caused many cities in Region C to experience record per capita municipal water use. Table D-1, in Appendix D, lists cities in Region C for which recent per capita municipal water use exceeds the TWDB projection for 2000. This list should be updated once 1998 per capita use figures are available for all cities in the region. For the whole region, actual per capita use in excess of TWDB projections caused a 9.7 percent increase in water demand. The biggest increases due to actual per capita use are in Collin, Cooke, Denton, Grayson, Kaufman, Rockwall, and Tarrant Counties.

Continuing increase in per capita water use. Many cities in Region C have a historical trend of increasing municipal per capita use. Such a trend is particularly common in cities undergoing rapid development. Water conservation decreases water use from what it would have been without conservation. However, there are many cities in which conservation is not projected to overcome a trend of increasing per capita use, at least in the near term. For most

Figure 2.6
Adopted Projections
for Water Use by Category in Region C

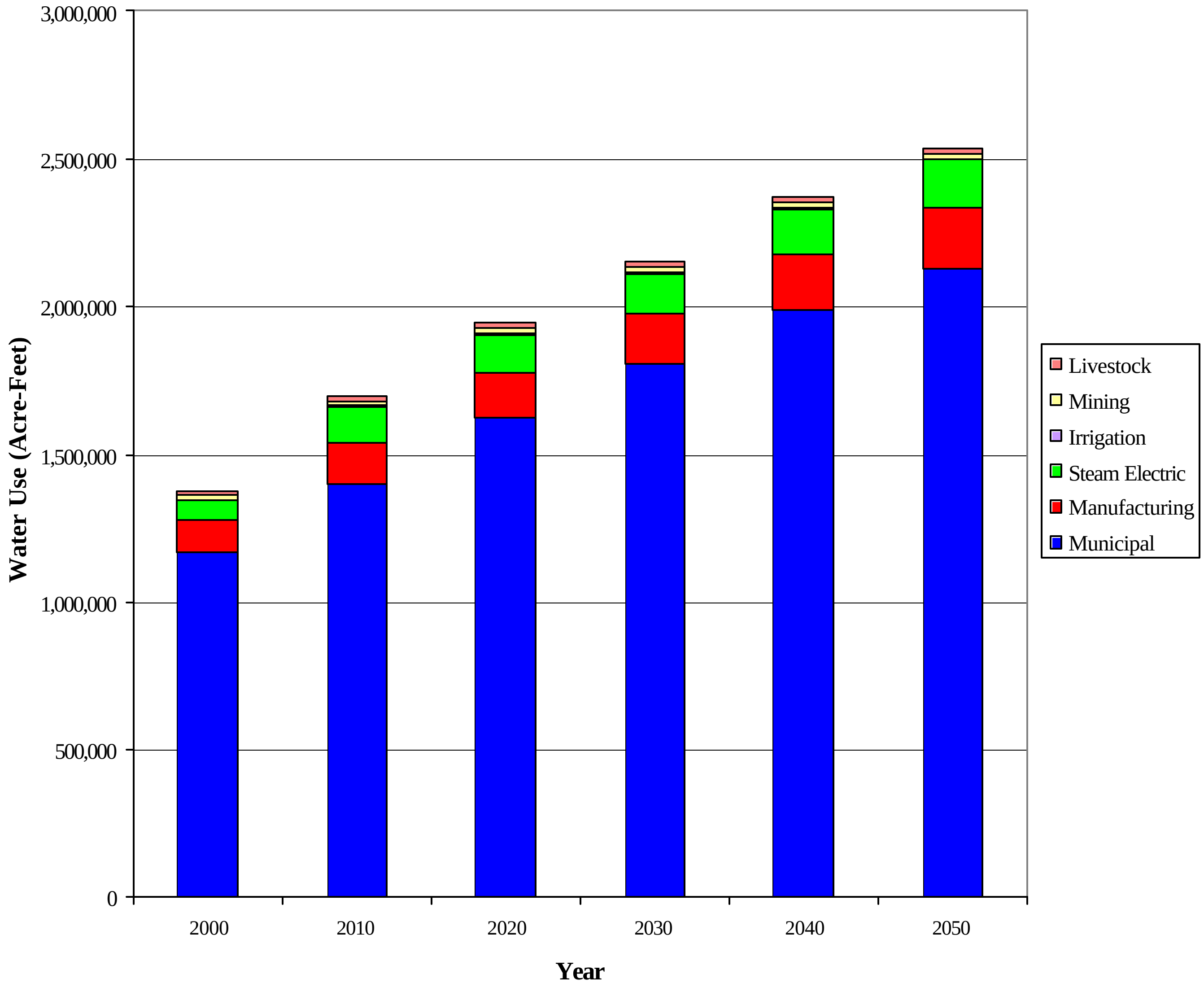
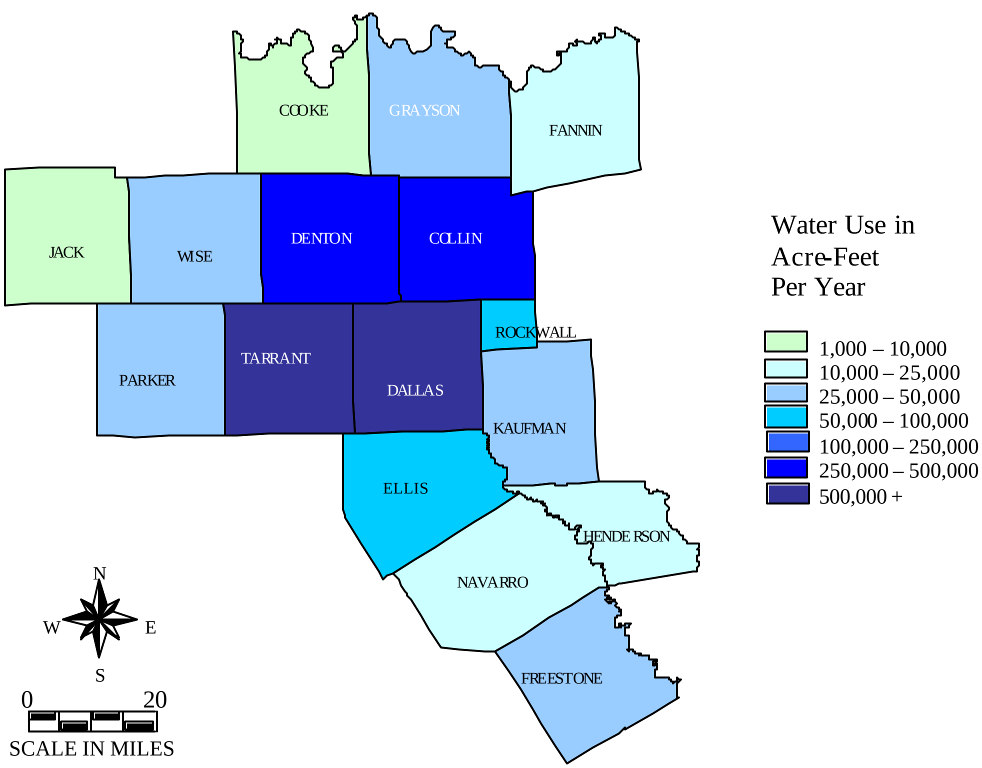
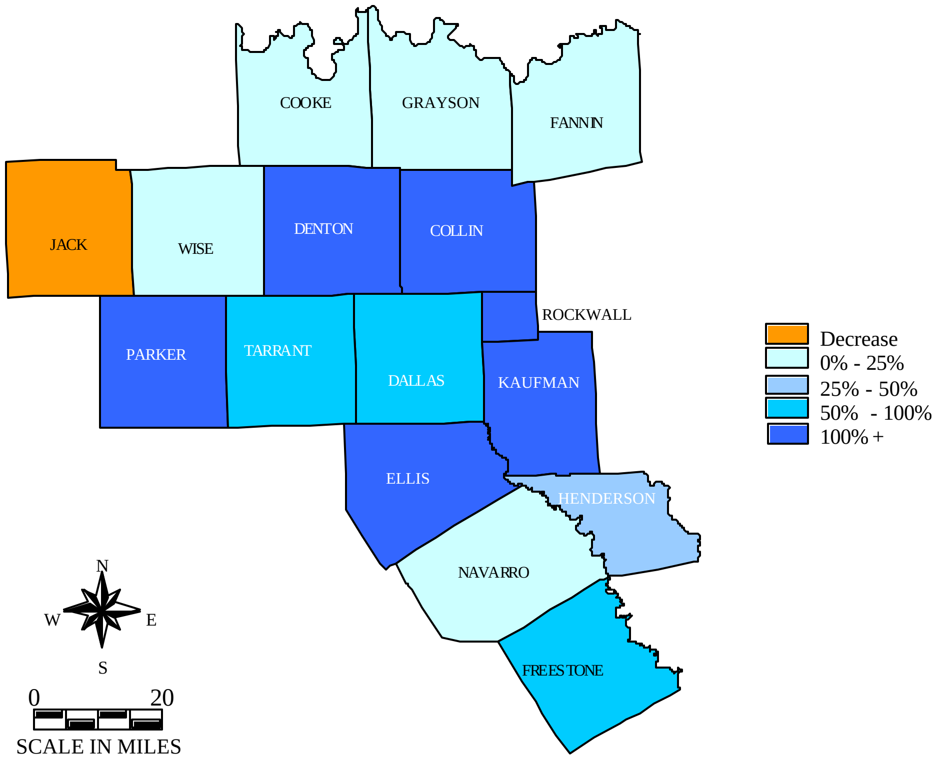


Figure 2.7
Adopted Water Demand Growth 1996-2050



Approved 2050 Water Demand Projection



Percent Change, 1996 To 2050 Recommended Projection

Table 2.7
Summary of Water Demand Changes and Reasons for Changes by County
- Values in Acre-Feet per Year -

County	2050 Water Demand		Change	Reasons (See key.)						
	Previous TWDB	**Adopted**		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Collin	202,680	401,007	198,327	50,798	78,424	57,466	15	4,271	6,500	853
Cooke	8,147	9,879	1,732	636	697	238	169	0	0	-8
Dallas	860,588	940,289	79,701	1,257	35,365	24,925	0	4,107	2,000	12,047
Denton	172,039	281,989	109,950	39,132	13,123	13,907	3,051	21,238	5,000	14,499
Ellis	36,674	55,575	18,901	-1,676	1,643	461	101	890	18,000	-518
Fannin	30,147	17,515	-12,632	1,628	432	187	21	0	-15,000	100
Freestone	17,691	37,290	19,599	95	206	47	93	0	19,192	-34
Grayson	28,553	33,688	5,135	276	3,468	416	29	939	0	7
Henderson (Partial)	44,014	13,908	-30,106	90	1,229	4	278	0	-31,000	-707
Jack	2,346	2,652	306	-1	187	64	17	0	0	39
Kaufman	17,035	42,017	24,982	4,801	2,791	2,132	33	233	15,000	-8
Navarro	10,342	12,735	2,393	1,575	739	0	58	0	0	21
Parker	21,858	45,725	23,867	1,889	2,413	2,963	1,098	3,605	11,900	-1
Rockwall	32,219	50,249	18,030	-1,697	5,804	7,264	0	0	6,000	659
Tarrant	462,903	553,302	90,399	-521	43,061	37,875	662	907	6,800	1,615
Wise	20,680	39,082	18,402	2,530	760	0	893	3,038	11,200	-19
Region C Total	1,967,916	2,536,902	568,986	100,812	190,342	147,949	6,518	39,228	55,592	28,545
Region C Total %			28.9%	5.1%	9.7%	7.5%	0.3%	2.0%	2.8%	1.5%

Key to Reasons for Change:

1 **Population change** is the change in projected water demand caused by changes to population projections.
2 **Actual per capita use** is the change in projected water demand caused by per capita use in the late 1990s being higher than projected for 2000 by TWDB.
3 **Continuing increase** is the change in projected water demand caused by an increase in per capita use in the future consistent with trends seen in the 1990s.
4 **Minimum per capita** is the change in projected water demand caused by assuming a minimum level of per capita use.
5 **Future development** is the change in projected water demand caused by assuming an increase in per capita use as cities change from rural to suburban in character.
6 **Steam electric** is the change in projected water demand caused by increased use for steam electric power production.
7 **Other** is the change in projected water demand cause by other factors, including anticipated commercial development.

Region C cities with increasing per capita use in the 1990s, the trend is assumed to continue through 2010, partially offset by conservation. For some cities expected to grow rapidly until 2020, per capita use is assumed to increase through 2020, again partially offset by conservation. For Region C as a whole, accounting for the continuing increase in per capita use causes a 7.5 percent increase in projected 2050 water demand, with the biggest change in rapidly growing areas such as Collin, Denton, Kaufman, Rockwall, and Tarrant Counties.

Minimum per capita use. In the process of determining projected water demands, Region C adopted a minimum dry year per capita municipal water use – a level designed to provide an adequate water supply and an adequate quality of life. Based on experience in the region, it was felt that most per capita municipal use less than 115 gallons per person per day occurs in systems with inadequate supplies and represents supply and delivery limitations rather than the true demand for water. With few exceptions, a minimum municipal water demand of 115 gallons per capita per day was adopted for Region C, reducing over 50 years to 95 gallons per capita per day. This change increases the overall regional projected 2050 water demand by about 0.3 percent, with the biggest increases in Denton, Parker, and Wise Counties.

Future development. As cities in Region C have changed from rural to suburban, the per capita municipal water use has historically risen. This occurs because the nature of the housing changes. The new suburban housing generally has irrigated lawns, swimming pools, water-using appliances and other features that tend to increase water use. Communities with low existing per capita water use expected to undergo rapid development are also expected to see a rise in per capita use, partially offset by water conservation. This assumption causes a 2.0 percent increase to the projected 2050 water demand for Region C, with the biggest impact in Denton, Parker, and Wise Counties.

Steam electric. TXU Electric provided revised steam electric power demands reflecting known development plans for TXU and other utilities. These revised numbers reflect the current trend toward development of new merchant power plants in Region C. The increase to the projected 2050 steam electric demand causes a 2.8 percent increase to total water demand for the region.

Other factors. Other factors that influence water demand projections include anticipated major commercial development, anticipated employment growth, changes in the rate at which water conservation is achieved (slower or faster), and increased water demand due to the development of better supplies in some areas. These other factors increase the overall Region C water demand by 1.5 percent. They are discussed on a case-by-case basis in Table D-3 in Appendix D.

Appendix G includes the adopted water demand projections by county, water user group, and basin. Table D-3 in Appendix D shows the reasons for the changes from previous TWDB demand projections for each water user group. Appendix H includes the adopted demand projections by major water provider.

One of the most important factors determining the increase to projected per capita demand for Region C over previous TWDB projections is the high water use recorded for many Region C water suppliers in 1996 and 1998. This high water use occurred despite significant efforts to implement water conservation in the region and despite the impact of low flow plumbing fixtures. There are several factors that tend to increase per capita municipal water use in the region:

- In many communities, new development is large houses with large lots, sprinkler systems, swimming pools, and other water-using amenities.
- The number of people per household is decreasing in most of Region C. This tends to cause an increase in per capita use because household uses are spread over fewer people.
- Many Region C communities are experiencing rapid commercial development, which also drives up per capita water use.

Table D-4 in Appendix D shows 1997 unaccounted water data for Region C water suppliers. (The table is based on TWDB records and includes only entities for which TWDB had data available.) Unaccounted water is potable water put into the distribution system but not metered as sold. Causes of unaccounted water can include inaccurate metering, unmetered uses, fire flows, line flushing flows, and losses to leaks. In general, unaccounted water less than 10 percent is excellent in a municipal distribution system, and values in the 15 to 20 percent range are acceptable. Rural water suppliers, which tend to have more pipeline per customer, may experience somewhat higher losses. For Region C as a whole, unaccounted water was 10.1 percent in 1997, which is excellent. Some water suppliers show high values for unaccounted water. For the most part, these are smaller cities and rural water suppliers. A continual pattern of high unaccounted water might indicate that the supplier should investigate the problem and make appropriate improvements.

In summary, the reasons for the 28.9 percent increase in projected 2050 water demands over previous TWDB projections, which would have been greater without the incorporated water conservation assumptions, are as follows:

- 5.1 percent due to increased population projections.
- 9.7 percent due to actual per capita municipal demand in recent years above the previous TWDB projection for 2000.
- 7.5 percent due to continuing recent trends of increasing per capita municipal demand through 2010 or 2020. (These trends have been reduced by conservation efforts, but per capita municipal demand is still increasing overall in many cities.)
- 0.3 percent due to adoption of a minimum per capita municipal demand.
- 2.0 percent due to increases in per capita municipal demand assumed to occur with rapid suburban development in rural areas.
- 2.8 percent due to increased projections for steam-electric power generation.
- 1.5 percent due to other factors, including commercial development and employment growth.

Figure 2.1
Texas Water Development Board Historical and Projected Population for Region C from the 1997 Water Plan

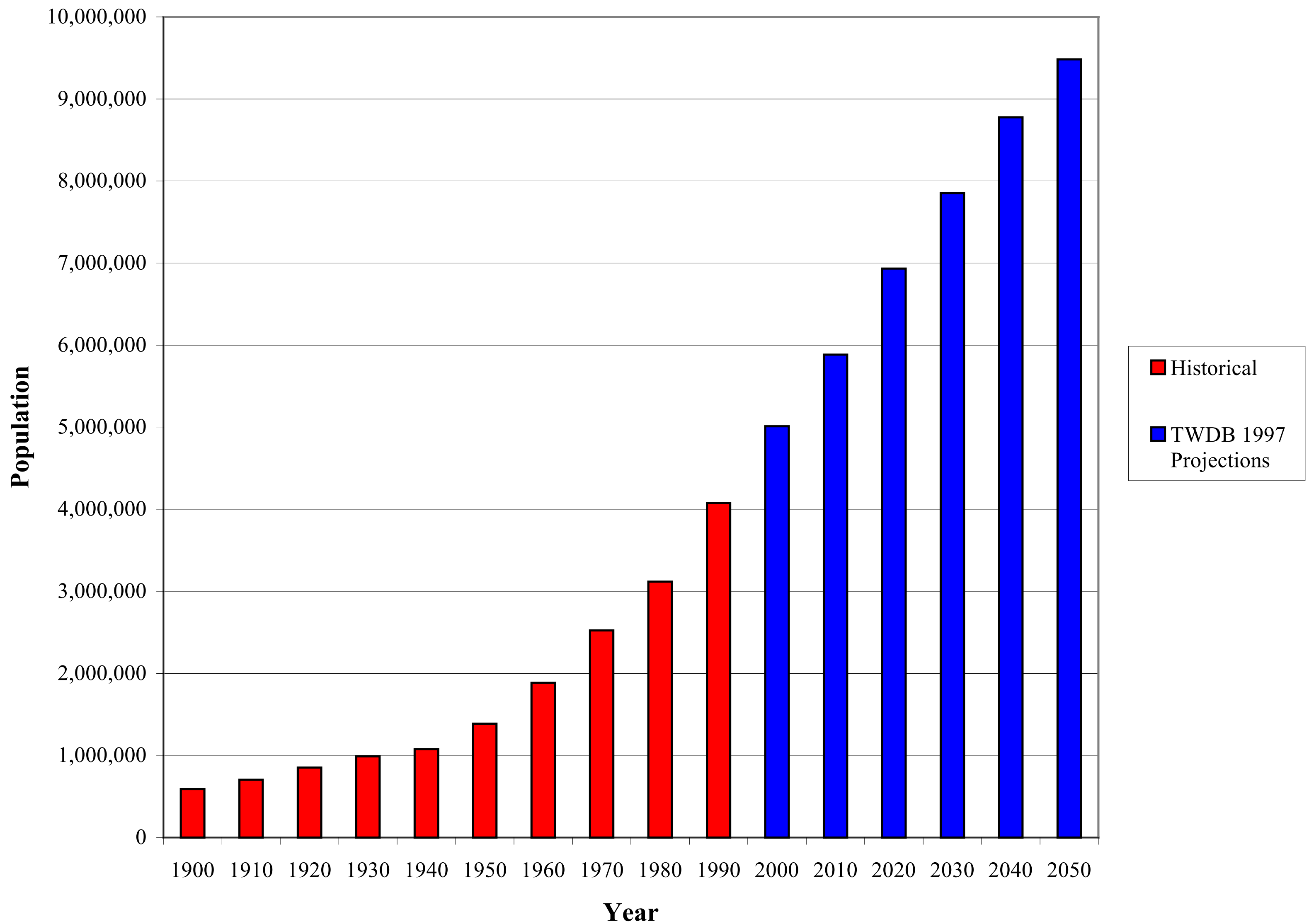


Figure 2.2
Texas Water Development Board 1997 Water Plan Projections for Water Use by Category in Region C

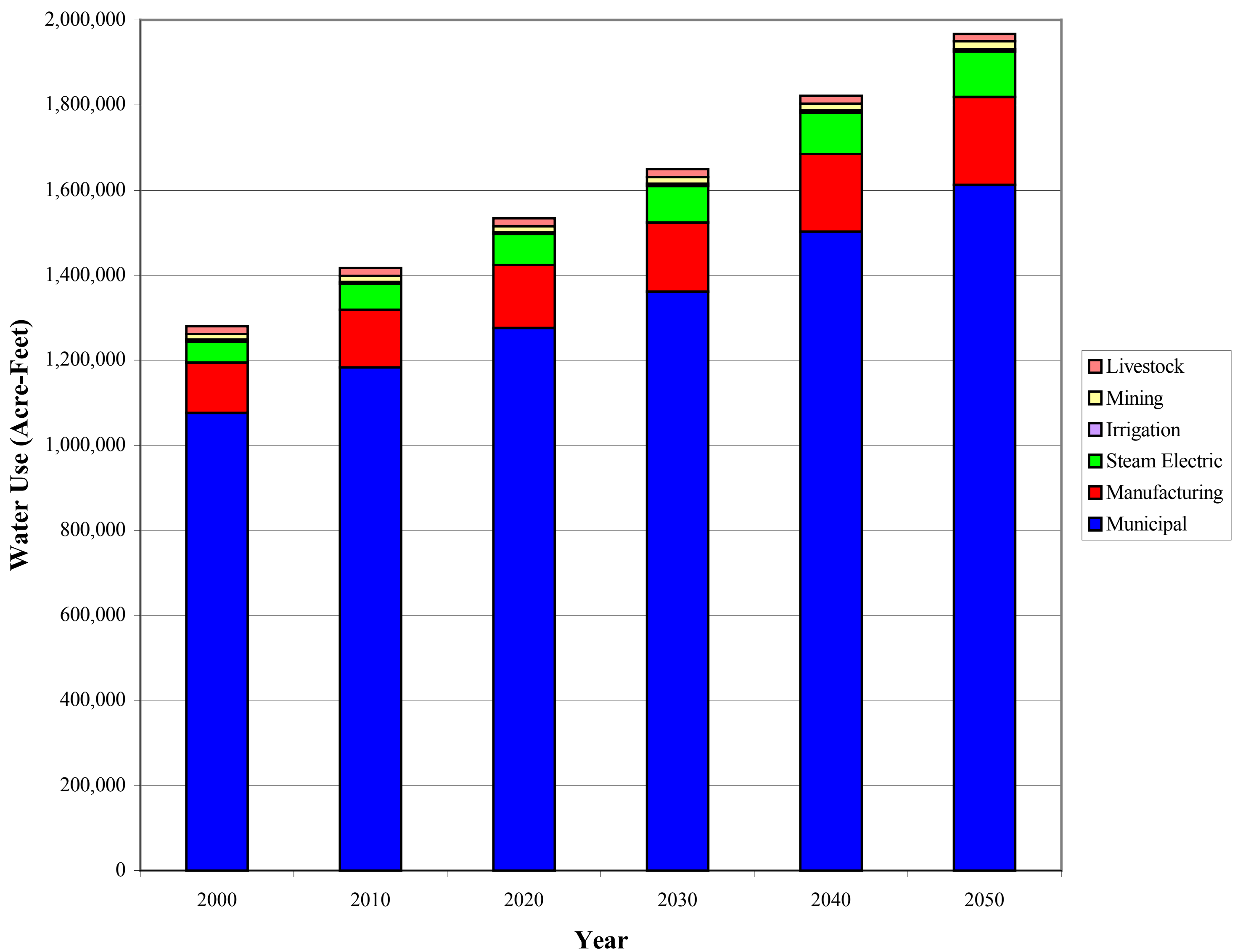


Figure 2.3
Region C County Classifications

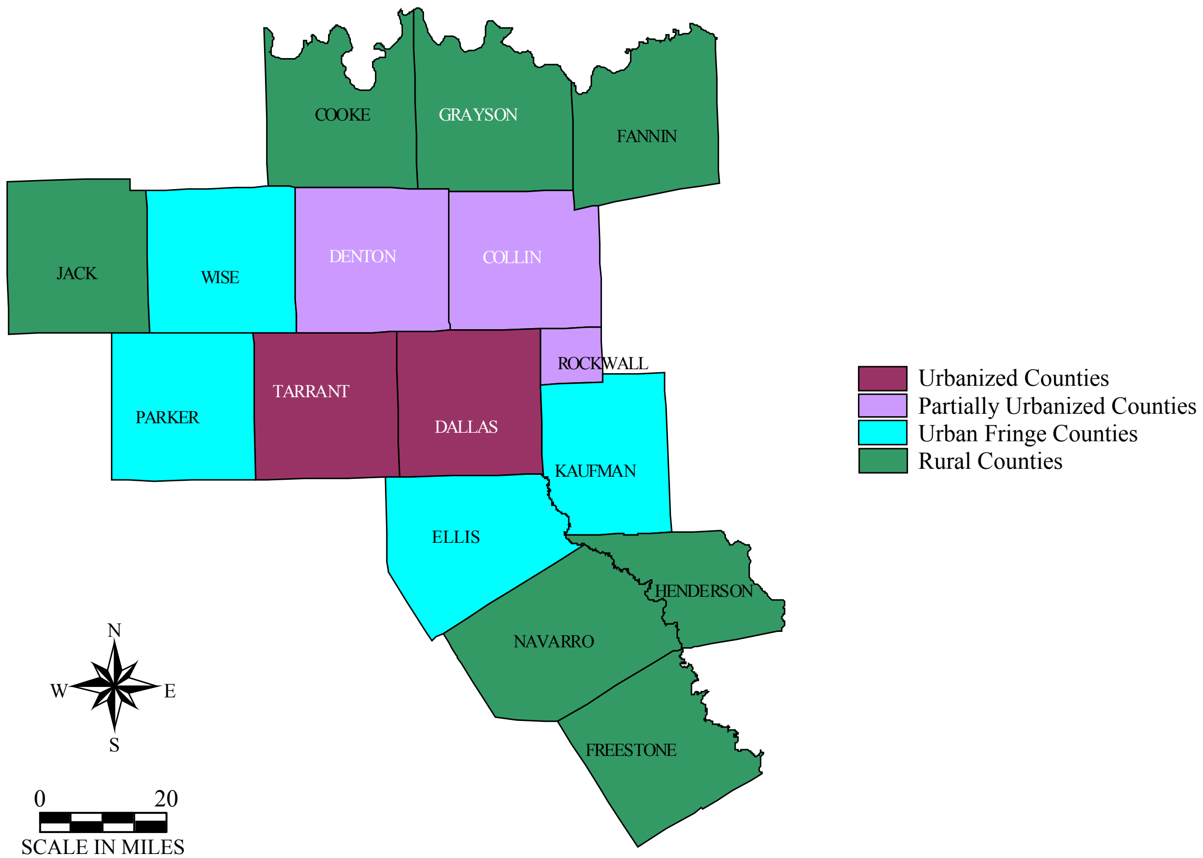


Figure 2.4
Historical and Projected Population for Region C

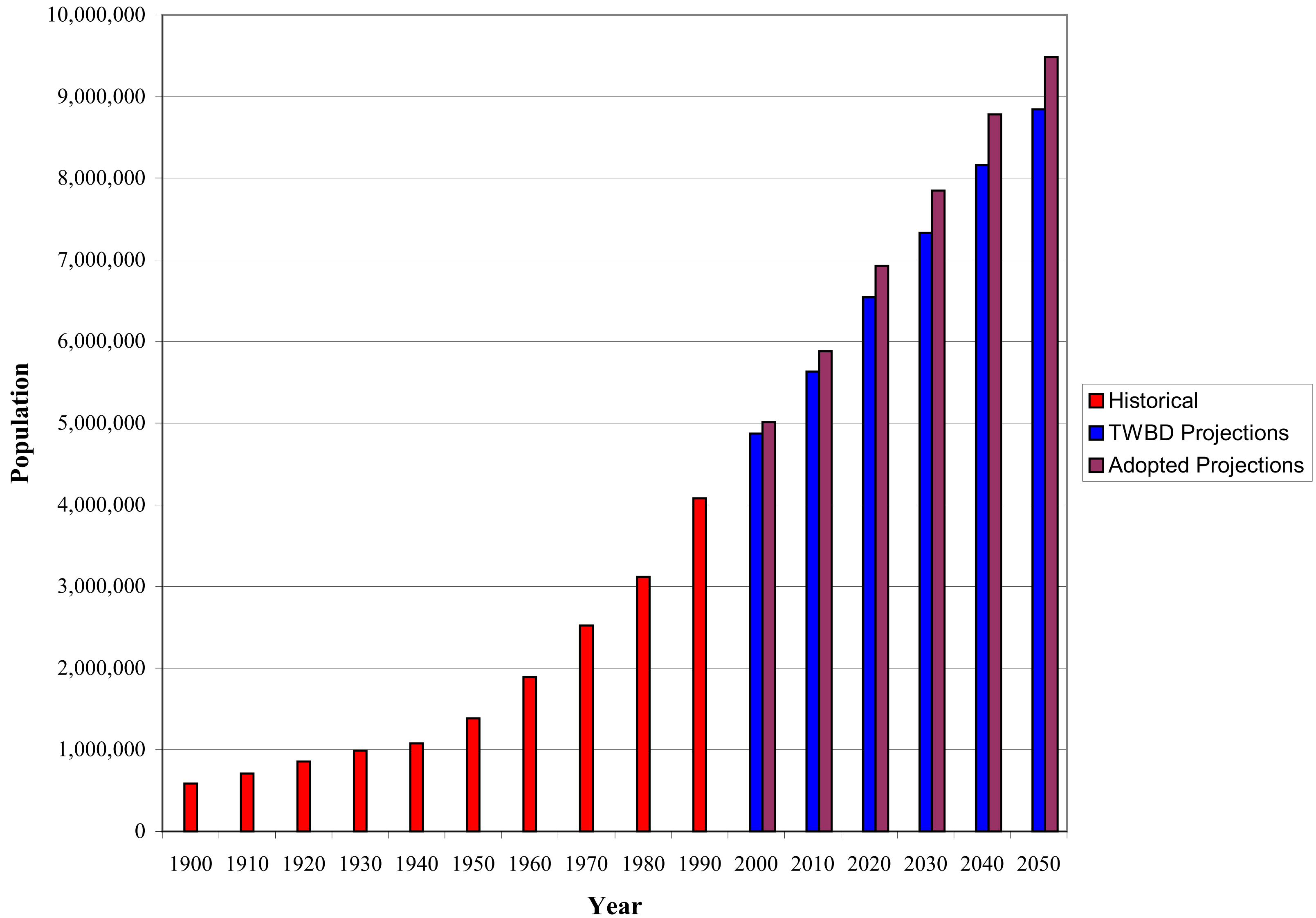
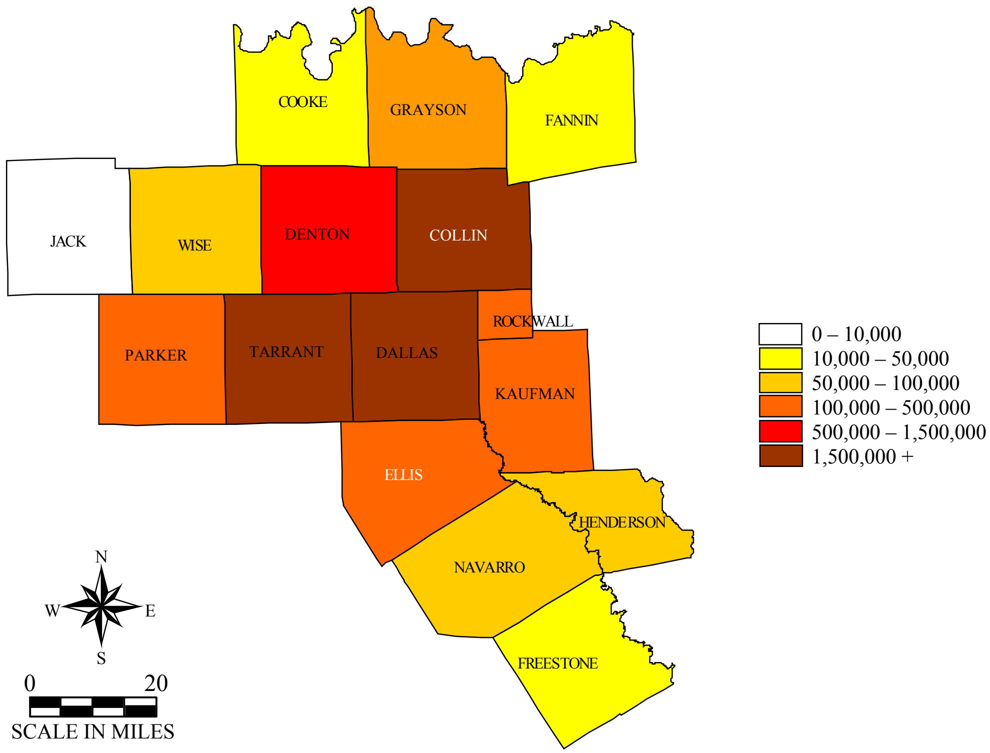
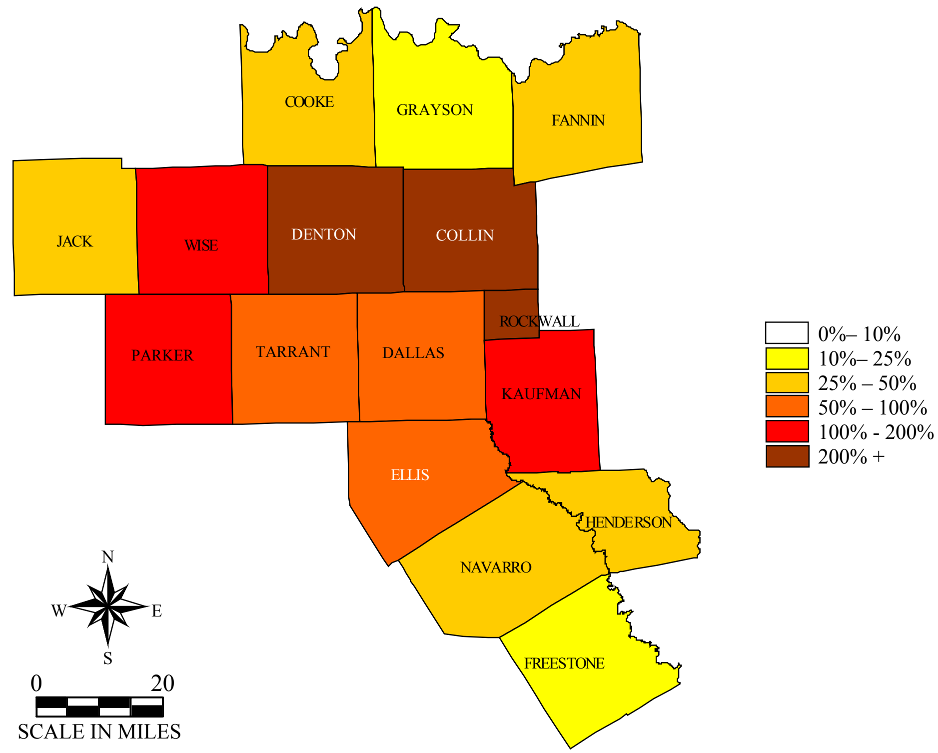


Figure 2.5
Adopted Population Projections for 2050



Approved Relative Population 2050



Approved % Increase 1996 - 2050

Figure 2.6
Adopted Projections
for Water Use by Category in Region C

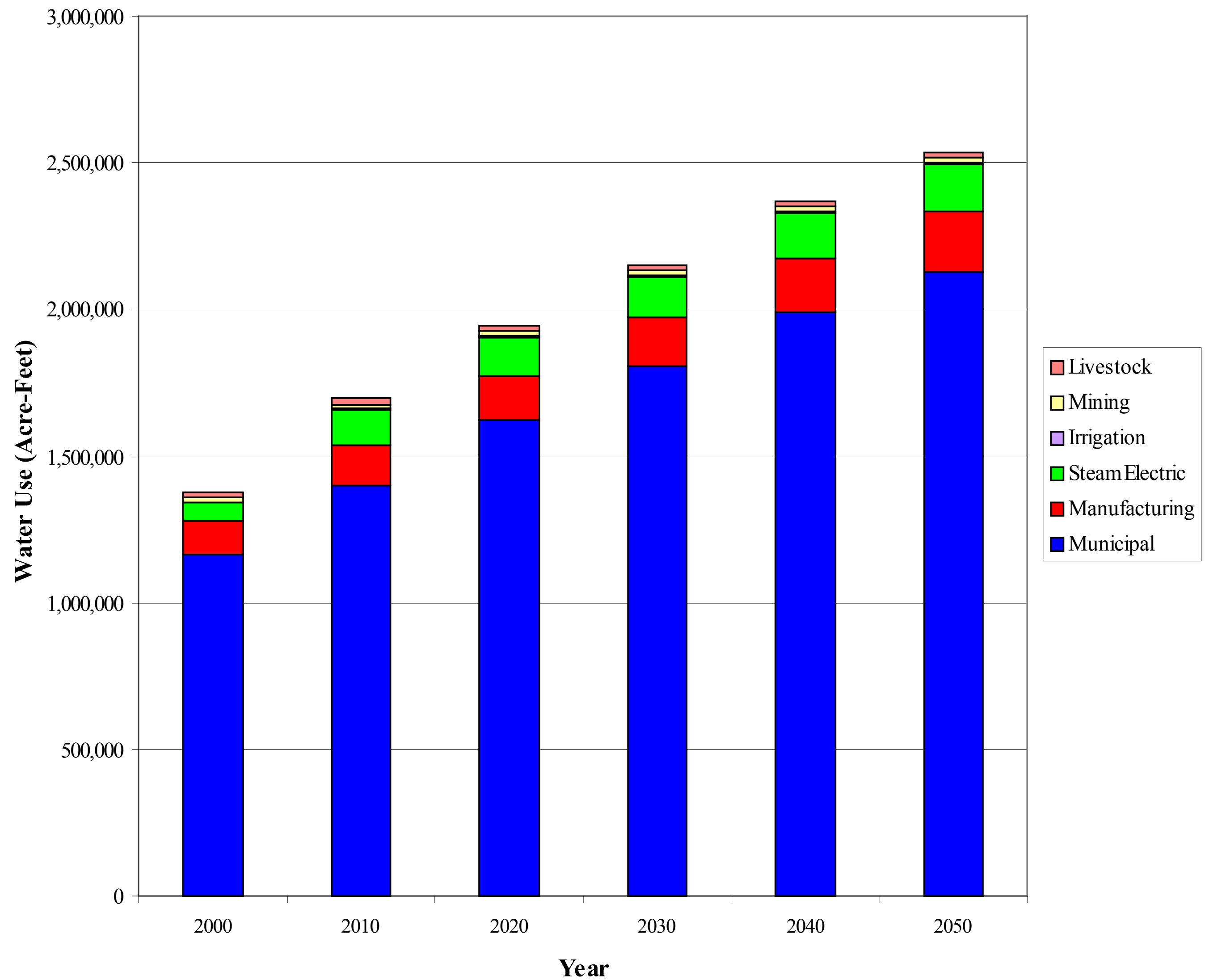
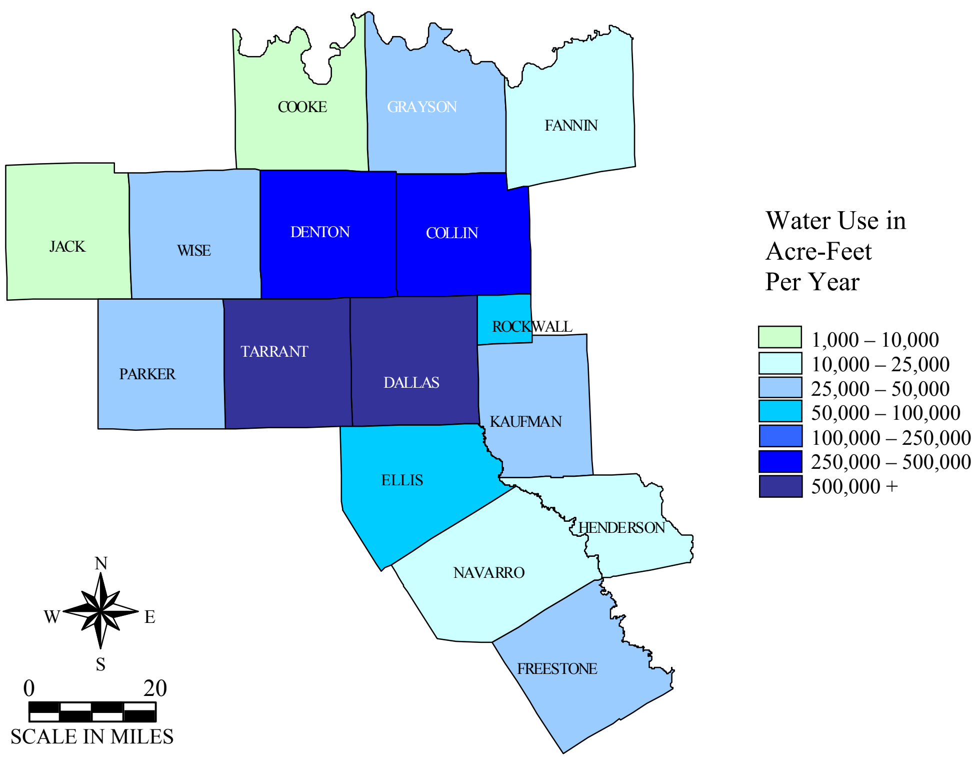
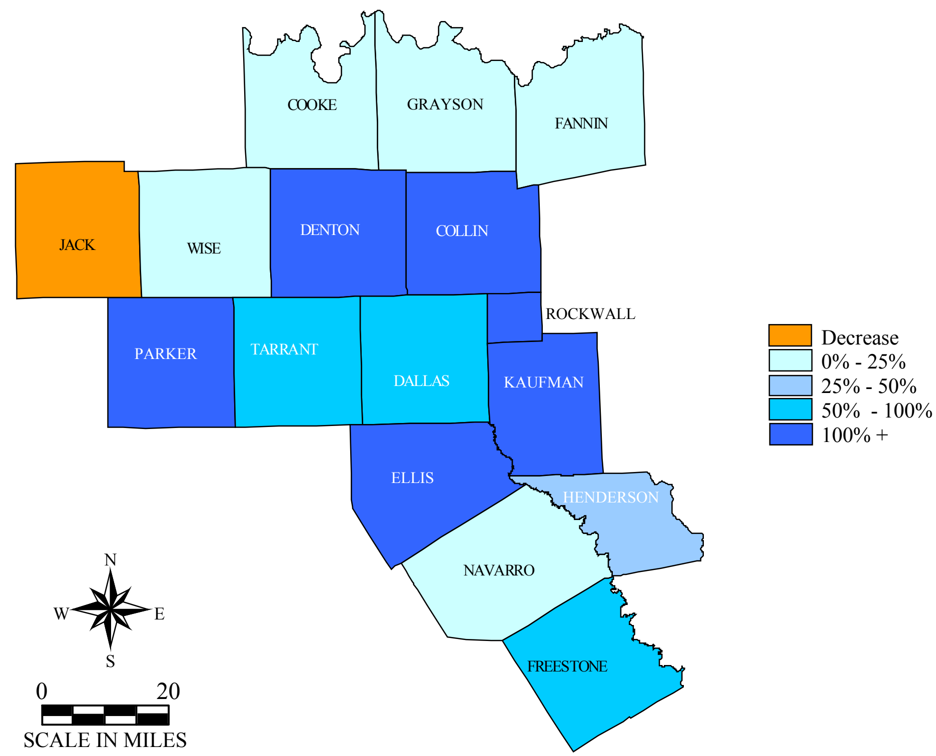


Figure 2.7
Adopted Water Demand Growth 1996-2050



Approved 2050 Water Demand Projection



Percent Change, 1996 To 2050 Recommended Projection

3. Analysis of Water Supply Currently Available to Region C

This section describes Task 3 of the Senate Bill One regional planning process in Region C, which is the analysis of water supplies currently available to the region. The available supplies will be compared to the projected water demands described in Section 2 in order to determine the region's water supply needs. In its guidelines for Senate Bill One planning, the Texas Water Development Board requires that each region develop three tables to present the information on the current water supplies (TWDB Tables 4, 5, and 6). These tables are included in Appendices I, J, and K:

- TWDB Table 4 (Appendix I) gives water supply sources available to Region C, whether or not they are currently connected.
- TWDB Table 5 (Appendix J) gives the currently connected supplies available to water user groups.
- TWDB Table 6 (Appendix K) gives the currently connected supplies available to major water providers.

Current water rights as listed by TNRCC[10] were reviewed in the development of TWDB Tables 4, 5, and 6. Hydrological information for the historical drought of record was also obtained and reviewed. Historical hydrologic information was used to evaluate the supply available if previous reliable studies were not available.

The remainder of this section covers the water supply currently available to Region C. Section 3.1 is a summary of the overall water supply availability. Section 3.2 is a general discussion of water availability by user group. Section 3.3 is a general discussion of water availability for the five major water providers in the region. Section 3.4 discusses the impacts of recent droughts in Region C, and Section 3.5 summarizes the water supply available.

3.1 Overall Water Supply Availability

Table 3.1 and Figure 3.1 summarize the overall water supply availability in Region C, which is described in greater detail in Appendix I. Table 3.1 and Figure 3.1 show the following:

- Region C is currently using most of the supply available on a reliable basis from reservoirs in the region, which provided almost ¾ of the water used in 1996.
- Over half of the water supply available to Region C is from in-region reservoirs.
- Region C is currently using less than half of the total reliable groundwater supply available in the region. However, TWDB Table 4 in Appendix I shows that more than the reliable supply is being used in some aquifers and some counties.

Table 3.1
Overall Water Supply Availability in Region C

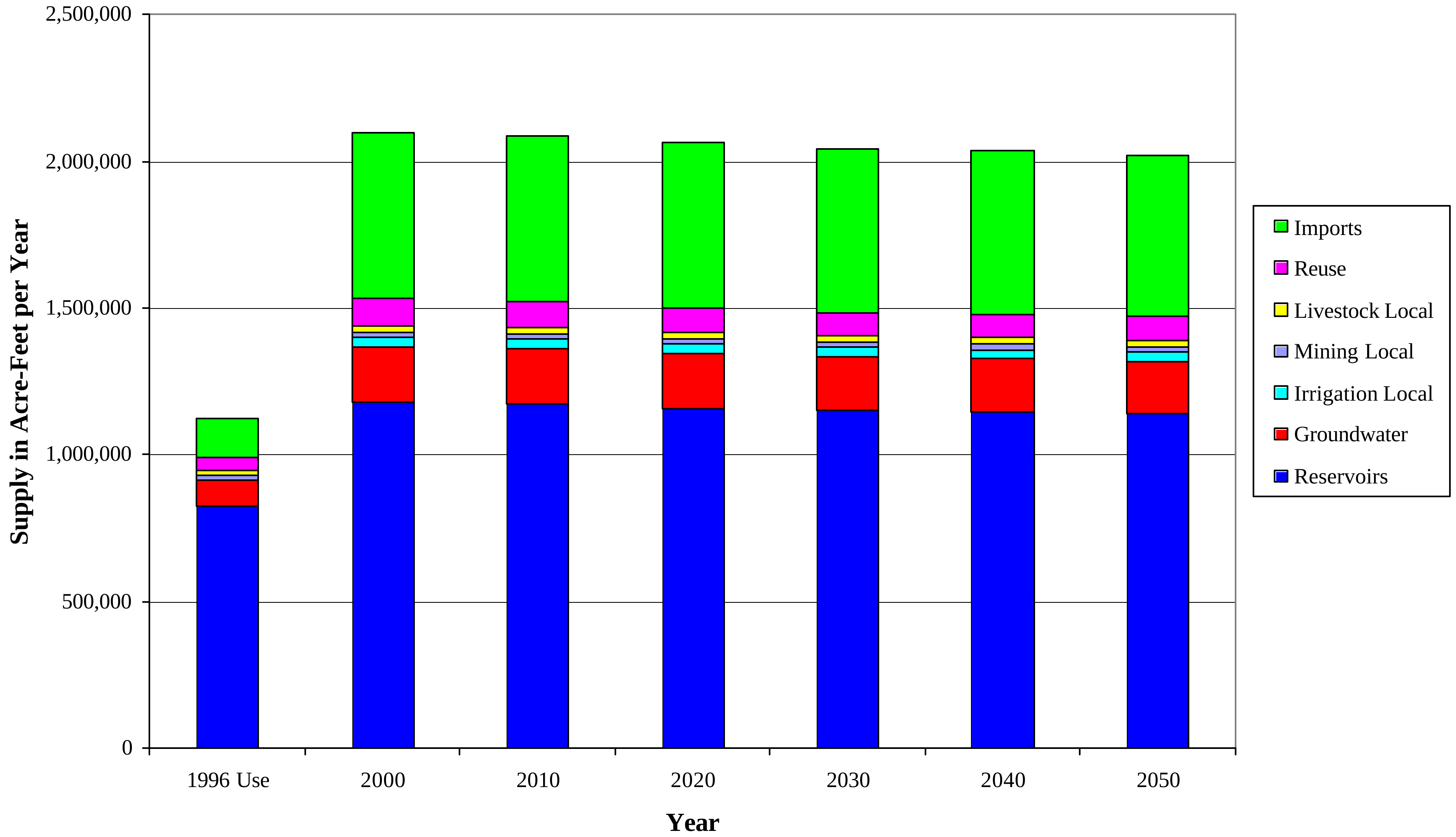
Source	Water Supply Available in Acre-Feet Per Year					
	2000	2010	2020	2030	2040	2050
Reservoirs in Region C	1,179,455	1,174,409	1,158,994	1,153,142	1,146,807	1,137,917
Groundwater	186,710	186,399	186,548	180,210	180,448	180,670
Irrigation Local Supply	33,300	31,632	31,632	31,632	31,632	31,632
Mining Local Supply	19,534	19,534	19,534	19,534	19,534	19,536
Livestock Local Supply	18,843	18,843	18,843	18,843	18,843	18,843
Reuse	94,543	90,243	85,343	80,843	81,343	81,572
Imports	566,470	564,477	562,566	560,407	558,289	552,468
REGION C TOTAL	2,098,855	2,085,537	2,063,360	2,044,611	2,036,896	2,022,638

- Groundwater is slightly less than 9 percent of the overall supply available to Region C.
- Local supplies are about 3 percent of the overall supply available to Region C.
- Currently authorized reuse is about 4 percent of the overall supply available to Region C.
- Importation of water from other regions is over 28 percent of the water available to Region C.
- If all available supplies can be utilized, Region C would have 2,022,636 acre-feet per year available in 2050.

The information in Table 3.1 and Figure 3.1 was developed on the basis of the following assumptions:

Reservoirs in Region C. All major reservoirs in Region C were included, as were smaller reservoirs used for municipal supply. (Major reservoirs are those with over 5,000 acre-feet of conservation storage.) The water supply available was limited to currently permitted diversions(12) or firm yield, whichever is less. (The firm yield is the greatest amount a reservoir could have supplied without shortage during a repeat of historical hydrologic conditions.) Firm yields from previous Texas Water Development analyses (37) or from previous studies by others were adopted where possible, with some additional yield studies conducted for this project. The specific yield for each reservoir and the source of the data are given in Appendix I. It should be noted that the firm yields listed do not consider inflows from return flows of treated wastewater. Since these return flows could be reused directly rather than discharged to the stream, they are not considered to be a reliable source of supply. However, many reservoirs in Region C

Figure 3.1
Overall Water Supply Availability in Region C by Source



currently have substantial return flows in their watersheds, and these return flows supplement project yields, at least on an interim basis.

Groundwater. Groundwater availability by county and basin was taken from previous TWDB analyses [38]. The only changes from previous TWDB groundwater availability figures were as follows:

- The addition of 2,919 acre-feet per year of available water in Fannin County from the "other/undifferentiated" aquifer in the Red River Basin, as described in Appendix I.
- The use of average annual recharge for 2050 water availability for the Trinity Aquifer, as described in Appendix I.

The groundwater availability figures included over 90,000 acre-feet per year of water from the Carrizo-Wilcox aquifer in Freestone County. The historical use from this source has been less than 3,000 acre-feet per year, and it is not clear that the full supply shown to be available by TWDB will ever be developed.

Irrigation Local Supply. The local irrigation availability is based on existing surface water rights for irrigation not associated with major reservoirs [10]. The TNRCC is currently developing Water Availability Models to determine the reliable supply available for existing water rights in Texas. However, the Water Availability Models for Region C basins are not yet available, and local supplies for irrigation were estimated as described in Appendix I. (The irrigation local supply available exceeds the projected irrigation water use in some counties.)

Mining Local Supply. The local mining supply is based on water rights for mining not associated with major reservoirs and on diversions from sources which may not require permits such as quarries and gravel pits filled by groundwater. The maximum historical use from these small local sources (according to TWDB records) is assumed to be available in the future. (TWDB's projected mining use can be non-consumptive in some cases, with most of the diversion returned to the sources. For this reason, small water sources can supply a significant amount of water.)

Livestock Local Supply. Most surface water used for livestock is taken from stock ponds (which do not require water rights permits) or directly from streams. The maximum historical use from these sources (according to TWDB records [9]) is assumed to be available in the future.

Reuse. The reuse listed as available to the region is for existing projects based on current permits and authorizations. Categories of reuse include (1) currently permitted and operating indirect reuse projects, in which water is reused after being returned to the stream; (2) existing indirect reuse for industrial purposes; and (3) authorized direct reuse projects for which facilities are already developed. The specific reuse projects included are discussed in Appendix I. It is likely that reuse will increase dramatically in Region C over the next 50 years, but proposed and potential direct reuse projects are not included as currently available supplies. For many reservoirs in Region C, return flows of treated wastewater serve to supplement project yields. In some cases, where permitted diversions exceed yields without return flows, water suppliers can make use of those return flows as long as they continue to occur. However, these are not considered to be reliable supplies for the future because of possible direct reuse of wastewater effluent.

Imports. The supply available from imports is limited to current Texas Natural Resource Conservation Commission (TNRCC) water rights [12] or the firm yield, whichever is less. The specific sources for imports are described in Appendix I.

Unpermitted Reservoir Yields. In addition to the water supply availability summarized in Table 3.1, Texas Water Development Board Table 4 in Appendix I includes information on "unpermitted reservoir yields." This is in response to TWDB's requirement that the table be based on firm yields for all existing reservoirs, whether or not the existing water rights allow use of the full firm yield. By far the largest unpermitted reservoir yield in Region C is Texas' share of the yield of Lake Texoma. Most of the conservation storage of Lake Texoma is currently reserved for hydropower generation. If all of the conservation storage were to be converted to water supply use, Texas' share of the additional yield beyond current permits would be almost 650,000 acre-feet per year as of 2050. It is highly unlikely that all of this water could be made available for water supply in Region C:

- Previous conversions of conservation storage to municipal use have been opposed by hydropower generators, recreational users of the lake, and the state of Oklahoma.
- Water in Lake Texoma is relatively high in dissolved solids, requiring desalination or blending before it can be used as a municipal supply.

However, the currently unpermitted yield of Lake Texoma is a considerable resource, and it is possible that some of that potential supply will be useful to Region C in the future.

3.2 Water Availability by Water User Group

As part of the Senate Bill One planning process, the Texas Water Development Board requires development of TWDB Table 5, a table presenting water availability for each water user group by river basin and zone. (Water user groups are cities, "county other" municipal uses, and countywide manufacturing, irrigation, mining, livestock, and steam electric uses.) TWDB Table 5 is included in Appendix J. Unlike the overall water availability figures in TWDB Table 4, the availability figures by water user group in TWDB Table 5 are limited by existing physical facilities, including raw water transmission facilities and groundwater wells. The table shows the amount of supply available to each user group from each source by decade based on existing physical facilities.

The development of TWDB Table 5 requires more or less arbitrary assumptions on the distribution of available supplies. (For example, if countywide pumping from an aquifer exceeds available supply, which water user groups are assumed to have access to the supply and which are assumed to have a shortage? If a reservoir does not have enough firm yield to supply all of the water user groups it serves, which water user groups are assumed to have access to the supply and how much is available to each group?)

In developing TWDB Table 5, several important points regarding the availability of water for water user groups in Region C became apparent:

- Most water user groups will need additional facilities over the next 50 years to meet growing demands.
- Current groundwater use in several areas exceeds the long-term reliable supply projected by TWDB. (Table 3.2 shows areas in which the 1996 use exceeds the projected reliable supply by county, aquifer and river basin.) In these areas, other sources of supply will be needed to allow reduced dependence on groundwater.
- There are several significant water supplies that can be made available by the development of additional water transmission facilities. Examples include Moss Lake in Cooke County, Irving's share of Lake Chapman in the Sulphur Basin, Upper Trinity Regional Water District's share of Lake Chapman, Dallas' share of Lake Fork in the Sabine Basin and Dallas' share of Lake Palestine in the Neches Basin.
- There are also many significant water supplies that cannot be fully utilized until additional raw water transmission facilities are developed.
- Some of the supply available to the region as a whole may not be used fully in the period covered by this water supply plan. One example is the substantial amount of groundwater TWDB shows to be available from the Carrizo-Wilcox aquifer in Freestone

County. This supply is significantly in excess of projected water use in Freestone County and may not be economically available to other users.

3.3 Water Availability by Major Water Provider

As part of the Senate Bill One planning process, the Texas Water Development Board requires development of TWDB Table 6, a table presenting water availability for each designated major water provider. TWDB Table 6 is included in Appendix K. The designated major water providers in Region C are the City of Dallas, Tarrant Regional Water District, North Texas Municipal Water District, the City of Fort Worth, and the Trinity River Authority. Unlike the overall water availability figures in TWDB Table 4, the availability figures by major water provider in TWDB Table 6 are limited by existing physical facilities, including raw water transmission facilities and groundwater wells. The table shows the amount available to each major water provider from each source by decade based on existing physical facilities. Table 3.3 provides some summary information on the sources of supply available to the major water providers in Region C.

Table 3.2

Areas in Which 1996 Groundwater Use Exceeds Texas Water Development Board Projections of Water Availability

County	Aquifer	River Basin (s)	1996 Use (Ac-Ft)	TWDB Availability in Ac-Ft/Yr	
				2000	2050
Cooke	Trinity	Red & Trinity	6,809	4,529	3,753
Denton	Trinity	Trinity	10,006	6,114	5,123
Denton	Woodbine	Trinity	1,845	1,010	1,010
Ellis	Woodbine	Trinity	2,656	1,832	1,832
Grayson	Trinity	Red & Trinity	9,325	3,434	3,088
Grayson	Woodbine	Red & Trinity	5,954	5,710	5,710
Kaufman	Nacatoch	Sabine & Trinity	249	184	184
Parker	Trinity	Trinity	5,500	2,633	2,172
Tarrant	Trinity	Trinity	14,616	4,996	4,996

Dallas Water Utilities

The City of Dallas used over 438,000 acre-feet of water in 1996. (Approximately 290,000 acre-feet were used in Dallas, with 148,000 acre-feet sold to other water suppliers.) The city's major

Table 3.3
Water Supplies Available to Major Water Providers in Region C

Major Water Provider	Source	Estimated 1996 Use/ (Acre-Feet)	Water Available (Ac-Ft/Yr) 2000	2050	Comments
Dallas Water Utilities	Elm Fork/Lake Grapevine	238,708	220,420	203,290	Currently overdrafting.
	Ray Hubbard/Tawakoni	199,862	250,225	245,340	
	Subtotal	**438,570**	**470,645**	**448,630**	Currently connected.
	White Rock Lake	0	3,000	3,000	Assumed irrigation only. Not connected.
	Lake Fork (Dallas)	0	120,000	120,000	Import. Not yet connected.
	Lake Palestine (Dallas)	0	112,700	109,600	Import. Not yet connected.
	Subtotal	**438,570**	**706,345**	**681,230**	
Tarrant Regional Water District	Lake Bridgeport Local	3,019	15,000	15,000	
	West Fork less Bridgeport Local	75,350	86,600	81,700	
	Benbrook Lake	4,650	6,833	6,000	
	Cedar Creek/ Richland-Chambers	162,313	385,000	382,700	Needs additional transmission facilities for full use.
	Subtotal	**245,332**	**493,433**	**485,400**	
North Texas Municipal Water District	**Total System**	**185,948**	**270,743**	**260,043**	
City of Fort Worth	**Tarrant Regional Water District System**	**157,344**	**-**	**-**	Future availability depends on distribution of TRWD supply.
Trinity River Authority	Joe Pool Lake	6,860	16,900	16,300	
	Navarro Mills Lake	6,236	19,400	19,130	
	Bardwell Lake	4,976	9,600	8,100	
	Lake Livingston	12,682	16,000	16,000	Upstream diversion for TXU Electric (Lake Fairfield).
	Reuse/Las Colinas	2,433	8,000	8,000	Irrigation.
	Reuse/Waxahachie	0	3,400	5,129	
	TRWD Ellis County	0	-	-	Future availability depends on distribution of TRWD supply.
	TRWD Tarrant County	23,970	-	-	Future availability depends on distribution of TRWD supply.
	Subtotal	**57,157**	**73,300 + TRWD supply**	**72,659 + TRWD Supply**	
Total Supply for Major Water Providers (Without Double Counting TRWD Sales to Fort Worth and TRA)		**903,037**	**1,543,821**	**1,499,332**	

supply sources include their Elm Fork/Lake Grapevine system (Lake Ray Roberts, Lake Lewisville, Dallas' share of Lake Grapevine, and Dallas' other water rights on the Elm Fork of the Trinity River), Lake Ray Hubbard/Lake Tawakoni, White Rock Lake, Lake Fork, and Lake Palestine. White Rock Lake is not currently used for municipal water supply, and the city does not plan to use it for municipal supply in the future. Lake Fork and Lake Palestine are significant supply sources that are not currently connected to the city's system. The estimated reliable supply for Dallas from currently connected sources is 470,600 acre-feet per year as of the year 2000. However, this does not include the yield available to the city from return flows of treated wastewater into the lakes. Dallas is currently developing plans for a transmission system to connect the Lake Fork supply to their system, which should be constructed and in operation in the next few years. Counting only irrigation use from White Rock Lake, Dallas' system has a projected reliable supply from current sources of 681,230 acre-feet per year in 2050.

Tarrant Regional Water District

The Tarrant Regional Water District used over 245,000 acre-feet of water in 1996. The District's major water supply sources include the West Fork lakes (Lake Bridgeport, Eagle Mountain Lake and Lake Worth, which is actually owned by Fort Worth), Benbrook Lake, Cedar Creek Lake, and Richland-Chambers Lake. The Tarrant Regional Water District system has a projected reliable supply of 485,400 acre-feet per year as of 2050 based on firm yield operation. (Tarrant Regional Water District plans and operates its water supply on the basis of safe yield, which is a more conservative approach and results in a lower reliable supply.)

North Texas Municipal Water District

The North Texas Municipal Water District used almost 186,000 acre-feet of water in 1996. The District's sources of supply include Lake Lavon, Lake Texoma, Lake Chapman, and reuse of treated wastewater effluent discharged into the Lake Lavon watershed. The North Texas Municipal Water District system has a projected reliable supply from current sources of 260,043 acre-feet as of 2050.

City of Fort Worth

The City of Fort Worth receives almost all of its water supply from the Tarrant Regional Water District. (The city has a water right for Lake Worth and a run-of-the-river water right on the Clear Fork of the Trinity River. However, under current operating policies neither of these water rights would provide a reliable water supply during a drought. The city does have authorization for one reuse project.) Fort Worth used over 157,000 acre-feet from the District in 1996. The amount of water available to Fort Worth in the future will depend on how the supplies available to the Tarrant Regional Water District are divided. (In 1996, Fort Worth used almost 65 percent of the water provided by the Tarrant Regional Water District. Sixty-five percent of the Tarrant Regional Water District's 2050 supply would be about 315,000 acre-feet per year.)

Trinity River Authority

The Trinity River Authority used over 57,000 acre-feet of water in 1996. The TRA has water rights in Navarro Mills Lake, Joe Pool Lake, and Lake Bardwell in Region C. TRA also imports water from Lake Livingston in Region H (by an upstream diversion from the Trinity River) and has permits and authorization for three reuse projects, two of which are in operation. TRA purchases water from the Tarrant Regional Water District for its Tarrant County water supply project and has plans to purchase water from TRWD for use in Ellis County. As of 2050, TRA's independent supply in Region C from current sources is projected to be 72,659 acre-feet, in addition to the water it purchases form the Tarrant Regional Water District.

As of 2050, the total projected independent supply from current sources for these five major water providers (without double counting water provided by Tarrant Regional Water District to Fort Worth and TRA) is almost 1,500,000 acre-feet per year – almost three-quarters of the total supply available to the region. The 1996 use by these major providers was over 903,000 acre-feet - about 80 percent of the region's total water use.

3.4 Impacts of Recent Droughts in Region C

Region C has experienced summer droughts and high water use in four of the last five years – 1996, 1998, 1999, and 2000. Winter and spring runoff filled most area lakes after the 1996 and 1998 droughts, but these short-term droughts have provided a test of local water supplies. Lessons learned from recent droughts include the following:

- Short-term droughts like those of recent years have put some stress on major reservoirs in Region C. Most major reservoirs in Region C are designed for a 5 to 7 year drought like that of the 1950's.

- The dry summers in 1996, 1998, 1999, and 2000 showed that the low water use of the early 1990's in Region C was a result of mild summers rather than a change in water use patterns. For many Region C suppliers, 1998 was a year of record per capita water use.
- The high demands of 1996, 1998, 1999, and 2000 exposed supply limitations for many smaller suppliers depending on overused groundwater supplies. As a result, many smaller suppliers are developing additional well capacity and/or seeking to purchase water from larger, regional suppliers.
- The high demands of 1996, 1998, 1999, and 2000 exposed treatment and distribution system limitations for many Region C water suppliers. Many area suppliers are making significant investments to overcome these limitations.
- Because most water supply systems were able to provide the needed supplies, the most significant economic impacts of the recent droughts were on agricultural production. Because there is very little irrigation water use in Region C, natural variations in rainfall are likely to continue to affect agricultural production in the region.

3.5 Summary of Current Water Supply in Region C

1. Total water use in Region C in 1996 was over 1,100,000 acre-feet. About 74 percent of the region's 1996 water use came from in-region reservoirs.
2. Region C water suppliers are currently using most of the reliable supply available from in-region reservoirs. Some in-region reservoirs are being overdrafted, with current use in excess of reliable supplies that would be available in an extended drought. (In all cases where this is being done, the water suppliers have or are developing access to other supplies.)
3. The projected reliable water supply available to Region C in 2050 from current sources will be about 2,023,000 acre-feet per year. (This figure does not consider supply limitations due to the capacities of current raw water transmission facilities and wells.) The sources of supply for Region C in 2050 include:
    - 1,138,000 acre-feet per year (56%) from in-region reservoirs
    - 181,000 acre-feet per year (9%) from groundwater
    - 70,000 acre-feet per year (3%) from local supplies
    - 82,000 acre-feet per year (4%) from reuse
    - 552,000 acre-feet per year (28%) from imports from other regions
4. The supply available to Region C from existing sources in 2050 is significantly less than the projected 2050 water use, which is about 2,537,000 acre-feet per year.
5. If the supply limitations due to the capacities of current raw water transmission facilities and wells are considered, the available supply for Region C is much less. Most water user groups will have to make improvements to these facilities to provide for projected needs.

6. Several major water supplies will require additional raw water transmission facilities before they can be utilized fully.

7. Current groundwater use in a number of areas exceeds the projected long-term water supply availability. Supplies from other sources will be needed in these areas so that groundwater use can be reduced.

8. Some sources of supply will probably not be utilized fully during the period covered by this plan.

9. The five major water providers in Region C (City of Dallas, Tarrant Regional Water District, North Texas Municipal Water District, City of Fort Worth, and Trinity River Authority) provided over 903,000 acre-feet of water in 1996 (80% of the total provided in the region). They have 74% of the 2050 water supply currently available to the region.

10. The recent drought summers of 1996, 1998, 1999, and 2000 have caused very high water use for many Region C water suppliers. These short-term droughts have put stress on some of the region's major reservoirs, which are designed for a 5 to 7 year drought like that of the 1950's. The high demands also exposed supply limitations for many smaller suppliers (especially those dependent on groundwater) and exposed treatment and distribution limitations for other suppliers.

4. Comparison of Current Water Supply and Projected Water Demand

This section describes the comparison of the current water supply for drought of record conditions (discussed in Section 3) and the projected water demand (discussed in Section 2). TWDB guidelines require that surpluses and needs for additional water supply be developed by decade for each water user group in the region based on this comparison. The specific surpluses and needs shown should be treated with caution because their development requires certain arbitrary assumptions:

- TWDB guidelines require that the comparison be based on currently connected supplies, without considering future connection of already developed supplies [(1)].
- As discussed in Section 3 and Appendix J, the division of existing supplies among users is necessarily arbitrary. (For example, the total amount of groundwater available in a county must be divided among users in that county. The total supply available from a major water provider must be divided among its customers. These divisions could be made in many ways.)
- TWDB guidelines require the assumption that water purchased under a contract will become unavailable at the current expiration date of the contract. In many cases, both the seller and the purchaser plan to renew the contract, and the assumption that renewal will not occur results in misleading information.

The resulting comparison shows the surpluses and needs that will exist in Region C <u>if no steps are taken to connect existing water supplies, develop additional water supplies or even to renew existing contracts when they expire.</u> This is the comparison required by TWDB planning guidelines [(1)]. Development of infrastructure to make existing supplies available to users, development of new supplies, and renewal of existing contracts are treated as water management strategies to develop additional supplies, and they will be discussed in Section 5.

The remaining parts of this section present the comparison of current water supply and projected water demand in Region C. Section 4.1 gives a regional comparison of current supply and projected demand. Section 4.2 presents comparison of current supply and projected demand by water user group. Section 4.3 discusses the comparison of current supply and projected demand for the five major water providers in the region. Section 4.4 presents the economic impacts of not meeting the needs projected for Region C, and Section 4.5 is a summary of the comparison of supply and demand for Region C.

4.1 Regional Comparison of Supply and Demand

Table 4.1 and Figure 4.1 summarize the comparison of total currently connected water supply and total projected water demand in Region C. For the region as a whole, a surplus of 129,325 acre-feet per year in 2000 turns into a need for additional supply of 204,373 acre-feet per year by 2010. The need for additional supply for the region as a whole is projected to grow to 1,096,407 acre-feet per year by 2050 based on currently connected supplies. In 2000, Cooke, Dallas, and Parker Counties (3 out of 16 in the region) show a net need for more water when all uses are totaled. By 2050, 11 out 16 Region C counties (all except Fannin, Grayson, Henderson, Jack, and Navarro Counties) show a net need for more water over all uses. Out of 281 individual water user groups in Region C, 193 water user groups are predicted to have a need for additional water by 2050 for drought of record conditions.

The comparison of supply and demand in Table 4.1 and Figure 4.1 focuses on currently connected supplies. Region C also has significant unconnected supplies that could be made available to the region. An unconnected water supply is an existing and permitted supply that is not currently available due to infrastructure limitations. Table 4.2 lists some of the major unconnected water supplies that could be made available to Region C. Table 4.3 and Figure 4.2 show the comparison of total supply with demand for Region C, including connected and unconnected supply. By 2030, the projected demand for Region C exceeds total connected and unconnected supply.

4.2 Comparison of Connected Supply and Demand by Water User Group

Appendix L includes Texas Water Development Board Table 7, which shows the surplus or need for additional supplies by water user group, county, and basin for each decade in the planning period. Table 4.4 summarizes the projected surpluses and needs by county for each decade of the planning period. In general, the largest water needs are in Collin, Dallas, Denton and Tarrant Counties, with lesser but still significant needs in other counties.

Appendix L also includes a county-by-county discussion of the surpluses and needs shown in TWDB Table 7. Section 5 of this report will discuss the selection of water

Table 4.1
Comparison of Connected Supply with Projected Demand by Decade for Region C

	Amount (Acre-Feet per Year)					
	2000	2010	2020	2030	2040	2050
Connected Supply	1,508,421	1,494,369	1,473,974	1,458,790	1,452,121	1,444,931
Projected Demand	1,376,373	1,695,661	1,944,893	2,149,826	2,368,188	2,536,902
Demands Exported from Region C[a.]	2,723	3,081	3,129	3,585	3,985	4,436
Region-Wide Surplus or (Need)	129,325	(204,373)	(474,048)	(694,621)	(920,052)	(1,096,407)
Counties with Needs (Out of 16)	3	11	11	11	11	11
User Groups with Needs (Out of 281)	82	178	185	188	190	193

Note: a. Water is exported from Region C to Hill and Johnson Counties to supply Post Oak WSC, Burleson, and Mansfield.

Table 4.2
Major Unconnected Water Supplies for Region C

Unconnected Source	Owner	Available Unconnected Suppl y in Acre-Feet per Year					
		2000	2010	2020	2030	2040	2050
Lake Fork Reservoir [a.]	Dallas	120,000	120,000	120,000	120,000	120,000	120,000
Additional Cedar Creek/ Richland-Chambers [b.]	Tarrant RWD	117,608	118,630	118,163	117,770	117,633	115,227
Lake Palestine [a.]	Dallas	112,700	112,100	111,500	110,900	110,200	109,600
Additional Freestone County Groundwater	-	89,407	89,407	89,406	89,405	89,404	89,403
Additional Lake Chapman	Irving and Upper Trinity RWD	65,700	65,200	64,800	64,300	63,800	59,700
Additional Lake Texoma	Denison and Greater Texoma UA	15,790	15,790	15,790	15,790	15,790	15,790
Corsicana's Richland-Chambers	Corsicana	13,650	13,650	13,650	13,650	13,650	13,650
Additional Navarro County Groundwater	-	11,338	11,338	11,338	11,035	11,035	11,035
Additional Joe Pool Lake	Trinity RA	11,558	10,623	9,830	9,264	8,995	8,753
Moss Lake	Gainesville	4,500	4,500	4,500	4,500	4,500	4,500

Notes: a. Values for Lake Fork Reservoir and Lake Palestine represent Dallas' share of the yield.
b. Additional Cedar Creek/Richland Chambers represents the additional supply that could be made available by expanding transmission facilities.

Figure 4.1
Comparison of Connected Supply and Projected Demand for Region C

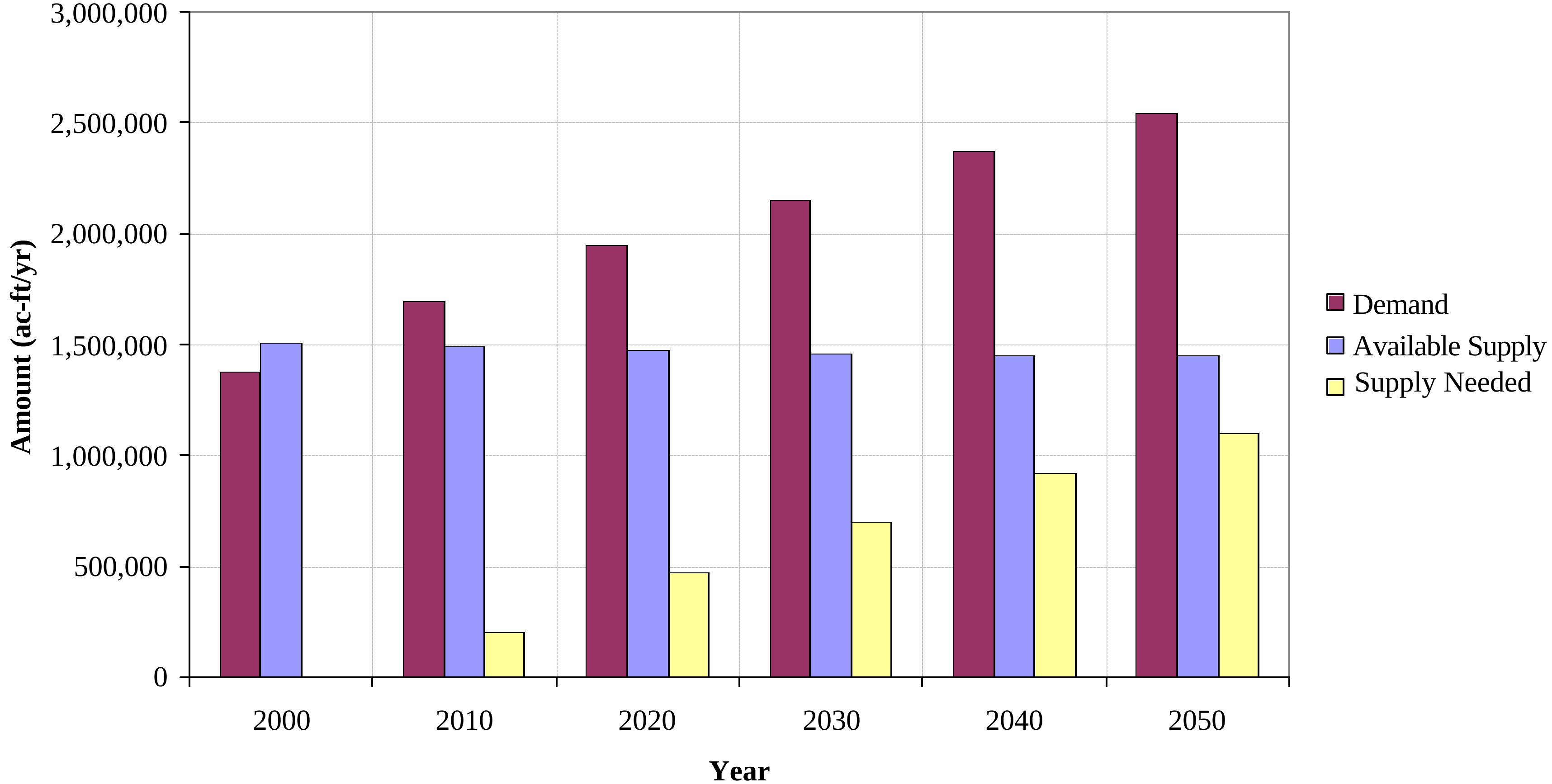


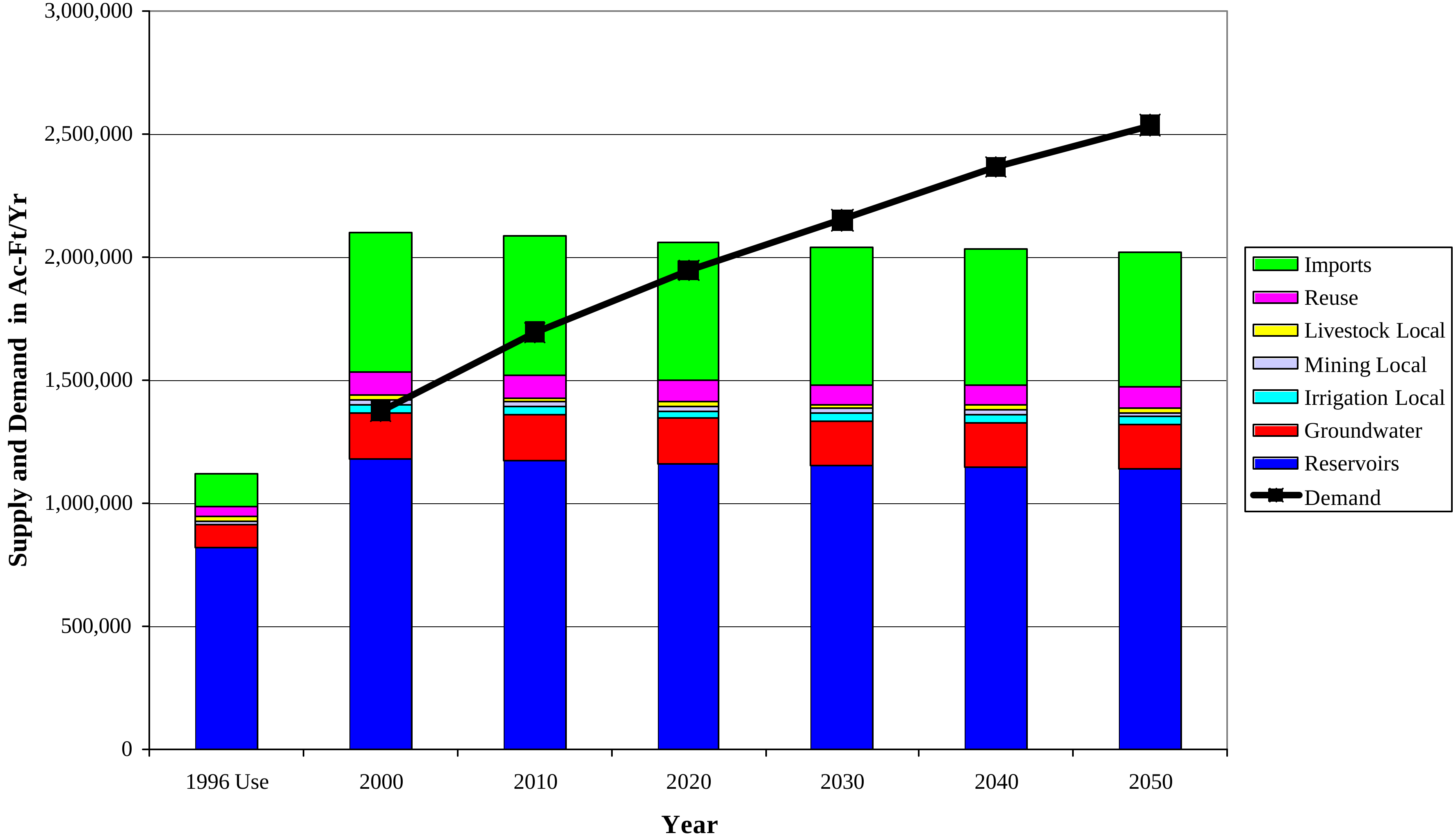
Table 4.3
Comparison of Total Connected and Unconnected Supply with Demand by Decade for Region C
- Values in Acre-Feet per Year -

	2000	2010	2020	2030	2040	2050
Total Connected and Unconnected Supply	2,098,855	2,085,537	2,063,360	2,044,611	2,036,896	2,022,638
Demand	1,376,373	1,695,661	1,944,893	2,149,826	2,368,188	2,536,902
Surplus (Need)	722,482	389,876	118,467	(105,215)	(331,292)	(514,264)

Table 4.4
Surplus or (Need) by County Using Only Connected Supplies

		Surplus or (Need) in Acre-Feet per Year					
Category	**Basin Name**	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Collin	Trinity/Sabine	23,020	(29,794)	(80,743)	(124,769)	(174,124)	(210,431)
Cooke	Trinity/Red	(3,008)	(3,087)	(3,192)	(4,034)	(4,311)	(4,609)
Dallas	Trinity	(34,250)	(168,112)	(241,696)	(267,472)	(350,525)	(415,879)
Denton	Trinity	3,108	(20,744)	(92,987)	(184,125)	(210,954)	(234,983)
Ellis	Trinity	6,935	(10,542)	(13,252)	(17,304)	(21,678)	(23,346)
Fannin	Trinity/Red/Sulphur	25,663	24,433	23,263	22,166	20,701	19,159
Freestone	Trinity/Brazos	4,057	(6,927)	(8,868)	(8,903)	(13,126)	(13,155)
Grayson	Trinity/Red	23,778	23,078	22,596	21,142	19,981	18,797
Henderson	Trinity	18,290	17,884	17,848	17,598	17,449	17,114
Jack	Trinity/Brazos	2,102	2,357	2,372	2,355	2,331	2,238
Kaufman	Trinity/Sabine	2,620	(1,024)	(3,566)	(7,921)	(10,145)	(17,119)
Navarro	Trinity	13,881	13,283	12,929	12,300	11,858	11,438
Parker	Trinity/Brazos	(1,613)	(11,469)	(15,008)	(24,715)	(30,336)	(33,874)
Rockwall	Trinity/Sabine	2,941	(6,362)	(10,849)	(15,603)	(21,694)	(28,106)
Tarrant	Trinity	30,270	(25,625)	(79,466)	(109,210)	(147,498)	(174,233)
Wise	Trinity	11,531	(1,722)	(3,429)	(6,126)	(7,981)	(9,418)
Region C Total		129,325	(204,373)	(474,048)	(694,621)	(920,052)	(1,096,407)

Figure 4.2
Comparison of Total Connected and Unconnected Supply with Demand for Region C



management strategies to address the requirements for additional supply shown in TWDB Table 7. Many water user groups in Region C are served by major water providers, and the needs of these water user groups will be addressed by obtaining additional supplies for the major providers. Other water user groups will require the development of individual water management strategies to address their needs.

4.3 Comparison of Supply and Demand by Major Water Provider

The Region C Water Planning Group has designated five major water providers for Region C:

- Dallas Water Utilities (DWU)
- Tarrant Regional Water District (TRWD)
- North Texas Municipal Water District (NTMWD)
- City of Fort Worth
- Trinity River Authority (TRA).

TWDB Table 8, which shows the comparison of currently connected supply with projected demand for each major water provider by basin and county, is presented in Appendix M. Table 4.5 summarizes the comparison of supply and demand and shows the surpluses or needs for additional supply for each major water provider. As a group, the major water providers are projected to have a need for additional supply in each decade of the planning period. Steps to meet these needs will be discussed in Section 5.

The numbers in Table 4.5 reflect two assumptions required by TWDB guidelines(1). The TWDB requires that all contracts for water supply from major water providers be treated as demands, event if actual use of the water is not expected to occur until later. TWDB requirements on contract expiration also have an effect on the surpluses and needs shown in Table 4.5. Some contracts for water from a major water provider will expire during the planning period. As required by TWDB rules, the demands for these entities are no longer considered to be a demand for the major water provider after the contract expiration date. If Table 4.5 (and TWDB Table 8) were developed without consideration of contract expiration, the major providers would have larger needs for additional supplies, and they would make up a larger percentage of the regional needs. The comparison of supply and demand for each major water provider is discussed below.

Table 4.5
Surplus or (Need) for Each Major Water Provider in Region C

Major Water Provider	Surplus or (Needs) in Acre-Feet per Year					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**
Dallas Water Utilities	(72,986)	(126,101)	(37,314)	21,833	2,866	(7,113)
Tarrant Regional Water District	12,797	(55,335)	(51,528)	(77,643)	(95,108)	(120,856)
North Texas Municipal Water District	34,253	(46,236)	(120,083)	(182,555)	(245,377)	(294,686)
Fort Worth	10,665	(9,025)	(6,288)	(15,075)	(25,665)	(35,373)
Trinity River Authority	(5,652)	(43,403)	(43,454)	(47,901)	(51,682)	(54,674)

Notes: a. As required by TWDB guidelines[1], all contracts with major water providers are treated as demands even if actual use is not expected to occur until later decades. This results in exaggerated demands (and needs for water) in early decades.

b. As required by TWDB guidelines[1], demands are assumed to disappear as current contracts expire. This results in understated demands (and needs for water) in later decades.

Dallas Water Utilities

DWU has a projected requirement for more water (for drought of record conditions) of 72,986 acre-feet per year in 2000, growing to 126,101 acre-feet per year in 2010. (See Table 4.5.) DWU shows a surplus for 2030 and 2040 and needs more supply in 2050. The change from a need for water to a surplus between 2020 and 2030 is due to expiration of contracts with wholesale customers. Renewal of these contracts is a water management strategy to be considered in Task 5. Figure 4.3 shows the comparison of supply and demand for DWU, while Figure 4.4 shows the same comparison with the assumption that all contracts are renewed indefinitely.

DWU has significant firm yield supplies in Lake Fork Reservoir and Lake Palestine that are not yet connected to the DWU system. Construction of the Lake Fork Reservoir transmission facilities will begin in September of 2000 and be completed by 2004. The potential supply from these reservoirs is more than 229,000 acre-feet per year in each decade of the planning period. Irving and Upper Trinity Regional Water District, both customers of Dallas, are currently constructing facilities to connect their water supplies in Lake Chapman. When these facilities are completed, the demand on DWU from these customers will be substantially reduced. To meet demands in 2000, DWU will make use of the yield available

Figure 4.3
Comparison of Connected Supply and Projected Demand for Dallas Water Utilities

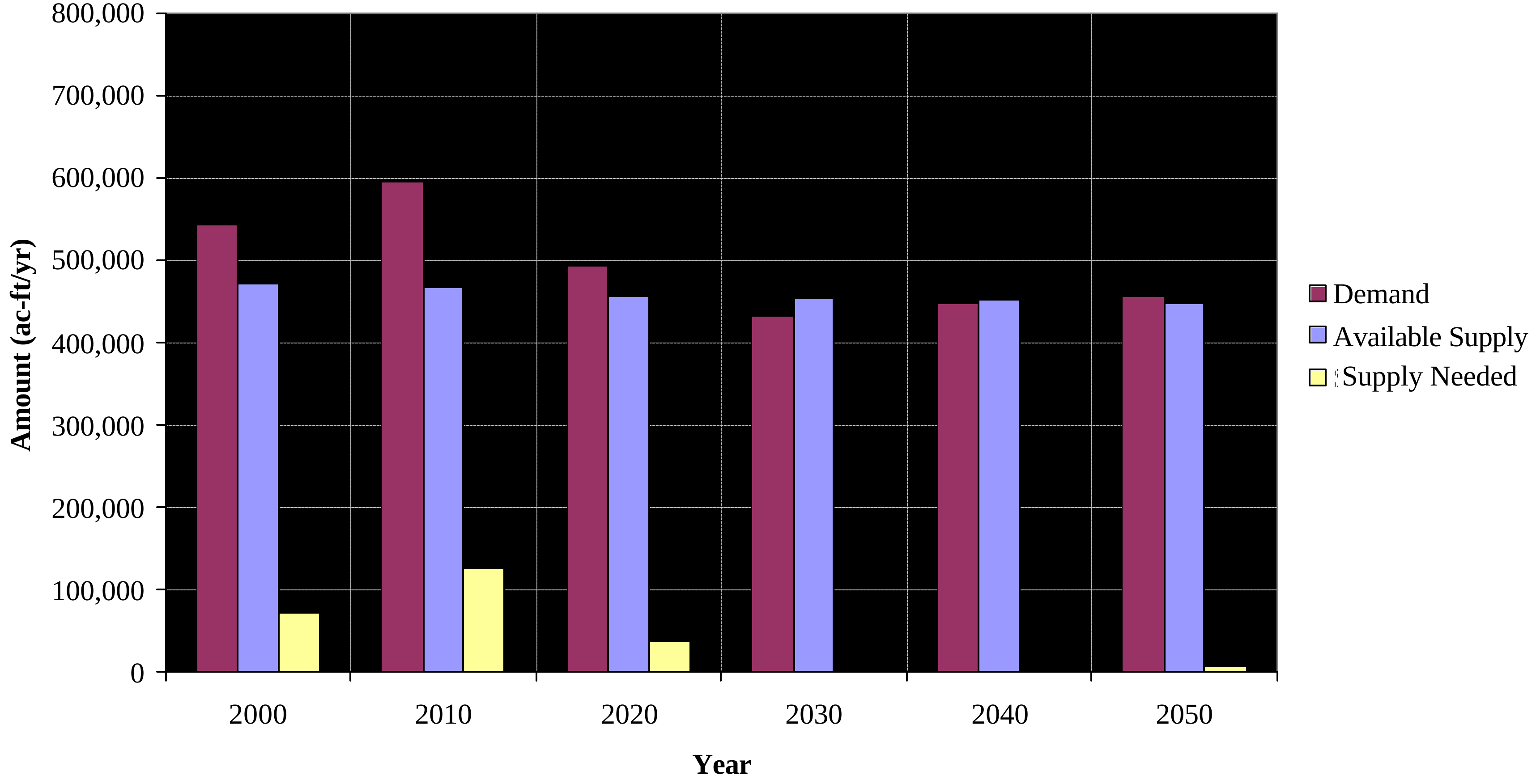
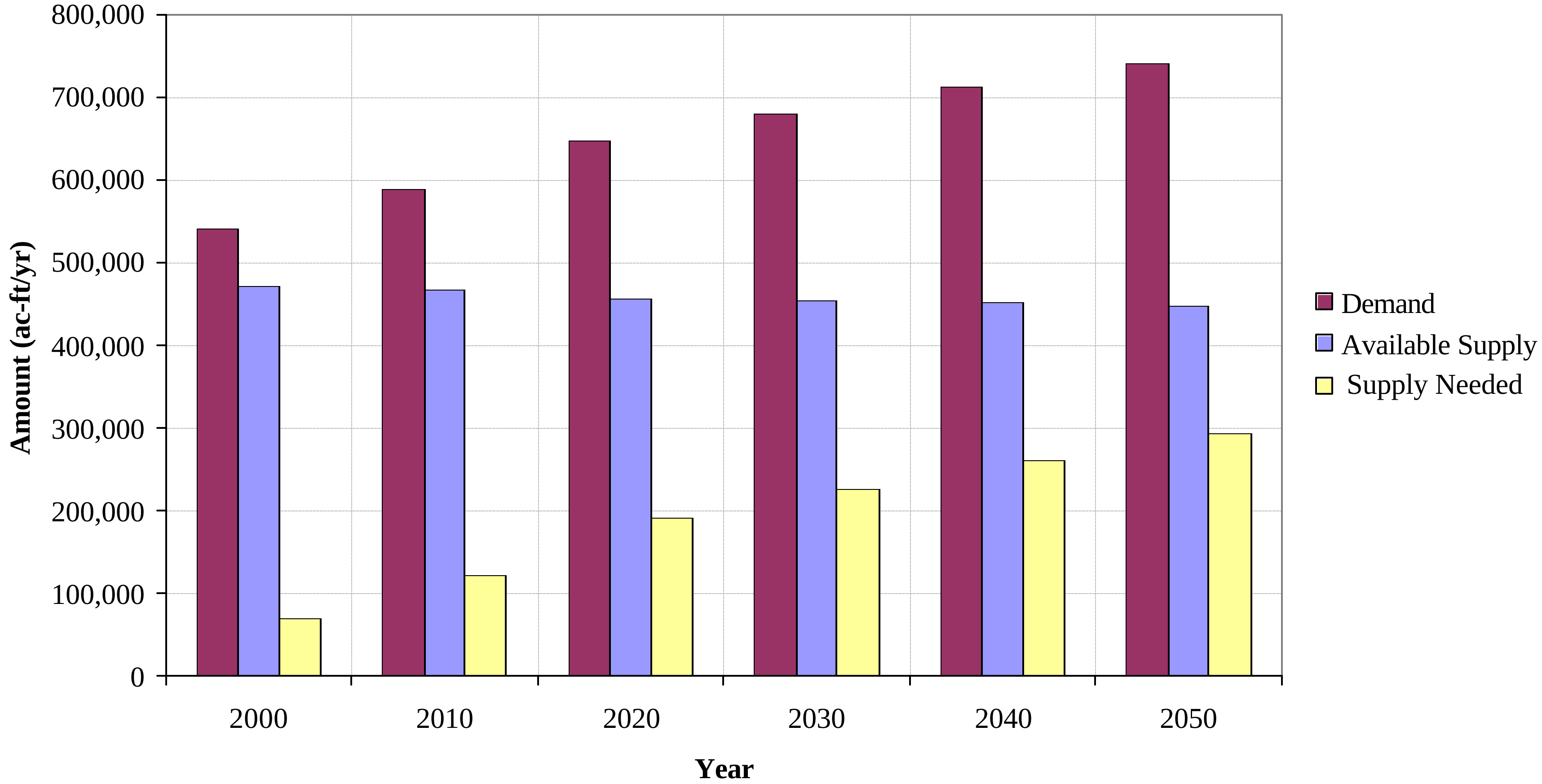


Figure 4.4
Comparison of Connected Supply and Projected Demand for Dallas Water Utilities without Contract Expiration



from current return flows of treated wastewater around its lakes and use system operation of its lakes. In 2000, the return flows amount to 49,300 acre-feet per year, and they are not included in the comparison of supply and demand in this section. System operation and temporary overdrafting will supply the additional water needed in 2000. As discussed in Section 5, DWU is also taking other steps to develop additional supplies.

Tarrant Regional Water District

TRWD shows a surplus of 12,797 acre-feet per year in 2000, changing to a need for an additional 55,335 acre-feet per year in 2010. By 2050, the TRWD need is 120,856 acre-feet per year. Figure 4.5 shows the comparison of supply and demand for TRWD, while Figure 4.6 shows the same comparison with the assumption that all contracts are renewed indefinitely. TRWD will obtain significant additional supplies from the Cedar Creek/Richland-Chambers system by increasing the capacity of its transmission system to Tarrant County. Section 5 describes other sources of additional supply TRWD will develop.

North Texas Municipal Water District

NTMWD shows a surplus of 34,253 acre-feet per year in 2000, changing to a need for 46,236 acre-feet per year in 2010. By 2050, NTMWD has a need for additional supplies of 294,686 acre-feet per year. Figure 4.7 shows the comparison of supply and demand for NTMWD. NTMWD does not have expiration dates in its contracts with customers. Section 5 describes the steps NTMWD is taking to increase its supply.

City of Fort Worth

The City of Fort Worth is projected to have a surplus of 10,665 acre-feet per year in 2000, changing to a need for 9,025 acre-feet per year in 2010. By 2050, Fort Worth will need an additional 35,373 acre-feet per year. The comparison of supply and demand for Fort Worth is significantly affected by expiration of contracts, particularly after 2010. If contracts with customer cities are renewed (as they probably will be), Fort Worth will need considerably more additional supplies than shown in Table 4.5.

Fort Worth obtains all of its water from TRWD. Surpluses and needs for Fort Worth are built into TRWD surpluses and needs shown in TWDB Table 8 (Appendix M). Water management strategies that meet the needs of TRWD will also meet the needs of Fort Worth.

Figure 4.5
Comparison of Connected Supply and Projected Demand
for Tarrant Regional Water District

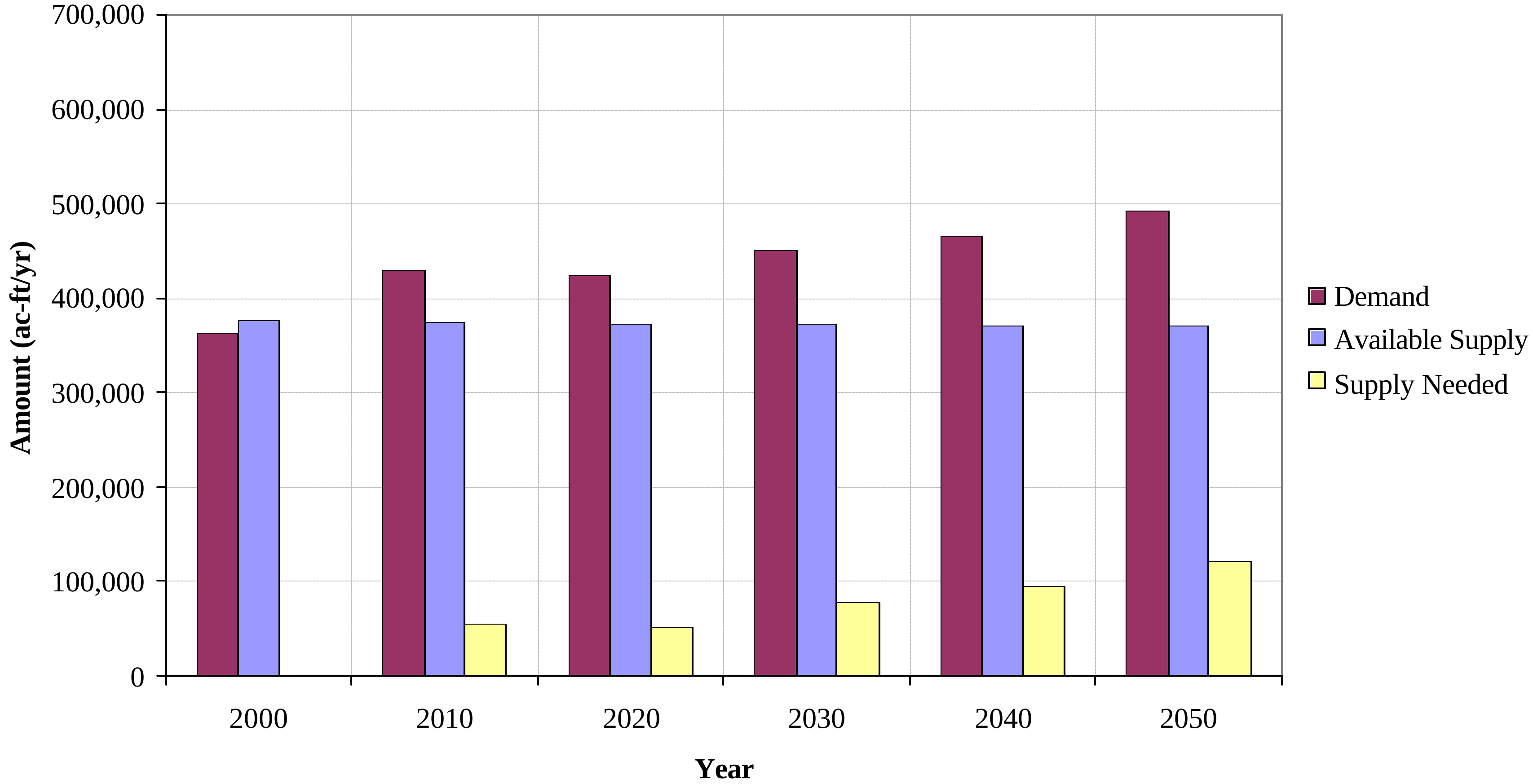


Figure 4.6
Comparison of Connected Supply and Projected Demand
for Tarrant Regional Water District without Contract Expiration

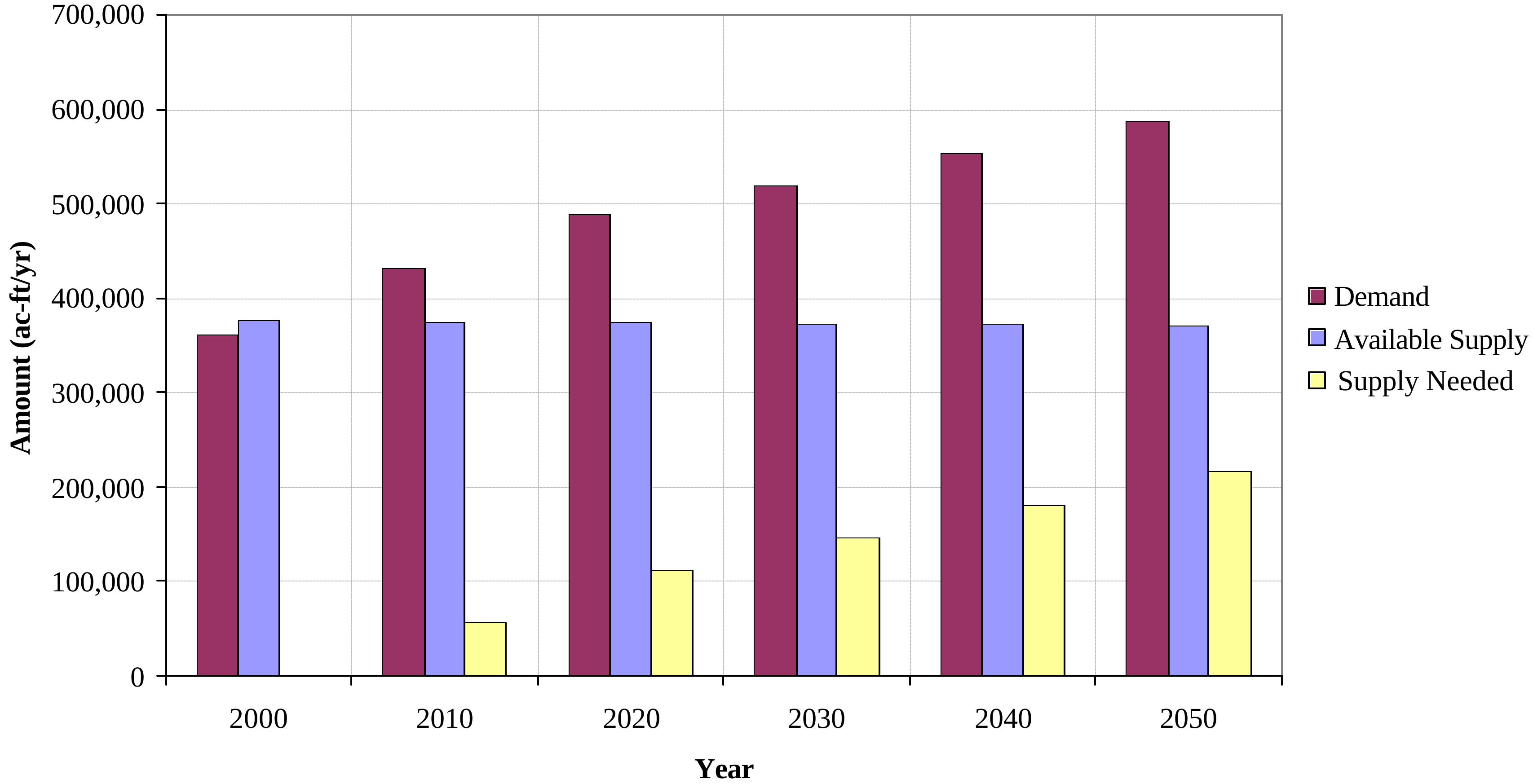
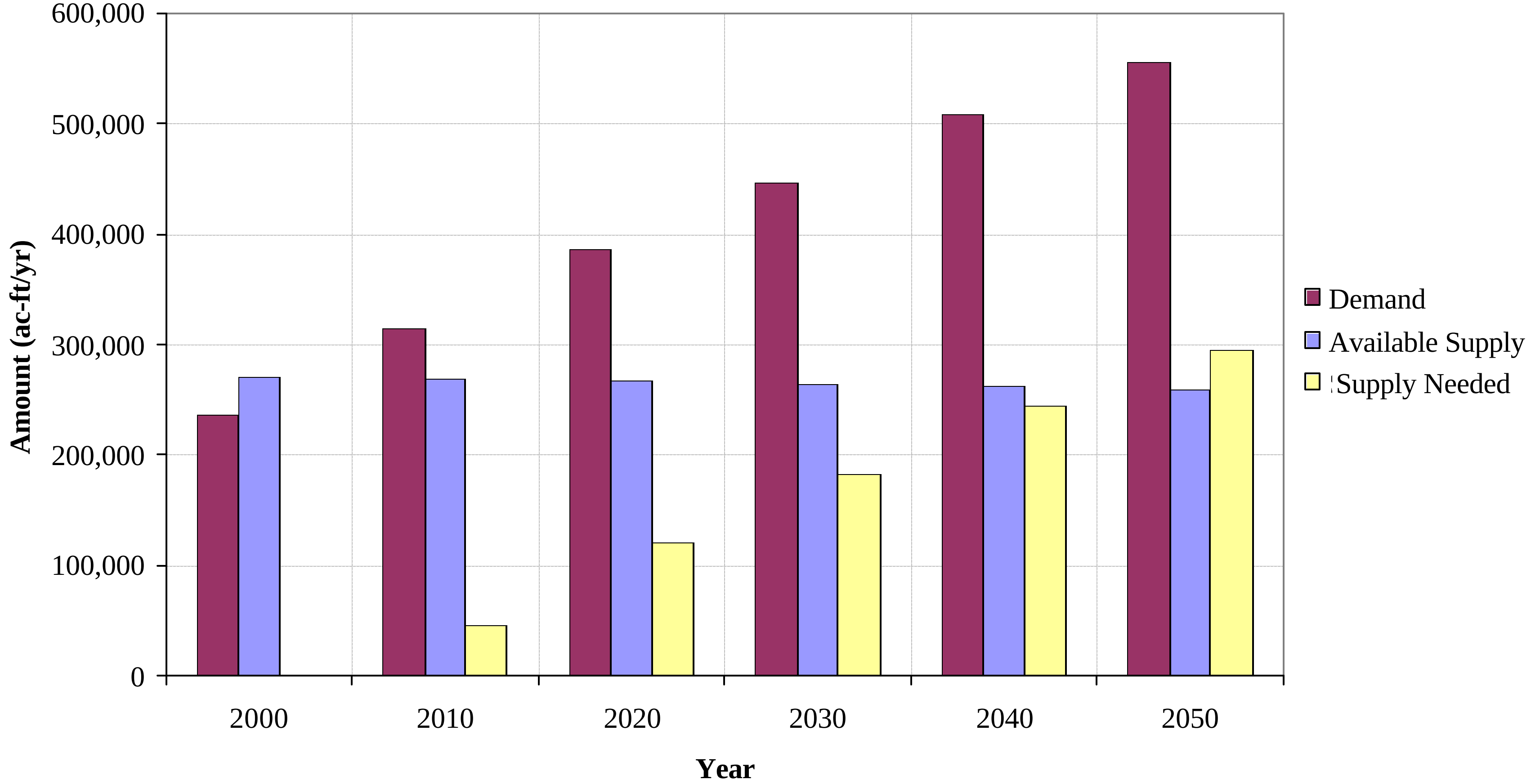


Figure 4.7
Comparison of Connected Supply and Projected Demand
for North Texas Municipal Water District



Trinity River Authority

TRA shows a need for 5,652 acre-feet per year in 2000, changing to a need for 43,403 acre-feet per year in 2010. By 2050, the TRA need is 54,674 acre-feet per year. The need for additional water for TRA in 2000 is an artificial number created by TWDB requirements for TWDB Tables 3, 6, and 8. TWDB Table 3 is required to include all major water provider contracts, whether they are currently being used or not. TRA has contracts for long-term water supply with several entities in Ellis County, but the water is not yet needed, and the infrastructure to supply it is not in place. Thus, the need for water shown for the year 2000 is not an actual supply shortage, but merely a need that results from the TWDB guidelines for TWDB Table 3. When entities in Ellis County activate their contracts with TRA, the facilities needed to make the water available will be built. TRA receives a portion of its current supply from TRWD. Specifically, the water that TRA provides to Bedford, Colleyville, Euless, Grapevine, and North Richland Hills originates from TRWD. Therefore, planning for the needs of TRWD will meet the needs of these cities.

4.4 Socio-Economic Impacts of Not Meeting Projected Water Needs

If no additional water supplies are developed, Region C will face substantial shortages in water supply over the next 50 years. The Texas Water Development Board provided technical assistance to regional water planning groups in the development of specific information on the socio-economic impacts of failing to meet projected water needs. This information is presented in TWDB Tables 9 and 10, which are included in Appendix N. Appendix N also includes TWDB's discussion of the socio-economic impacts of failing to meet water supply needs in Region C and how those impacts were determined.

The TWDB analysis of socio-economic impacts is based on information provided to TWDB in December of 2000. Table 4.6 and Figure 4.8 summarize the TWDB's analysis of the impacts of failing to take steps to supply additional water and meet the projected water needs in Region C. TWDB's findings can be summarized as follows:

- The currently connected supplies in Region C meet only 52.5 percent of the projected 2050 demand.
- Without any additional supplies, the projected water needs would reduce the region's projected 2050 population from 9,481,157 to 6,078,289, a reduction of 35.9 percent.

Table 4.6
Impacts of Water Needs in Region C If No Additional Supplies Are Developed

Water

Decade	Projected Demand (acre-feet)	Projected Water Need (acre-feet)	Percent Shortage
2000	1,376,373	91,046	6.6%
2010	1,695,661	339,957	20.0%
2020	1,944,893	600,677	30.9%
2030	2,149,826	836,375	38.9%
2040	2,368,188	1,038,801	43.9%
2050	2,536,902	1,203,947	47.5%

Employment

Decade	Baseline Employment (FTE jobs)	Employment With No New Supplies (FTE jobs)	Percent Loss
2000	2,500,725	2,340,800	6.4%
2010	2,955,702	2,438,551	17.5%
2020	3,316,463	2,481,154	25.2%
2030	3,646,334	2,488,083	31.8%
2040	4,049,283	2,557,832	36.8%
2050	4,425,184	2,605,111	41.1%

Population

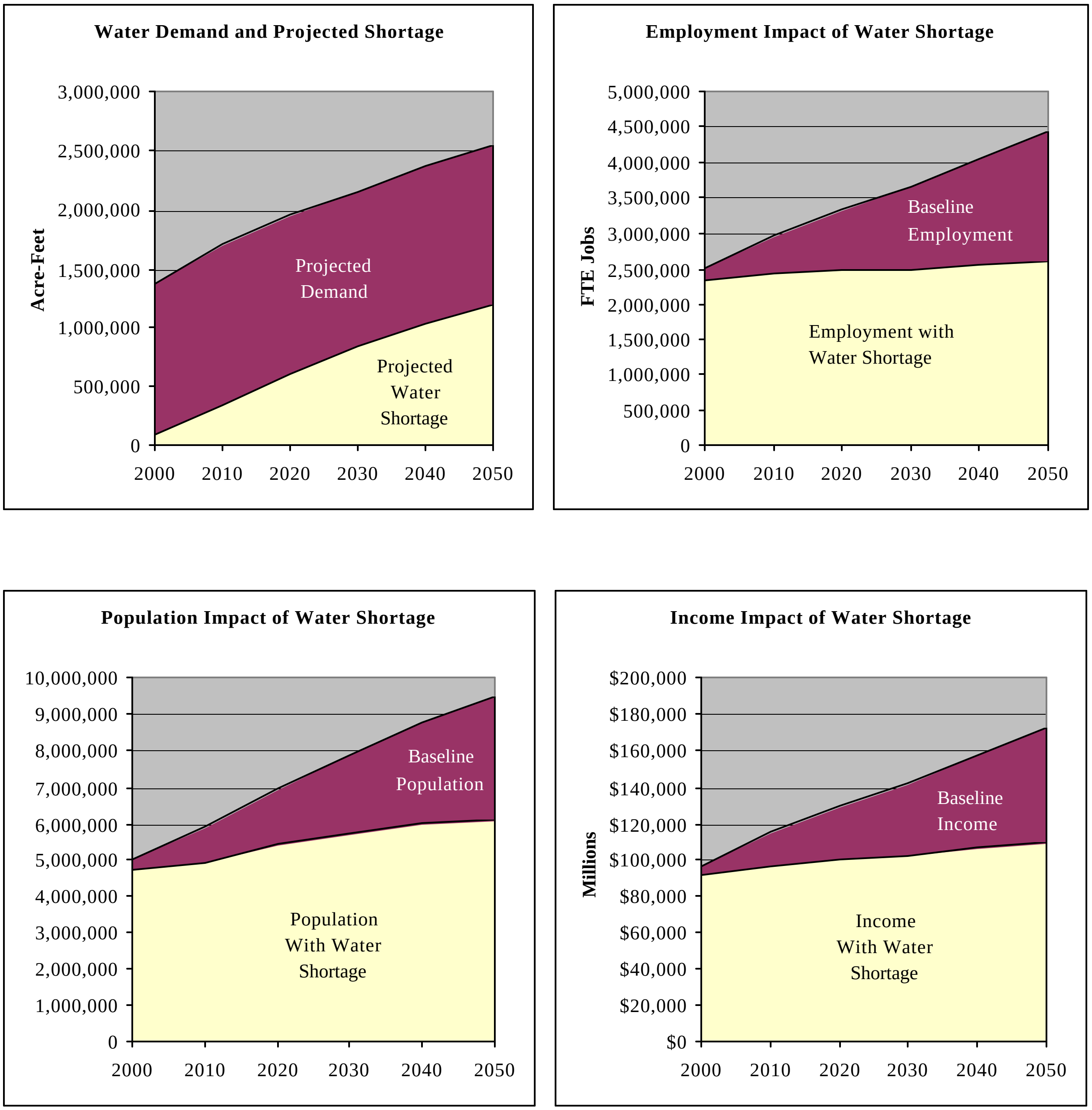
Decade	Baseline Population	Population With No New Supplies	Percent Loss
2000	5,012,860	4,723,816	5.8%
2010	5,882,173	4,938,757	16.0%
2020	6,931,543	5,389,966	22.2%
2030	7,850,797	5,693,234	27.5%
2040	8,778,041	5,988,297	31.8%
2050	9,481,157	6,078,289	35.9%

Income

Decade	Baseline Income (millions, 1999 $)	Income With No New Supplies (millions, 1999 $)	Percent Loss
2000	97,086	91,490	5.8%
2010	114,749	96,627	15.8%
2020	128,755	100,199	22.2%
2030	141,562	102,261	27.8%
2040	157,205	106,390	32.3%
2050	171,799	109,505	36.3%

Note: These impacts are based on data provided to the TWDB by Region C in December 2000.

Figure 4.8
Summary of Socio-Economic Impacts of
Not Meeting Water Needs for Region C, 2000-2050



Note: These impacts are based on shortage data provided to the TWDB by Region C in December 2000.

- Without any additional supplies, the projected water needs would reduce the region's projected 2050 employment from 4,425,184 to 2,605,111, a reduction of 41.1 percent.

- Without any additional supplies, the projected water needs would reduce the region's projected 2050 income from $171,199,000,000 to $109,505,000,000, a reduction of 36.3 percent.

4.5 Summary of Comparison of Supply and Demand for Region C

1. If no new supplies are developed, Region C has a net surplus of connected supply of 129,325 acre-feet per year in 2000, changing to a need for an additional 204,373 acre-feet per year by 2010. The projected need continues to grow through the rest of the planning period, reaching 1,096,407 acre-feet per year by 2050.
2. There are substantial unconnected supplies in Region C that could be made available by completing water transmission facilities.
3. The number of Region C counties with net needs for more water changes from 3 out of 16 counties in 2000 to 11 out of 16 counties in 2050.
4. There are 281 individual water user groups in Region C. Of these, 82 water user groups are projected to need more supply in 2000. The number grows to 193 by 2050.
5. Many Region C water suppliers depend on the region's major water providers (Dallas Water Utilities, Tarrant Regional Water District, North Texas Municipal Water District, Fort Worth, and Trinity River Authority) for all or part of their supplies. Each of those major water providers will need to develop additional supplies by 2050.
6. If additional supplies are not developed, the projected needs for water will have major socio-economic impacts in Region C.

TABLE 1
REGION C WATER SURPLUS/(SHORTAGE) BY DECADE

CATEGORY	YEAR					
	2000	2010	2020	2030	2040	2050
REGION C SURPLUS/SHORTAGE (acre-feet/year)	129,325	**(204,373)**	**(474,048)**	**(694,621)**	**(920,052)**	**(1,096,407)**
COUNTIES WITH SHORTAGES (16 COUNTIES TOTAL)	3	11	11	11	11	11
USER GROUPS WITH SHORTAGES (281 USER GROUPS TOTAL)	82	178	185	188	190	193

TABLE 2
REGION C MAJOR UNCONNECTED SOURCES OF SUPPLY
COMPARISON OF TWDB TABLES 4 AND 5
(acre-feet per year)

Source Name	Available Yield 2000	Available Yield 2010	Available Yield 2020	Available Yield 2030	Available Yield 2040	Available Yield 2050
Lake Fork (Dallas)	120,000	120,000	120,000	120,000	120,000	120,000
Cedar Creek/Richland-Chambers System	117,608	118,630	118,163	117,770	117,633	115,227
Lake Palestine (Dallas)	112,700	112,100	111,500	110,900	110,200	109,600
Freestone County Groundwater	89,407	89,407	89,406	89,405	89,404	89,403
Lake Chapman	65,700	65,200	64,800	64,300	63,800	59,700
Lake Texoma	15,790	15,790	15,790	15,790	15,790	15,790
Richland-Chambers Reservoir	13,650	13,650	13,650	13,650	13,650	13,650
Navarro County Groundwater	11,338	11,338	11,338	11,035	11,035	11,035
Joe Pool Lake	11,558	10,623	9,830	9,264	8,995	8,753
Moss Lake	4,500	4,500	4,500	4,500	4,500	4,500
Grapevine Lake (PCMUD)	4,100	4,100	4,100	4,100	4,100	4,100
Benbrook Lake	0	1,997	2,481	2,973	3,419	3,786
White Rock Lake	3,000	3,000	3,000	3,000	3,000	3,000
Parker County Groundwater	1,816	1,997	2,216	2,455	2,692	2,878
Fannin County Groundwater	2,903	2,903	2,903	2,522	2,522	2,521
Collin County Groundwater	2,797	2,797	2,797	1,868	1,868	1,868
Lake Mineral Wells	1,500	1,500	1,500	1,500	1,500	1,500

TABLE 3
REGION C UNPERMITTED SOURCES OF SUPPLY
(acre-feet per year)

Source Name	Available Yield 2000	Available Yield 2010	Available Yield 2020	Available Yield 2030	Available Yield 2040	Available Yield 2050
Moss	1,800	1,600	1,400	1,200	1,000	800
Texoma	787,550	759,800	732,050	704,300	676,550	648,700
Bonham	1,900	1,300	700	100	0	0
Cedar Creek	47,900	44,500	41,100	37,700	34,300	31,000
Richland-Chambers	28,200	22,100	16,000	9,900	3,800	0
Bardwell	900	400	0	0	0	0
Navarro Mills	3,500	2,100	700	0	0	0
TOTAL	871,750	831,800	791,950	753,200	715,650	680,500

TABLE 4
SURPLUS/(SHORTAGE) FOR EACH COUNTY IN REGION C
(acre-feet per year)

Category	Basin Number	Year					
		2000	2010	2020	2030	2040	2050
COLLIN	8/5	23,020	(29,794)	(80,743)	(124,769)	(174,124)	(210,431)
COOKE	8/2	(3,008)	(3,087)	(3,192)	(4,034)	(4,311)	(4,609)
DALLAS	8	(34,250)	(168,112)	(241,696)	(267,472)	(350,525)	(415,879)
DENTON	8	3,108	(20,744)	(92,987)	(184,125)	(210,954)	(234,983)
ELLIS	8	6,935	(10,542)	(13,252)	(17,304)	(21,678)	(23,346)
FANNIN	8/2/3	25,663	24,433	23,263	22,166	20,701	19,159
FREESTONE	8/12	4,057	(6,927)	(8,868)	(8,903)	(13,126)	(13,155)
GRAYSON	8/2	23,778	23,078	22,596	21,142	19,981	18,797
HENDERSON	8	18,290	17,884	17,848	17,598	17,449	17,114
JACK	8/12	2,102	2,357	2,372	2,355	2,331	2,238
KAUFMAN	8/5	2,620	(1,024)	(3,566)	(7,921)	(10,145)	(17,119)
NAVARRO	8	13,881	13,283	12,929	12,300	11,858	11,438
PARKER	8/12	(1,613)	(11,469)	(15,008)	(24,715)	(30,336)	(33,874)
ROCKWALL	8/5	2,941	(6,362)	(10,849)	(15,603)	(21,694)	(28,106)
TARRANT	8	30,270	(25,625)	(79,466)	(109,210)	(147,498)	(174,233)
WISE	8	11,531	(1,722)	(3,429)	(6,126)	(7,981)	(9,418)
REGION C TOTAL		129,325	(204,373)	(474,048)	(694,621)	(920,052)	(1,096,407)

TABLE 5
SURPLUS/(SHORTAGE) FOR EACH COUNTY IN REGION C
AS A PERCENTAGE OF DEMAND

Category	Basin Number	Year					
		2000	2010	2020	2030	2040	2050
COLLIN	8/5	18%	(15%)	(31%)	(40%)	(48%)	(52%)
COOKE	8/2	(33%)	(34%)	(35%)	(43%)	(45%)	(47%)
DALLAS	8	(6%)	(25%)	(32%)	(33%)	(40%)	(44%)
DENTON	8	3%	(15%)	(50%)	(80%)	(82%)	(83%)
ELLIS	8	28%	(24%)	(29%)	(35%)	(40%)	(42%)
FANNIN	8/2/3	212%	183%	160%	142%	125%	109%
FREESTONE	8/12	20%	(22%)	(27%)	(27%)	(35%)	(35%)
GRAYSON	8/2	82%	78%	75%	67%	61%	56%
HENDERSON	8	144%	136%	132%	128%	127%	123%
JACK	8/12	80%	91%	92%	91%	89%	84%
KAUFMAN	8/5	12%	(4%)	(13%)	(24%)	(29%)	(41%)
NAVARRO	8	135%	122%	115%	104%	96%	90%
PARKER	8/12	(11%)	(47%)	(53%)	(66%)	(71%)	(74%)
ROCKWALL	8/5	32%	(32%)	(42%)	(47%)	(53%)	(56%)
TARRANT	8	8%	(6%)	(17%)	(22%)	(28%)	(31%)
WISE	8	63%	(5%)	(10%)	(17%)	(21%)	(24%)
REGION C TOTAL		9%	(12%)	(24%)	(32%)	(39%)	(43%)

TABLE 6
SURPLUS/(SHORTAGE) FOR EACH MAJOR WATER PROVIDER IN REGION C
(acre-feet per year)

Major Water Provider	Year					
	2000	2010	2020	2030	2040	2050
Dallas Water Utilities	(72,986)	(126,101)	(37,314)	21,833	2,866	(7,113)
Fort Worth	10,665	(9,025)	(6,288)	(15,075)	(25,665)	(35,373)
North Texas Municipal Water District	34,253	(46,236)	(120,083)	(182,555)	(245,377)	(294,686)
Tarrant Regional Water District	12,797	(55,335)	(51,528)	(77,643)	(95,108)	(120,856)
Trinity River Authority	(5,652)	(43,403)	(43,454)	(47,901)	(51,682)	(54,674)

TABLE 7
SURPLUS/(SHORTAGE) FOR EACH MAJOR WATER PROVIDER IN REGION C
AS A PERCENTAGE OF DEMAND

Major Water Provider	Year					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**
Dallas Water Utilities	**(13%)**	**(21%)**	**(8%)**	5%	1%	**(2%)**
Fort Worth	6%	**(5%)**	**(4%)**	**(9%)**	**(15%)**	**(19%)**
North Texas Municipal Water District	14%	**(15%)**	**(31%)**	**(41%)**	**(48%)**	**(53%)**
Tarrant Regional Water District	4%	**(13%)**	**(12%)**	**(17%)**	**(20%)**	**(25%)**
Trinity River Authority	**(5%)**	**(30%)**	**(28%)**	**(30%)**	**(32%)**	**(34%)**

FIGURE 3
REGION C UNCONNECTED AND UNPERMITTED SUPPLIES

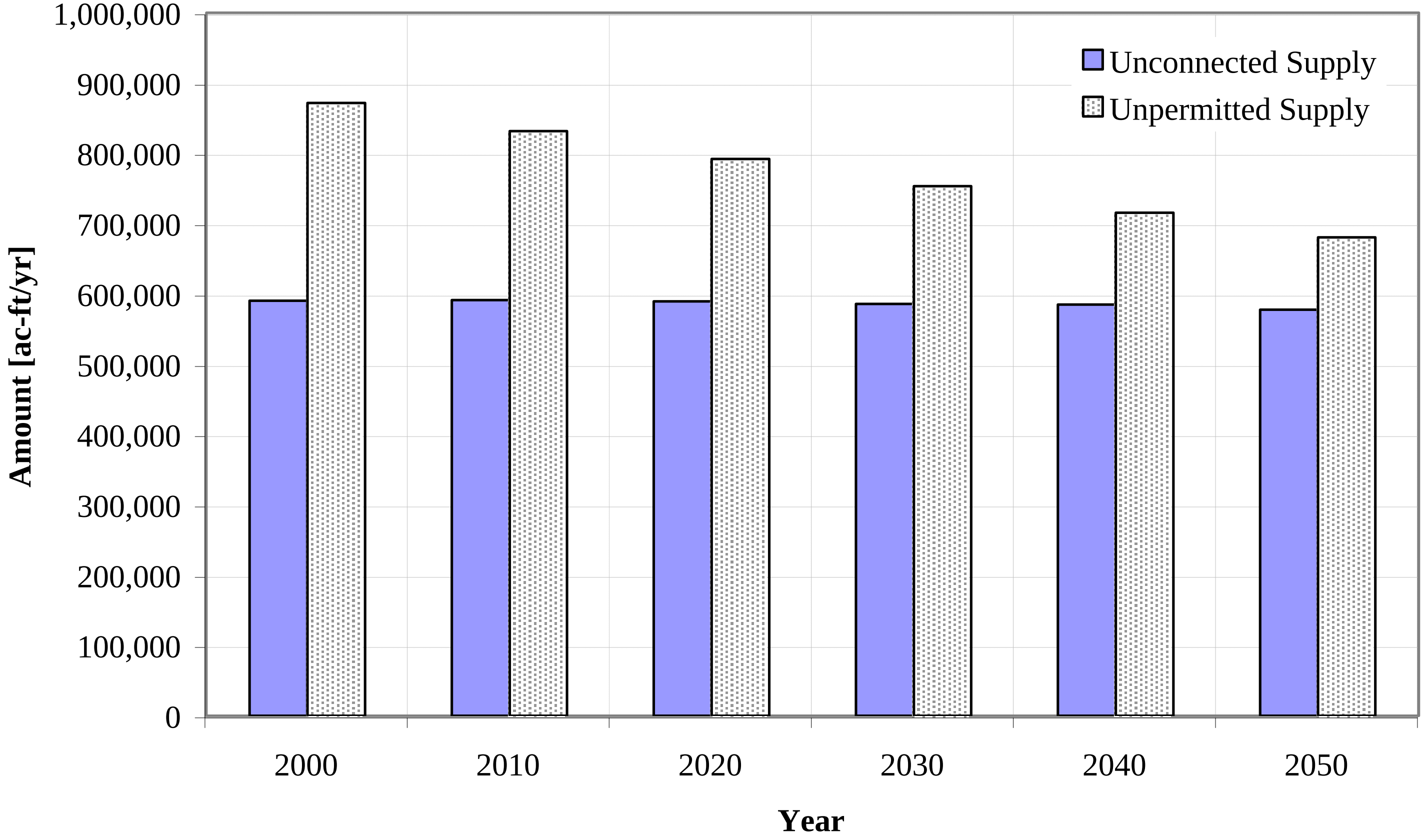


FIGURE 5
COMPARISON OF SUPPLY AND DEMAND
CITY OF FORT WORTH

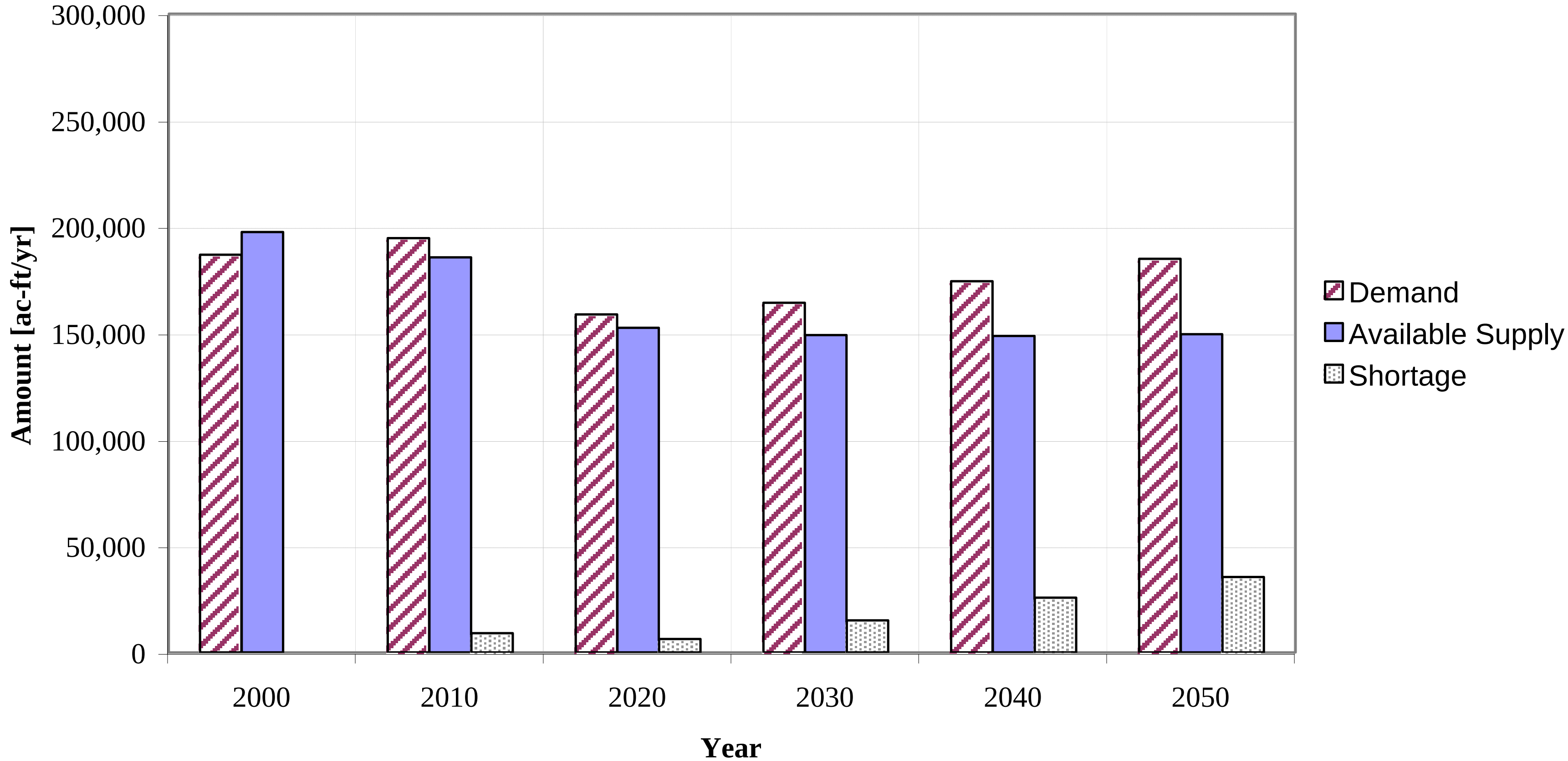


FIGURE 8
COMPARISON OF SUPPLY AND DEMAND
TRINITY RIVER AUTHORITY

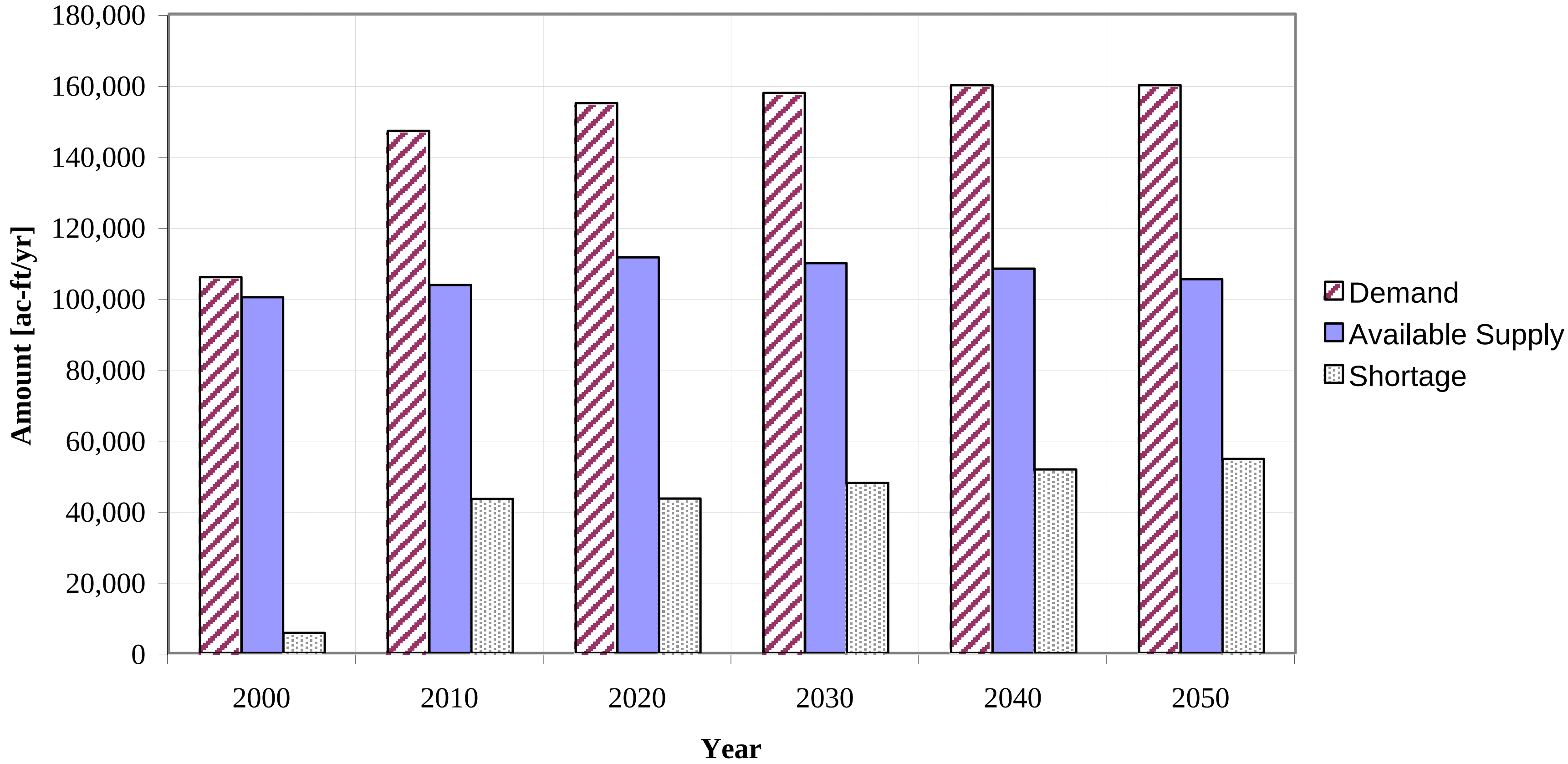


Figure 4.1
Comparison of Connected Supply and Projected Demand for Region C

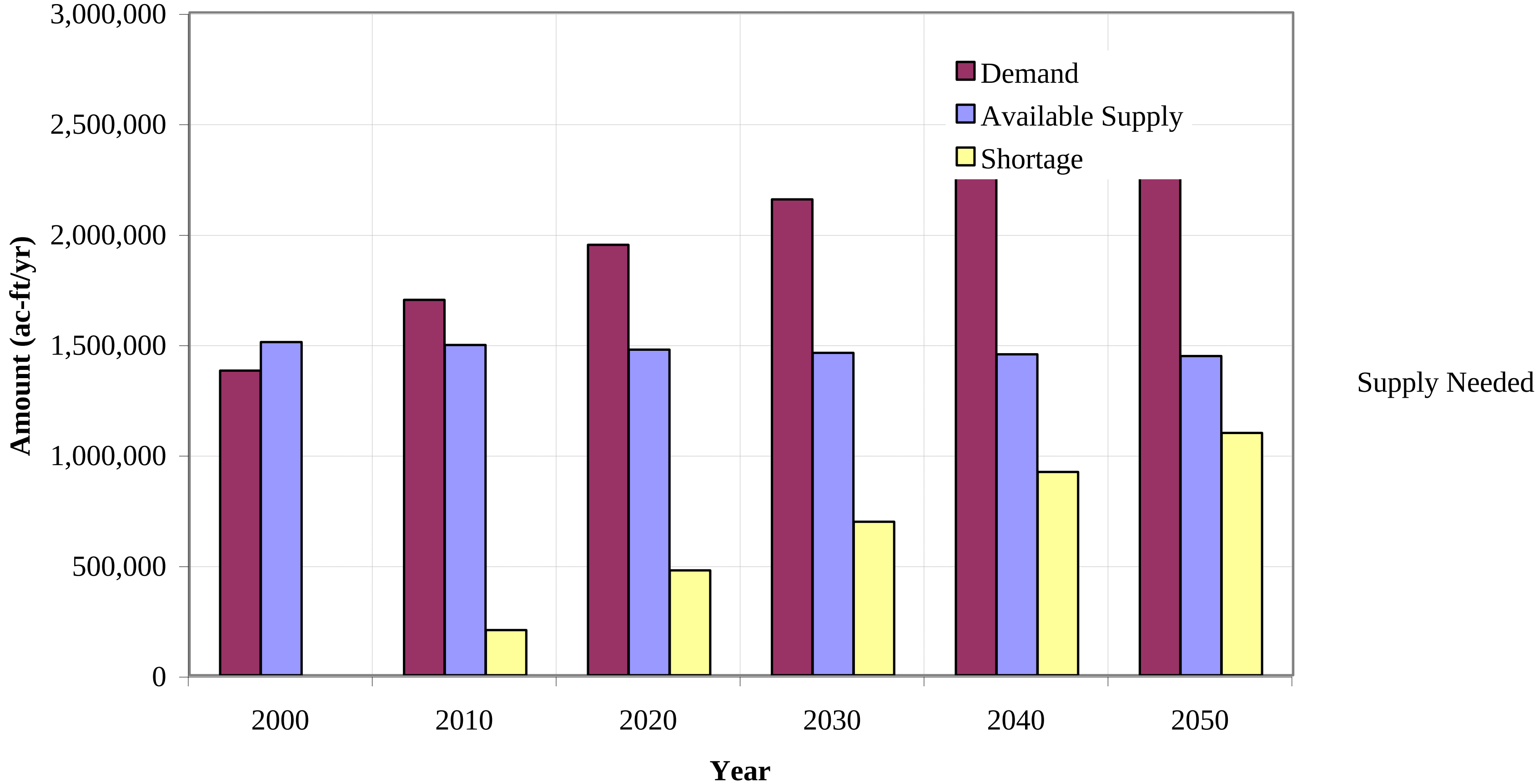


Figure 4.3
Comparison of Connected Supply and Projected Demand
for Dallas Water Utilities

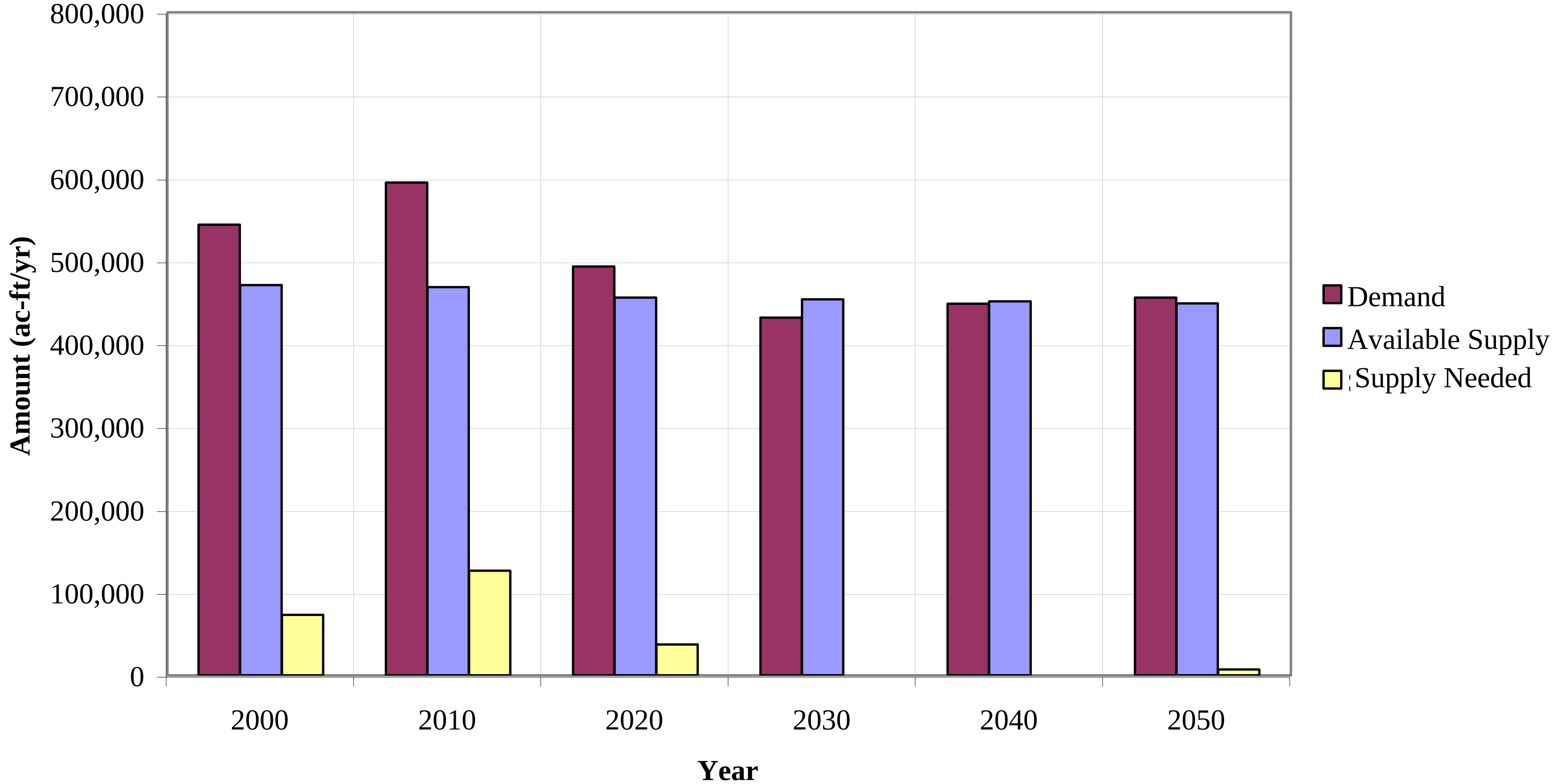


Figure 4.4
Comparison of Connected Supply and Projected Demand
for Dallas Water Utilities without Contract Expiration

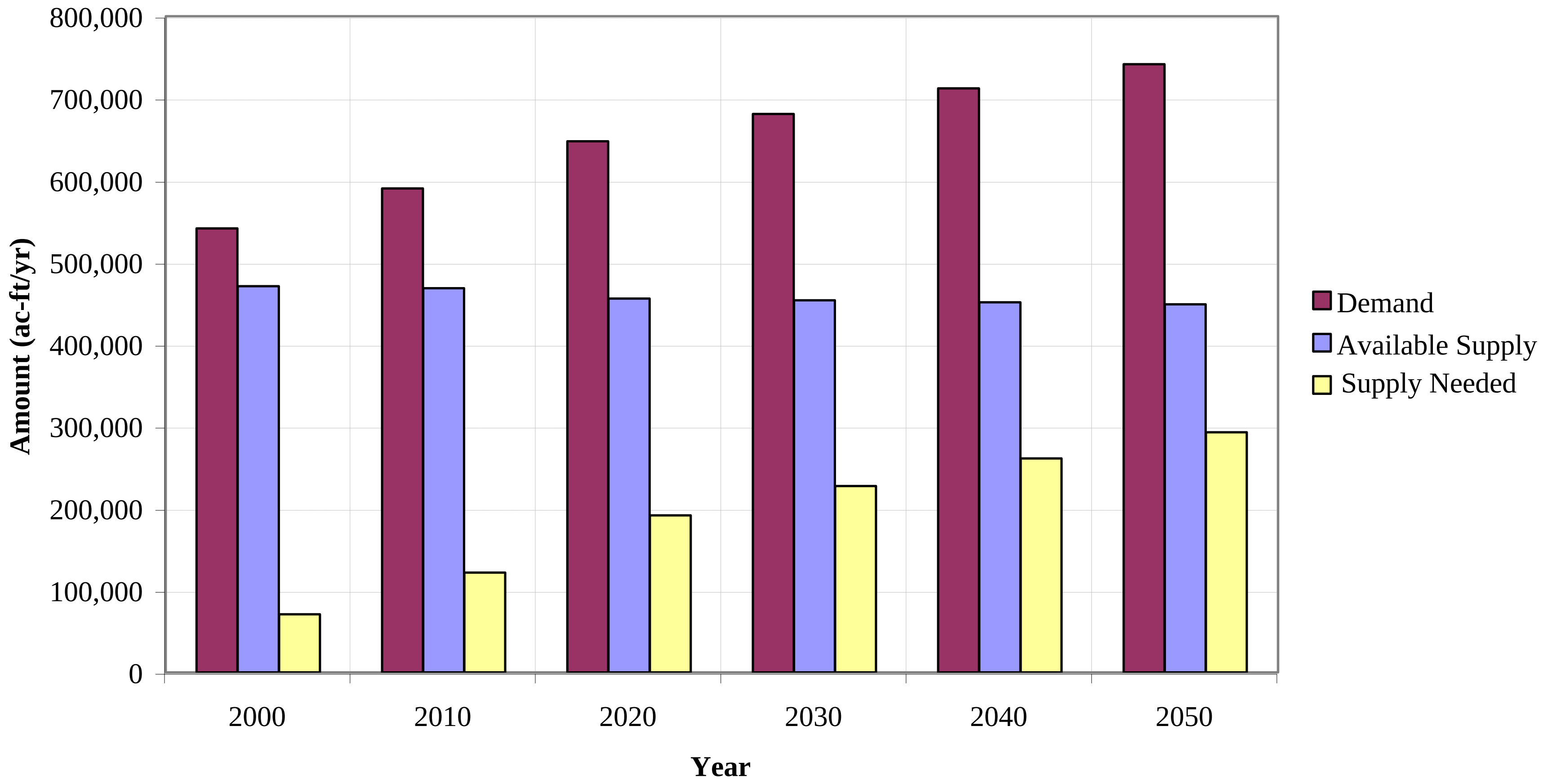


Figure 4.5
Comparison of Connected Supply and Projected Demand
for Tarrant Regional Water District

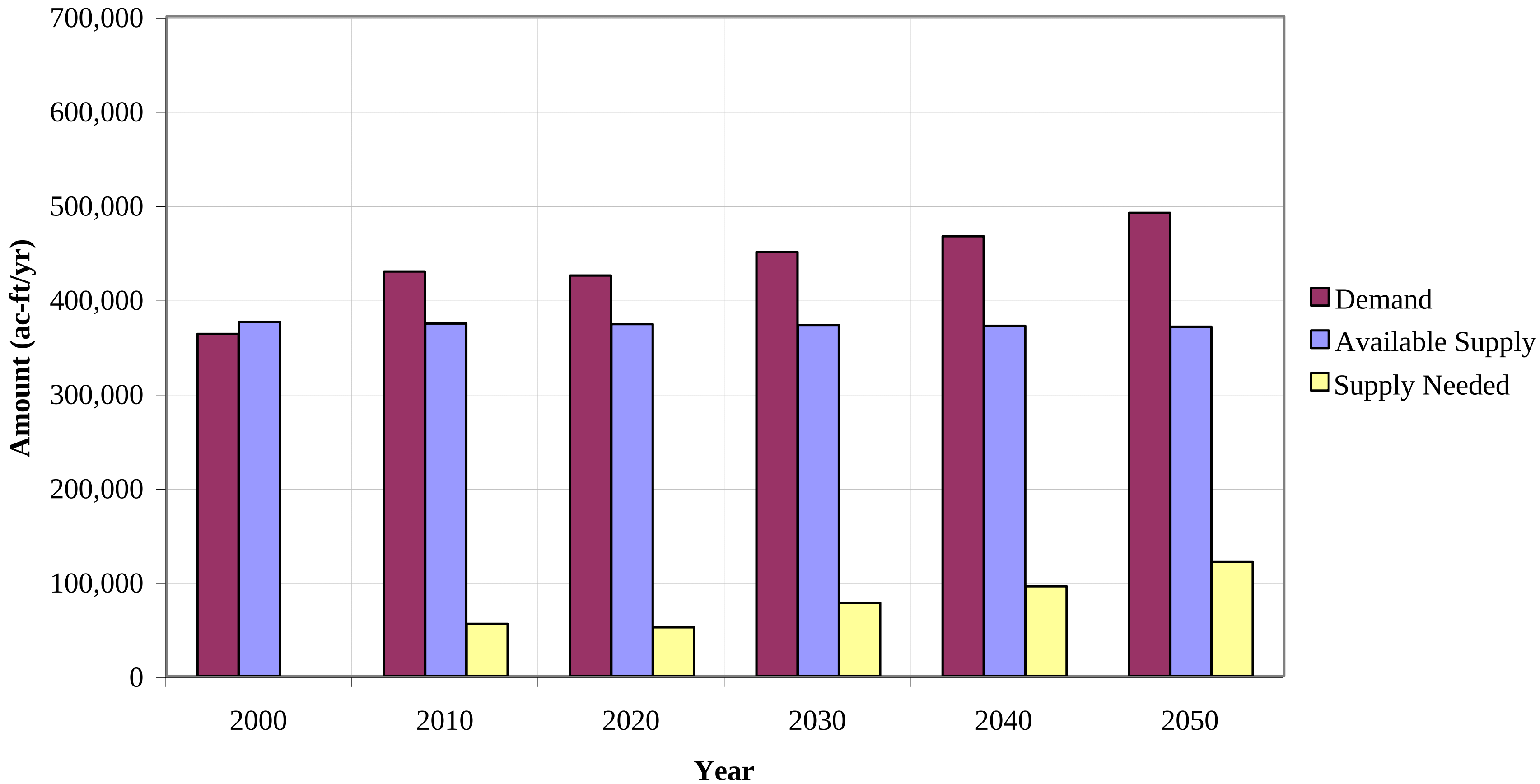


Figure 4.6
Comparison of Connected Supply and Projected Demand
for Tarrant Regional Water District without Contract Expiration

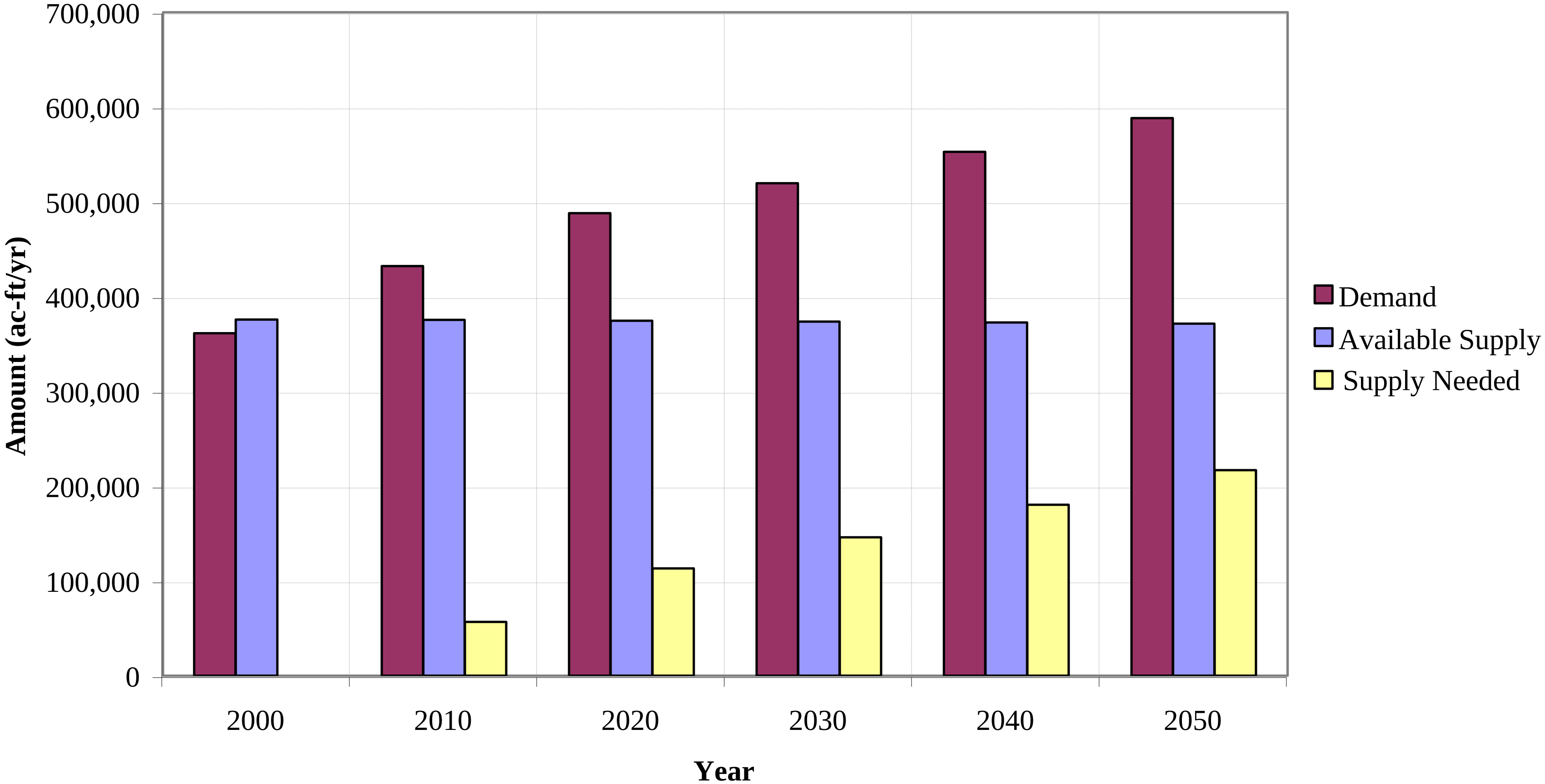
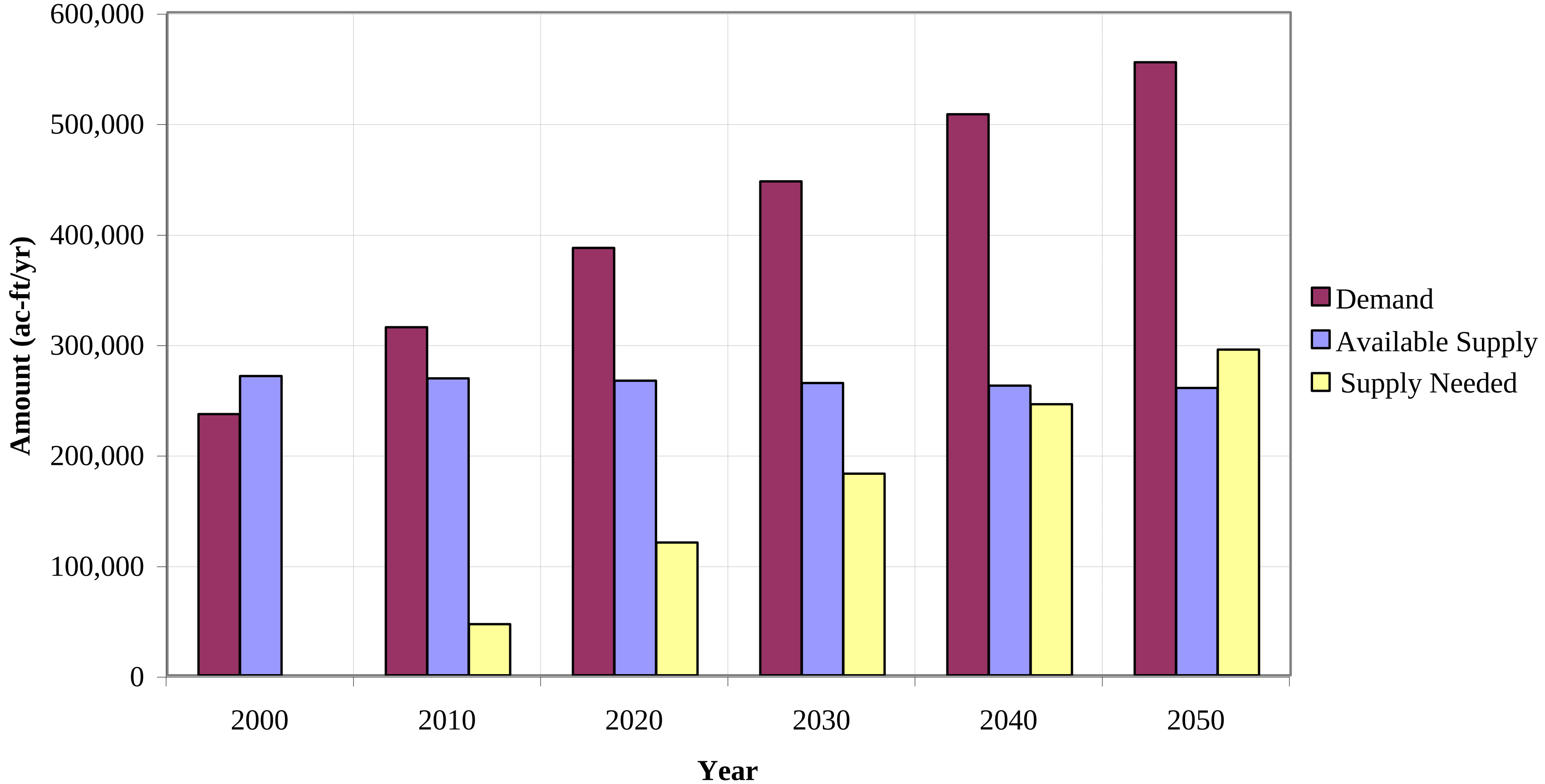


Figure 4.7
Comparison of Connected Supply and Projected Demand
for North Texas Municipal Water District



5. Evaluation and Selection of Water Management Strategies

This section describes the evaluation and selection of water management strategies to address the needs for additional water supply identified in Section 4. The regional water planning group went through several steps in the evaluation and selection of water management strategies for Region C:

- Review of previous plans for water supply in Region C, including locally developed plans and the most recent state water plan[11]
- Development of goals, issues, and concerns for the planning process
- General consideration of the types of water management strategies required by Senate Bill One regional planning guidelines[1]
- Development of evaluation criteria for management strategies
- Environmental evaluation of individual strategies
- Development of cost information for individual strategies
- Selection of strategies.

This section reviews the selection and evaluation process outlined above, summarizes the water management strategies adopted for major water providers, discusses the management strategies county by county, provides an extended discussion on management strategies for livestock demands in Region C, and discusses consistency with the regional water plan.

It is important to bear in mind that the water management strategies and the costs provided are intended to provide the additional water supplies needed for the region. The strategies (and thus the costs) do not include replacement and upgrading of aging facilities or improvements to water treatment facilities needed to respond to changes in regulations. They also do not include the cost of water distribution improvements to deliver water to retail customers.

The development of a water plan covering fifty years for a region as large and populous as Region C is full of uncertainties. The implementation of the plan must be flexible to allow for slower or faster than expected growth, for unexpected obstacles in development of water management strategies, and for unexpected opportunities. Specific points to remember include the following:

- The order in which steps are taken and the exact amount of supply available from each source are subject to variation.
- Water suppliers may need to turn to other alternatives if the recommended alternatives prove to be impractical.
- Changes in one element of the plan can affect other elements.
- Given the uncertainty in developing future supplies, flexibility in plan implementation is essential to success.
- The details of the plan will probably change as implementation proceeds.

5.1 Previous Plans for Water Supply in Region C

Appendix B is a list of previous water-related plans and reports for Region C. The region has a long history of successful local water supply planning and development. When the Senate Bill One planning process began, pre-existing plans for future water supply in Region C included the following:

- Dallas planned to connect its currently unused supplies in Lake Fork Reservoir and Lake Palestine to its system.
- Dallas was engaged in an update of its long-range water supply plan.
- Tarrant Regional Water District was planning to divert return flows of treated wastewater from the Trinity River into Cedar Creek Lake and Richland-Chambers Lake to increase the yield of its system.
- Tarrant Regional Water District was planning to develop Lake Tehuacana on Tehuacana Creek or participate in Marvin Nichols I Reservoir on the Sulphur River.
- North Texas Municipal Water District was planning to expand its reuse project and seek additional water supplies.
- Irving and Upper Trinity Regional Water District had obtained water supplies in Chapman Lake and were planning to construct water transmission facilities to deliver the supplies to Lake Lewisville.
- Several Region C water suppliers were considering the development of water supplies in the Sulphur Basin to the east. Alternatives included George Parkhouse Reservoirs I and II and Marvin Nichols Reservoirs I and II. Development of any of these sites would require a cooperative effort with water suppliers in the vicinity of the reservoir sites, which are located in Senate Bill One Region D.
- Other Region C suppliers were planning and developing smaller water supply projects to meet local needs. Examples included Muenster (new reservoir), Wortham (contract with Mexia), and many entities developing additional wells or seeking water supplies from the major water suppliers in the region.

There has also been an increasing interest in the reuse of treated wastewater in Region C in recent years. There are several permits for significant indirect reuse projects in the region. In addition to the permitted indirect reuse projects, many of the reservoirs in Region C make use of treated wastewater return flows in their watersheds, which increase reservoir yields. Many of the major water suppliers in the area, including Dallas, Tarrant Regional Water District, Trinity River Authority, North Texas Municipal Water District, Fort Worth, Irving, Denton, Lewisville, Flower Mound, Grapevine, Weatherford, Upper Trinity Regional Water District, and others, are considering reuse projects. Direct reuse, often for irrigation of golf courses, is also increasing in the region. It is clear that reuse of treated wastewater will remain a significant part of future water planning for Region C.

Most Recent State Water Plan

The most recent state water plan, *Water for Texas,* published in 1997, proposed several water supply projects for Region C [(11)]:

- Diversion of Trinity River wastewater return flows from the Fort Worth area into Cedar Creek and Richland-Chambers Lakes to serve Tarrant Regional Water District by 2030.
- Construction of Tehuacana Reservoir on Tehuacana Creek to serve Tarrant Regional Water District by 2050.
- Development of George Parkhouse II Reservoir in the Sulphur River Basin to serve North Texas Municipal Water District by 2015. (This project might also serve Upper Trinity Regional Water District.)
- Reallocation and permitting of the unappropriated share of Texas' portion of Lake Texoma to serve the North Texas Municipal Water District if the Red River Chloride Control Project improves the amount of usable supply from Lake Texoma by 2050.
- Construction of transmission facilities from Lake Fork Reservoir to serve Dallas by 2005.
- Construction of transmission facilities from Lake Palestine to serve Dallas by 2015.
- Construction of the Marvin Nichols I Reservoir to serve Dallas by 2040. (This project might also serve North Texas Municipal Water District, Tarrant Regional Water District, and Upper Trinity Regional Water District).
- Development of transmission facilities from Lake Chapman in the Sulphur Basin to serve Irving and Upper Trinity Regional Water District.

- Possible use of Lake Joe Pool to supply additional water to Waxahachie.

5.2 *Goals, Issues and Concerns in the Planning Process*

Early in the planning process, the Region C Water Planning Group adopted goals, issues, and concerns for the planning effort. The issues and concerns covered specific categories, including water supply, environmental, water quality, and regulatory. The goals, issues, and concerns given below were used to guide the planning process as it proceeded.

Goals of the Planning Process

The goals for the Region C water planning effort are as follows:

- Provide sufficient water to meet realistic estimates of demand in a timely manner.
- Develop an effective continuing planning process to maintain reliable estimates of supply, maintain realistic estimates of demand, and identify appropriate programs and facilities to meet the water supply needs of Region C.
- Provide for the water supply needs of Region C in a manner that supports the continued economic strength of both Region C and the state as a whole.
- Develop a water supply plan that recognizes the economic, environmental, and cultural importance of natural resources and provides for the maintenance of those resources.
- Address the water supply needs of small cities and rural areas as well as large metropolitan areas.
- Provide for sustainable groundwater use in areas where groundwater is an essential component of the water supply plan.

Water Supply Issues and Concerns

Water supply issues and concerns include the following:

- The projected 2050 water needs in Region C total approximately 2.5 million acre-feet per year.
- Currently available resources can provide approximately 2.0 million acre-feet per year if connected and used fully.
- Some major water suppliers need to connect or develop additional water supplies in the very near future.

- The timing of water supply needs varies significantly among the major water providers. This complicates the scheduling and funding of regional water supply projects.
- Reuse of treated wastewater is a key component of existing plans to meet water needs in Region C. There are technical and public perception issues that need to be investigated in order to develop the needed supply from reuse.
- Groundwater resources are being overdrafted in Cooke, Denton, Grayson, Tarrant, and Parker Counties. The reliability of groundwater supplies in Wise and Henderson Counties is uncertain.
- Some small towns are using groundwater supplies of unknown capacity, and some of these towns do not have readily available alternative sources of supply.
- Rural areas are experiencing significant growth, which is creating water supply demands that are difficult for rural water systems to meet.

Environmental Issues and Concerns

Environmental issues and concerns include the following:

- Proposed reservoirs and major new diversions from streams must provide releases or bypasses that are adequate to maintain instream aquatic habitats and protect against water quality standards violations.
- There are significant environmental concerns that must be addressed before major new reservoirs can be constructed. These concerns include loss of bottomland hardwoods and wetland habitats, inundation of lignite resources, and inundation of prime farmland.
- Major construction projects will have to address potential impacts on threatened and endangered species and on riparian or wetland-dependent species. The Texas Parks and Wildlife Department has identified 28 species in these categories that may reside in or migrate through Region C.

Water Quality Issues and Concerns

Water quality issues and concerns include the following:

- It has not been determined whether water from Lake Texoma can be treated to levels expected by municipal and industrial consumers in the Metroplex for an acceptable cost; or whether, alternatively, the Red River Chloride Control Project will improve the water quality sufficiently to enhance the use of Lake Texoma for municipal and industrial purposes.
- Some existing surface water supplies do not meet drinking water criteria being considered for arsenic due to natural conditions. Treatment to remove arsenic using existing technologies is difficult and expensive.

- Deteriorating quality of groundwater supplies has occurred as over-pumping has lowered groundwater tables in parts of Region C.
- Some groundwater supplies do not comply with existing or proposed primary or secondary drinking water criteria for arsenic, radon, fluoride, nitrate, chloride, sulfate, total dissolved solids, iron, or manganese.

Regulatory Issues and Concerns

Regulatory issues and concerns included the following:

- Current regulatory requirements may limit the extent to which reuse can meet water supply needs.
- Permitting and construction of a major reservoir require approximately 20-30 years, which requires careful advance planning to provide for increasing demands.
- Major alternatives for future water supplies for Region C will require approval of interbasin transfers.
- There are competing demands among water purveyors, recreational interests, and hydropower generators for reservoir waters in storage, and demands are increasing in all of these sectors.
- Securing water resources in East Texas for transfer to Region C will require development of an arrangement that is beneficial to, and meets the socio-economic objectives of, both regions.
- The planning requirements of the Texas Water Development Board assume water conservation programs will be implemented that will significantly reduce per capita municipal water use. Aggressive measures may be required to achieve the projected reductions in demand.

5.3 Types of Water Management Strategies Considered

Senate Bill One guidelines require that certain types of water management strategies be considered as means of developing additional water supplies by all of the regional water planning groups. The types of strategies that must be considered include the following[(1)]:

- Water conservation and drought response planning
- Reuse of wastewater
- Expanded use or acquisition of existing supplies, including system optimization and conjunctive use
- Reallocation of reservoir storage to new uses
- Voluntary redistribution of water resources

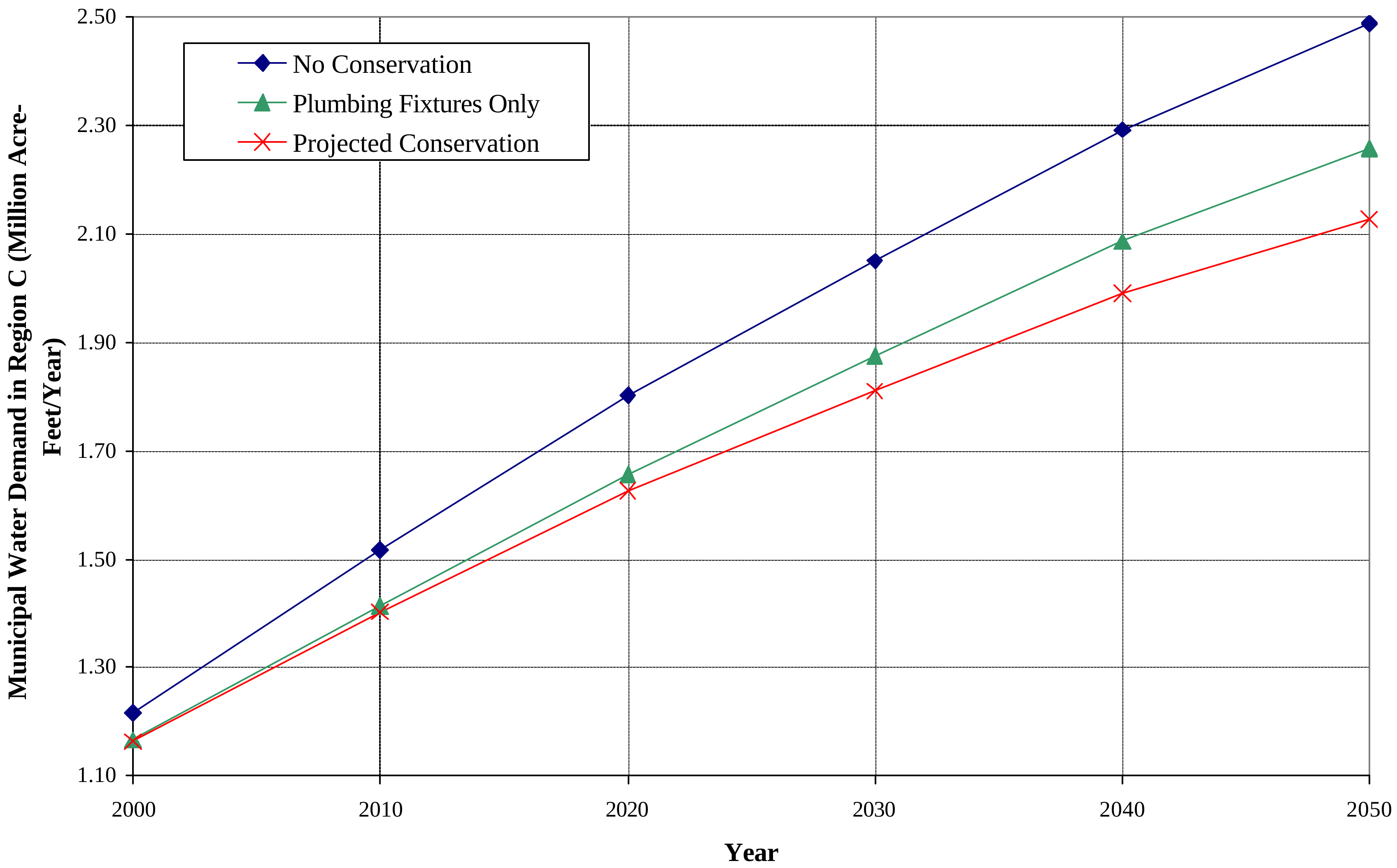
- Voluntary subordination of water rights
- Enhancement of yields of existing sources
- Control of naturally occurring chlorides
- Interbasin transfers
- New supply development
- Water management strategies in the current state water plan
- Brush control, precipitation enhancement, and desalination
- Water right cancellation
- Aquifer storage and recovery
- Other measures.

The Region C Water Planning Group reviewed each of these types of water management strategies at one or more meetings and made a general evaluation of the potential effectiveness of each strategy for Region C. The regional water planning group determined that some types of strategies are not suitable for use in Region C. Potentially feasible strategies were evaluated in greater detail on an individual basis. The reviews of types of management strategies and the conclusions reached are discussed below. The Region C Water Planning Group evaluated some types of water management strategies not listed by the TWDB planning guidelines and subdivided some of the TWDB categories.

Water Conservation

Significant savings in water use due to water conservation are included in the projected demands for Region C adopted by the regional water planning group and the Texas Water Development Board. The projected municipal water demands for Region C include savings of 15 percent in per capita municipal water use for the region. Without the reduction in per capita demand assumed to result from conservation, the projected 2050 municipal demand in Region C would have been 2.5 million acre-feet per year, rather than the 2.1 million acre-feet per year adopted. Figure 5.1 shows the projected municipal water demand for Region C (a) with no conservation, (b) with conservation

Figure 5.1
Effect of Conservation on Projected Municipal Demand in Region C



savings resulting from the use of low-flow plumbing fixtures (as estimated by TWDB), and (c) with the conservation savings in the adopted water demand projections.

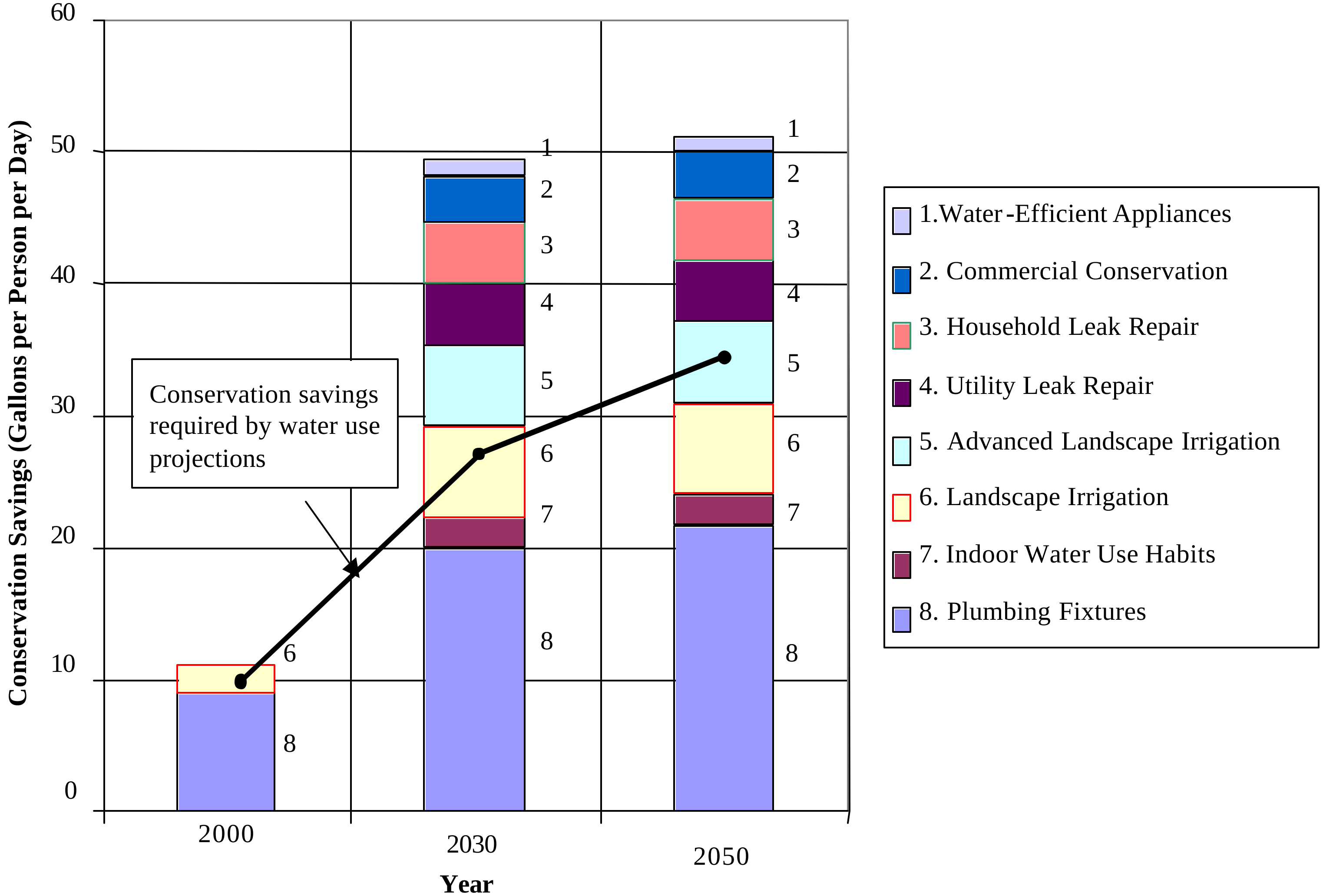
Figure 5.2 shows the projected water conservation savings in gallons per person per day of municipal water demand in the adopted Region C water demand projections. The figure also shows the savings in gallons of water use per person per day estimated by TWDB and the American Water Works Association[68, 69] for various water conservation measures.

The Region C water planning group adopted the following strategies to pursue water conservation:

- Take active measures to achieve the 15 percent water conservation savings included in the municipal demand projections. Measures would include:
    - Low-flow plumbing fixtures (required by state and federal law)
    - Outdoor water conservation measures
    - Improved indoor water use habits
    - Continued and expanded public education programs for water conservation
        - Education for policy makers
        - Education programs in the public schools.
- Assess the effectiveness and applicability of specific water conservation measures in Region C during the next five years.
- Encourage state funding for research on the effectiveness of water conservation programs and for support of education programs.

Many water suppliers in Region C and elsewhere in Texas have already implemented significant water conservation programs, including public education efforts, adoption of conservation-oriented rate structures, and other measures. In order to provide policy makers in the region and the state with the information needed to make informed decisions about water conservation efforts, the state of Texas should provide funding for evaluation of current water conservation programs. The goal of the evaluation should be to determine what conservation measures have proved to be effective in Region C and across Texas and what educational programs are needed to gain public support for successful implementation of effective measures. Since there is significant public concern about low-flow toilets, the evaluation should consider the effectiveness and

Figure 5.2
Potential Savings from Various Conservation Measures



public acceptance of these fixtures to determine whether they should continue to be required.

The state of Texas should also expand public funding for water conservation education in order to build a foundation for future water conservation efforts. An education program for policy makers, including water utility boards and operators, elected officials, and water supply corporation boards, will increase awareness of the importance of conservation efforts for these key officials. Expanded education efforts in the schools will build long-term conservation efforts.

The intent of the Region C Water Planning Group is to gather information during the next five-year planning cycle to provide a sound technical and scientific basis for decisions regarding the viability of current projections of conservation savings and the feasibility of achieving additional conservation savings. At this point, adoption of water conservation savings beyond the 15 percent reduction in municipal demands included in the current projections should be deferred until the next five-year update of the Region C water plan.

Summary of Decision: Continue efforts to implement water conservation, focusing on meeting the 15 percent reduction in municipal per capita use due to conservation included in the projections. Encourage state funding of conservation education and of efforts to evaluate and improve conservation programs. Use data developed to evaluate additional conservation savings in the next five-year planning cycle.

Emergency Management and Drought Response

In addition to its regional water planning provisions, Senate Bill One contained many other water management measures, including a requirement that water suppliers develop drought contingency and emergency demand management plans. Emergency management and drought response planning are intended to preserve water resources for the most essential uses when water supplies are threatened by an unexpected condition such as a multi-year drought, an unexpected increase in demands, or a water supply system component failure

Regional water supply plans under Senate Bill One are required to include potential trigger conditions for drought and emergency response measures and potential measures to be taken for each water source in the region. Appendix O includes a summary of current drought contingency and emergency management plans in Region C and discussion of potential triggers and response measures.

Drought contingency and emergency response measures are important planning tools for all water suppliers. They provide protection in the event of water supply shortages, but they are not a reliable source of additional supplies to meet growing demands. These measures were not considered as a water management strategy to provide additional supplies for Region C.

Summary of Decision: Continue efforts to implement drought contingency and emergency response planning, but do not treat these as water management strategies to provide additional long-term supplies.

Reuse of Wastewater

Reuse of treated wastewater is becoming an increasingly important source of water in Region C and across the state of Texas. The 1997 Texas Water Plan projected that the reuse of reclaimed water will provide as much water for the state as a whole by 2050 as new water sources [(11)]. There are a number of water reuse projects in operation in Region C, and many others are currently in the planning and permitting process. Reuse will serve a major role in meeting future water supply requirements for the region.

Direct reuse and indirect reuse have significantly different permitting requirements and potential applications. Direct reuse occurs when treated wastewater is delivered directly from a wastewater treatment plant to a water user, with no intervening discharge to waters of the state. Direct reuse requires a notification to the TNRCC, which is routinely accepted so long as requirements to protect public health are met. Direct reuse is most commonly used to supply water for landscape irrigation (especially golf courses) and industrial uses (especially cooling for steam electric power plants).

Indirect reuse occurs when treated wastewater is discharged to a stream or reservoir and is diverted downstream or out of the reservoir for reuse. The discharged water mixes with ambient water in the stream or reservoir as it travels to the point of diversion. Many of the water supplies within Region C have historically included return flows from treated wastewater as well as natural runoff. Indirect reuse can also occur when wastewater treatment plant effluent is injected into an aquifer and a water user withdraws groundwater from the aquifer. Indirect reuse can provide water supplies for municipal use, as well as irrigation and industrial supplies. Indirect reuse requires a permit from the TNRCC, and TNRCC's regulatory approach to such reuse permits is not entirely clear at this point.

Reuse has been a source of water supply in Region C for a number of years. Table 5.1 lists currently permitted or operating reuse projects in Region C. In addition to those listed, there may be other projects that were not identified in the planning process. Another form of reuse in Region C is the use of return flows in the watersheds of existing reservoirs. Many Region C reservoirs have permits in excess of firm yield, and return flows in the watersheds of those reservoirs provide a supplement to supply that can be used as long as the return flows continue. (These return flows are not generally considered to be a long-term reliable supply because they could be diverted for direct reuse projects.)

Table 5.1

Reuse Projects Currently Permitted or Underway in Region C

Project Description	**Type of Reuse**	**Purpose(s)**	**Use (Acre-Feet/Year)**	
			1996	**Maximum Expected**
Trinity River Authority - Las Colinas	Indirect	Irrigation/ Lake Level	2,433	8,000
Trinity River Authority - Waxahachie	Indirect	Municipal	0	5,129
Trinity River Authority - Ennis	Indirect	Municipal	0	3,696
Jacksboro Irrigation	Indirect	Irrigation	0	200
North Texas MWD - Lavon	Indirect	Municipal	23,345	35,943
Denton Power Plant	Direct	Steam Electric	135	500
UTRWD - Denton County FWSD #1	Direct	Golf Course Irrigation	0	2,240
Denison	Direct	Golf Course Irrigation	0	100
Country Club (Kaufman County)	Direct	Golf Course Irrigation	18	100
Crandall	Direct	Golf Course Irrigation	153	200
Azle	Direct	Golf Course Irrigation	123	100
Water Chase	Direct	Golf Course Irrigation	0	2,240
North Texas MWD Buffalo Creek	Direct	Golf Course Irrigation	0	1,120
Grapevine Direct Reuse	Direct	Golf Course Irrigation	0	2,000

A significant expansion of the supply available to Region C from reuse is currently in the developmental stages. A number of specific reuse projects have already been defined, and planning is in the early stages for other reuse projects. Potential applications for water reuse projects in Region C include:

- Landscape irrigation (parks, school grounds, freeway medians, golf courses, cemeteries, residential)
- Agricultural irrigation (crops, commercial nurseries)
- Industrial and power generation reuse (cooling, boiler feed, process water, heavy construction)
- Recreational/environmental uses (lakes and ponds, wetlands, stream flow augmentation)
- Supplementing potable water supplies (surface and groundwater supplies)

There are a number of benefits associated with water reuse as a water management strategy for Region C, including:

- Water reuse represents an effective water conservation measure.
- Water reuse provides a reliable source that remains available in a drought.
- Water reuse quantities increase as population increases.
- Water demands that can be met by reuse are typically near reuse sources.
- Water reuse is a viable way to defer and avoid construction of new surface water impoundments.

Some of the reuse projects in the planning and permitting process in Region C include the following:

- North Texas Municipal Water District is in the planning and permitting stage of increasing its existing reuse project to supplement the water supply in Lake Lavon with reclaimed water.
- Tarrant Regional Water District has completed planning and is in the process of developing scientific and technical data necessary to implement a project to supplement its water supply in the Richland Chambers and Cedar Creek reservoirs. The District has submitted an application for a water right permit to implement this strategy.

- Trinity River Authority has submitted an application to TNRCC for reuse of return flows from the Authority's wastewater treatment plants. The specific strategies for use of the reclaimed water are in the developmental stages.
- Upper Trinity Regional Water District has completed planning and is in the process of developing technical information to support an application to obtain a water right permit to reuse Chapman Lake water that UTRWD will import into the Trinity River Basin. This project would involve the reuse of the amount of Chapman Lake water imported, less conveyance losses.
- City of Dallas has included in its long-range water supply plan a water management strategy to reuse reclaimed water to supplement its water supply in Lake Ray Hubbard.
- City of Grapevine has submitted a water right permit application to reuse reclaimed water to supplement its supply in Lake Grapevine.
- The City of Irving has submitted an application to obtain a water right permit to reuse Chapman Lake water that it will import into the Trinity River Basin. The strategy for use of the reclaimed water is in the developmental stages.
- City of Denton is in the planning stage of developing a water reuse program to use reclaimed water from its wastewater treatment plant.
- The City of Lewisville is in the planning stage of developing a water reuse program to use reclaimed water from its wastewater treatment plant.
- The City of Fort Worth is in the planning stage of developing a water reuse program to use reclaimed water from its wastewater treatment plant.
- The City of Flower Mound is in the planning stage of developing a water reuse program to use reclaimed water from its wastewater treatment plant.
- The City of Weatherford is in the planning stage of developing a water reuse program to use reclaimed water from its wastewater treatment plant.

Specific management strategies involving reuse will be part of the Region C water plan. Reuse projects currently seeking permits and developing specific approaches to reuse, including those listed above and others, should be considered to be consistent with the Region C water plan. Reuse will be an important part of the future water supply for Region C and for Texas.

Summary of Decision: Incorporate water management strategies involving reuse as a major component of the long-term water supply for Region C. Encourage planning and implementation of additional reuse projects. Monitor legislation and regulatory actions related to reuse.

Reservoir System Operation

Region C already has a number of reservoir systems in operation. System operation is being used in several places in the region, including:

- North Texas Municipal Water District system
- Dallas Water Utilities system
- Tarrant Regional Water District system
- Lost Creek Lake/ Lake Jacksboro system
- Lake Weatherford/Lake Benbrook system
- Lake Waxahachie/Lake Bardwell System
- Lake Halbert/Navarro Mills Lake system

System operation can enhance yield, reduce pumping costs, and maintain acceptable quality. Most of the systems in Region C are operated primarily to reduce pumping costs. Tarrant Regional Water District has studied system operation to enhance yield, but this would conflict with TRWD's planned reuse project and would result in only a small gain in yield. Dallas Water Utilities operates its system to produce additional supply during high demand years in a drought, and this system yield gain is considered in the existing supply. The proposed Region C plan allows for system operation when needed or desired. However, system operation is not a likely source of significant additional supplies in Region C.

Summary of Decision: Include system operation for Dallas Water Utilities as a source of yield. System operation should be allowed when needed or desired but is not considered as a source of significant additional yield for Region C.

Connecting Existing Sources

There are several sources of water supply that are committed for use in Region C and will be connected and used between now and 2050. Plans for connecting existing sources include:

- Dallas Water Utilities connecting Lake Fork
- Irving connecting Lake Chapman

- Upper Trinity Regional Water District connecting Lake Chapman
- Gainesville connecting Moss Lake
- Weatherford connecting to Lake Benbrook
- Connecting two proposed Wise County power plants to Lake Bridgeport
- Connecting proposed Freestone County power plants to Richland-Chambers Reservoir
- Tarrant Regional Water District connection of Lake Benbrook and Eagle Mountain Lake
- Tarrant Regional Water District East Texas pipeline capacity expansion
- Dallas Water Utilities connecting Lake Palestine
- Grapevine direct reuse project
- Other projects.

Other existing supplies that could be connected for use in Region C include:

- Uncommitted Lake Texoma supply
- Corsicana's Richland-Chambers supply
- Duncanville, Cedar Hill, and remainder of Grand Prairie supply in Joe Pool Lake
- TXU Forest Grove supply in Cedar Creek Lake
- Mineral Wells Lake Mineral Wells supply
- Carrizo-Wilcox aquifer in Freestone County
- Carrizo-Wilcox aquifer in Navarro County
- Trinity River Authority/Ennis reuse project

Region C water suppliers could also connect to uncommitted supplies in other regions, but these supplies are not necessarily available for use in Region C.

Summary of Decision: Include connection of existing supplies as a major component of the Region C plan.

Reallocation of Reservoir Storage

There are two types of reallocation of existing reservoir storage. Reallocation among various water supply uses (municipal, industrial, irrigation, etc.) is a relatively simple matter. It is considered to be a minor water right amendment by TNRCC. This type of reallocation should be allowed at the discretion of the owner of the water right.

The more complex type of reallocation is to transfer water from other uses such as hydropower generation or flood control to water supply. This type of reallocation is more difficult to achieve. The most promising example of this type of reallocation in Region C is the reallocation of water in Lake Texoma from hydropower generation to municipal use, which will be evaluated as an individual water management strategy. Congress has authorized the Corps of Engineers to convert an additional 150,000 acre-feet of Lake Texoma storage from hydropower use to municipal water supply in Texas. Based on previous permits, that would provide slightly less than 150,000 acre-feet per year of firm yield for municipal water supply. Use of additional Lake Texoma water beyond the 150,000 acre-feet storage already authorized by Congress would require an Act of Congress. Use of substantial supplies from Lake Texoma in Region C would also require:

- Blending with water from other sources or desalination
- Interbasin transfer permit from the Red Basin to the Trinity Basin, where most of the Region C demands are centered.

Summary of Decision: Permit transfers among types of water use at the discretion of the water right holder. Conduct further studies of reallocation to municipal use of Lake Texoma water.

Voluntary Transfer of Water Rights

Water rights can be transferred from one owner to another. There are no specific water right transfers included in the Region C plan, but the plan allows for voluntary transfers of water rights as needed and as desired by the owners of the water rights.

Summary of Decision: Allow voluntary transfers as needed and desired by the owners of the water rights.

Voluntary Subordination of Water Rights

Voluntary subordination of water rights is most useful where senior hydropower rights limit reservoir yields. Very little additional yield is available in Region C by voluntary subordination. Voluntary subordination of water rights is not considered as a potential source of supply for Region C.

Summary of Decision: Do not include voluntary subordination of water rights as a source of water supply for Region C.

Enhancement of Yields of Existing Sources

Examples of ways to enhance the yield of existing sources might include the following:

- Artificial recharge of aquifers
- System operation of reservoirs
- Conjunctive use of surface water and groundwater

System operation of reservoirs is discussed separately above. Artificial recharge of aquifers has not been implemented or studied in Region C. If artificial recharge were to be implemented, it would probably be as part of an aquifer storage and recovery (ASR) program, which is discussed separately below. Some Region C water suppliers are already implementing the conjunctive use of groundwater and surface water. The most common form of conjunctive use is meeting peak needs with groundwater to reduce the required capacity of more expensive surface water supply systems. This does not increase the total supply available to the region.

Summary of Decision: Do not include enhancement of yields of existing sources as a source of water supply for Region C except as discussed above under reservoir system operation.

Control of Naturally Occurring Chlorides

The Brazos and Red River Basins have chloride concentrations in excess of desirable levels for municipal use. Chloride control has been studied in the Brazos and Red Basins and partially implemented in the Red Basin. Current plans call for additional chloride control in the Lake Kemp watershed in Region B. If that project is successful, additional chloride control in the Lake Texoma watershed is possible. However, it does not appear likely that chloride control will have a significant impact on chloride levels in Lake Texoma during the current planning horizon. Chloride control projects should continue to be monitored. TNRCC and the Railroad Commission should continue efforts to control chloride resulting from man-made conditions.

Summary of Decision: Monitor chloride control projects. Do not include control of naturally occurring chlorides as a source of water supply for Region C.

Interbasin Transfers

Table 5.2 shows the currently permitted interbasin transfers for Region C, which total approximately 650,000 acre-feet per year. Existing sources with the potential to provide increased supply through interbasin transfers include Lake Texoma, Lake Granbury, Lake Whitney, Toledo Bend Reservoir, Lake Sam Rayburn, Lake Palestine, and Oklahoma reservoirs. Potential reservoir sites that could provide increased water supply to Region C by interbasin transfers include Marvin Nichols I and II, George Parkhouse I and II, Lower Bois d'Arc Creek, Waters Bluff, South Bend, Black Cypress, Little Cypress, Marshall, Big Pine, Pecan Bayou, Rockland, and Ralph Hall. Development of adequate supplies for Region C and the other growing areas of Texas will require interbasin transfers.

Summary of Decision: Include interbasin transfers as management strategies in the Region C plan.

Table 5.2

Currently Permitted Interbasin Transfers to Region C Suppliers

Destination	Source	Source Basin	Destination Basin	Permitted Amount (Acre-Feet/Year)	Raw or Treated	Status
Gainesville	Moss Lake	Red	Trinity	4,500	Raw	Under Construction
North Texas MWD	Lake Texoma	Red	Trinity	84,000	Raw	Operating
North Texas MWD	Lake Chapman [b]	Sulphur	Trinity	57,214	Raw	Operating
Irving	Lake Chapman [b]	Sulphur	Trinity	54,000	Raw	Partially Developed
Upper Trinity RWD	Lake Chapman [b]	Sulphur	Trinity	16,106	Raw	Partially Developed
Dallas	Lake Tawakoni	Sabine	Trinity	190,480	Raw	Operating
Dallas	Lake Fork	Sabine	Trinity	120,000	Raw	Not Yet Developed
Dallas	Lake Palestine	Neches	Trinity	114,337	Raw	Not Yet Developed
Athens [c]	Lake Athens	Neches	Trinity	8,500	Treated	Operating
Terrell	Lake Tawakoni	Sabine	Trinity	10,090	Raw	Operating
Notes:	a. Permit allows exportation of 84,000 acre-feet/year, with only 77,300 to be used in the Trinity Basin. The remainder is allocated to channel losses.					
	b. Lake Chapman was formerly Cooper Lake.					
	c. Most of Athens is in the Trinity Basin.					

Development of New Supplies

New supplies that might be developed for Region C include new reservoir sites and currently undeveloped groundwater supplies. Over the years, many new reservoirs have been considered as sources of water supply for Region C. New reservoirs represent a large source of potential supply for Region C, but environmental impacts of reservoir development are a concern. Impacts of reservoir development include:

- Inundation of wetlands and other wildlife habitat, including bottomland hardwoods

- Changes to streamflows and streamflow patterns downstream
- Impacts on inflows to bays and estuaries
- Impacts on threatened and endangered species.

Table 5.3 presents basic information on 32 reservoir sites considered by the Region C Water Planning Group, within and outside of Region C. After a preliminary evaluation, many of these potential reservoir sites were eliminated from further study for one or more of the following reasons:

- Major conflicts at the reservoir site
- Insufficient yield and/or high cost
- Small yield considering the distance for water transmission
- Combination of environmental impacts, distance, and yield
- Supply needed locally and unlikely to be available for Region C.

Table 5.4 shows the reservoir sites eliminated from further study and the reasons that they were eliminated.

After the preliminary review, the regional water planning group retained nine potential reservoir sites as possible water management strategies to provide additional supply for Region C. Figure 5.3 shows the location of the nine potential reservoir sites. Five of the potential reservoir sites retained for further study are located in Region C:

- Lower Bois d'Arc Creek (formerly known as New Bonham)
- Tehuacana
- Muenster
- Ralph Hall
- Upper Bois d'Arc Creek.

The other four sites retained for further study are located in the Sulphur Basin in Region D:

- George Parkhouse I (South)
- George Parkhouse II (North)

Potential New Reservoirs for Region C Water Supply

Name	Region	County	Basin	Stream	Yield in Acre-Feet/Year			Estimated Capital Cost			Year 2000	Approximate	Environmental Impacts					Interbasin	Region C	Comments
					Holding	With	Source	Previous	Base	1999 Cost	Cost per	Delivery	Acres	Wetland	Bottomland	Endangered	Other	Transfer	Entities	
					All Inflow	Releases*		Estimate	Year		Ac-Ft/Yr	Distance (Miles)	Flooded	Impacts	Hardwood	Species	Issues	Required?	Interested	
Tehuacana	**C**	**Freestone**	**Trinity**	**Tehuacana Creek**	**68,300**	**64,900****	**A, D**	**$113,121,000**	**1989**	**$196,402,000**	**$3,026**	**90**	**14,900**	**Moderate**	**Moderate**	**Low**	**Lignite**	**No**	**TRWD**	
Muenster	**C**	**Cooke**	**Trinity**	**Brushy Elm Creek**	**500**		**B**					**5**		**Low**	**Low**	**Low**		**No**	**Muenster**	
Roanoke	C	Denton	Trinity	Denton Creek	26,800		G					0		Moderate	Low	Low	Urban development	No	None	Yield is from increase to Lake Grapevine yield.
Upper Red Oak	C	Ellis	Trinity	Red Oak Creek		4,700	G					0		Moderate	Low	Low		No	None	
Lower Red Oak	C	Ellis	Trinity	Red Oak Creek		7,200	G					0		Moderate	Low	Low		No	None	
Boyd	C	Wise	Trinity	West Fork Trinity								0		Low	Low	Low		No	None	
Italy	C	Ellis	Trinity	Chambers Creek	56,000	7,200	A, G					10	12,900	Moderate	Low	Moderate	Downstream water rights	No	None	Yield limited by prior rights.
Tennessee Colony	C	Anderson/Freestone/ Henderson/Navarro	Trinity	Trinity River	300,100±	285,100**	A, D	$621,112,000	1989	$838,501,000	$2,941	100	85,100	High	High	Moderate	Lignite, mitigation land	No	None	
Lower Bois d'Arc Creek	**C**	**Fannin**	**Red**	**Bois d'Arc Creek**	**124,700**	**123,000**	**C**	**$95,961,000**	**1995**	**$114,846,000**	**$934**	**80**	**16,400**	**Moderate**	**Moderate**	**Low**	**National grassland**	**Yes**	**NTMWD**	
Upper Bois d'Arc Creek	**C**	**Fannin**	**Red**	**Bois d'Arc Creek**								**10**		**Low**	**Low**	**Low**		**No**	**Fannin Co.**	
Ralph Hall	**C**	**Fannin**	**Sulphur**	**North Sulphur River**								**15**		**Low**	**Low**	**Low**	**National grassland**	**Yes**	**Fannin Co.**	
Ringgold	B	Clay	Red	Little Wichita River	27,600		A, D					90	15,000	Low	Low	Low		Yes		
Big Pine	D	Lamar	Red	Big Pine Creek	35,900		A, D					120	5,100	Moderate	Moderate	Low		Yes	None	Yield includes diversions from Red River.
Pecan Bayou	D	Red River	Red	Pecan Bayou	82,000		A					130	16,200	Moderate	Low	Moderate		Yes	None	Yield includes diversions from Red River.
Parkhouse I (South)	**D**	**Delta/Hopkins**	**Sulphur**	**North Sulphur River**	**122,900**	**119,100**	**A, C, D**	**$167,598,000**	**1995**	**$186,034,000**	**$1,562**	**100**	**29,700**	**Moderate**	**Moderate**	**Low**	**Mitigation land**	**Yes**	**Several**	
Parkhouse II (North)	**D**	**Delta/Lamar**	**Sulphur**	**South Sulphur River**	**141,200**	**129,700**	**A, C, D**	**$112,095,000**	**1995**	**$126,667,000**	**$977**	**100**	**12,300**	**Moderate**	**Low**	**Low**	**Prime farmland**	**Yes**	**Several**	
Marvin Nichols I (North)	**D**	**Red River/Morris/ Titus**	**Sulphur**	**Sulphur River**	**641,700**	**619,100**	**A, C, D**	**$384,521,000**	**1995**	**$426,818,000**	**$689**	**130**	**62,100**	**High**	**High**	**Low**	**Lignite**	**Yes**	**Several**	
Marvin Nichols II (South)	**D**	**Morris/Titus**	**Sulphur**	**White Oak Creek**	**294,800**	**280,100****	**A**	**$191,081,000**	**1989**	**$250,316,000**	**$894**	**130**	**39,900**	**High**	**Moderate to high**	**Low**	**Mitigation land, oil wells**	**Yes**	**Several**	
Little Cypress	D	Marion/Upshur	Cypress	Little Cypress Bayou	129,000		A, D					150	14,000	High	Moderate	Moderate		Yes	None	
Upper Little Cypress	D	Upshur	Cypress	Little Cypress Bayou	71,700		A					130	24,500	High	Moderate	Moderate		Yes	None	
Black Cypress	D	Marion/Cass	Cypress	Black Cypress Bayou	192,000		A					150	32,200	High	High	Moderate		Yes	None	
Marshall	D	Marion/Upshur	Cypress	Little Cypress Bayou	284,100		A					150	32,300	High	Moderate	Moderate		Yes	None	
Waters Bluff	D	Smith/Upshur/Wood	Sabine	Sabine River	324,000	307,800**	A, F	$489,532,000	1998	$514,009,000	$1,670	120	36,400	High	High	High	Wildlife mangement area, wetland banks	Yes	None	
Carl Estes	D	Van Zandt	Sabine	Sabine River	94,000	89,300**	D, F	$373,815,000	1998	$392,506,000	$4,395	80	24,900	Moderate	Moderate	Moderate	Lignite	Yes	None	
Big Sandy	D	Wood	Sabine	Big Sandy Creek	46,600	44,300**	A, D, F	$82,818,000	1998	$86,959,000	$1,963	110	4,400	Moderate	Moderate to high	Moderate		Yes	None	
Carthage	D	Harrison/Panola/Rusk	Sabine	Sabine River	537,000	510,200**	A, F	$495,838,000	1998	$520,630,000	$1,020	160	41,200	High	High	High		Yes	None	
South Bend	G	Stephens/Young	Brazos	Brazos River	106,700		A, D					100	29,700	Moderate	Low	Moderate	Oil wells	Yes	None	Yield is increase to BRA system.
Bedias	H	Grimes/Madison/ Walker	Trinity	Bedias Creek	78,500	74,600**	D, H	$147,245,000	1989	$198,781,000	$2,665	170	24,700	Moderate	Low	Moderate		No	TRA	Not for Region C

Ponta	I	Cherokee/ Nacogdoches/Rusk	Neches	Angelina River	163,700		A					150	36,800	High	Moderate	Moderate		Yes	None	
Eastex	I	Cherokee	Neches	Mud Creek	85,500		A, D					140	10,000	Moderate	Moderate	Moderate		Yes	None	Has TNRCC permit.
Weches	I	Anderson/Cherokee	Neches	Neches River	193,000		A, D					140	33,100	High	High	Moderate		Yes	None	
Rockland	I	Angelina/Polk/Trinity	Neches	Neches River	555,400		A, D					200	101,100	High	High	Moderate to high	Timber	Yes	None	

Sources: A. Freese and Nichols, Inc., and Alan Plummer Associates, Inc.: *Regional Water Supply Plan,* prepared for the Tarrant County WCID #1 in conjunction with the Texas Water Development Board, Fort Worth, 1990.

B. Texas Water Development Board Yield Estimates.

C. Freese and Nichols, Inc.: *Preliminary Study of Sources of Additional Water Supply,* prepared for North Texas MWD, Fort Worth, 1996.

D. Texas Parks and Wildlife Department: *An Assessment of Direct Impacts to Wildlife Habitat from Future Water Development Projects,* Austin, 1990.

E. U.S. Fish and Wildlife Service: *Texas Bottomland Hardwood Preservation Program,* Albuquerque, 1984.

F. Freese and Nichols, Inc., Brown and Root, Inc., and LBG-Guyton Associates: *Comprehensive Sabine Watershed Management Plan,* prepared for Sabine River Authority of Texas in conjunction with the Texas Warer Development Board, Fort Worth, 1999.

G. Espey-Houston and Associates, Inc., Alan Plummer Associates, Inc., and Rone Engineering: *Regional Water Study for Ellis County and Southern Dallas County,* prepared for Trinity River Authority in conjunction with Texas Water Development Board, Austin, 1989.

H. Burns and McDonnell: *Bedias Project Inventory, Texas, Plan Formulation Working Document,* prepared for the U.S. Bureau of Reclamation, Kansas City, 1989.

Notes: * Releases are to allow full diversions for downstream water rights and to satisfy TWDB consensus criteria for instream flows. Releases were assumed to reduce yield by 5% if data were not available.

** Releases were assumed to reduce yield by 5% for these reservoirs.

+ Yield for Tennessee Colony does not include return flows.

Reservoirs shown in bold were retained for further study.

Table 5.4					
Reservoir Sites Eliminated from Further Study and Reasons for Eliminating Them					
Reservoir Site	**Reasons for Elimination**				
	Conflicts	**Yield/ Costs**	**Yield/ Distance**	**Yield/ Distance/ Impacts**	**Unavailable Supply**
Roanoke	X	X			
Upper Red Oak		X			
Lower Red Oak		X			
Boyd		X			
Italy		X			
Tennessee Colony	X				
Ringgold			X		X
Big Pine			X		
Pecan Bayou			X		
Little Cypress				X	
Upper Little Cypress				X	
Black Cypress				X	
Marshall				X	
Waters Bluff	X				
Carl Estes	X				
Big Sandy			X		
Carthage				X	
South Bend					X
Bedias			X		X
Ponta				X	
Eastex			X		
Weches				X	
Rockland				X	

- Marvin Nichols I (North)
- Marvin Nichols II (South).

Some parts of the region have groundwater resources that are not fully developed, and additional groundwater use is a possibility. According to past TWDB analyses, the largest available groundwater supplies are in the Carrizo-Wilcox aquifer in Freestone County.

Summary of Decision: Conduct additional studies of Upper Bois d'Arc Creek, Lower Bois d'Arc Creek, Tehuacana, Muenster, Ralph Hall, George Parkhouse I, George Parkhouse II, Marvin Nichols I, and Marvin Nichols II. Develop additional groundwater supplies where appropriate.

Brush Control

Brush control is the process of removing non-native brush from the banks along rivers and streams in order to reduce water consumption by vegetation and increase stream flows and groundwater availability. Studies and pilot projects on brush control in West Texas show promising results. The first large-scale projects are currently underway. Undertaking and maintaining brush control is expensive.

Brush control has not been studied extensively in the Region C area. None of the major streams in Region C has shown a decline in flow over time due to invasion of non-native plant species. Brush control does not seem to be promising as a large-scale management strategy for Region C. However, brush control may be a management strategy for localized areas within the region, especially as a means to help meet localized livestock water supply needs.

Summary of Decision: Allow for studies and localized pilot projects to further investigate brush control, and request state funding for these studies.

Precipitation Enhancement

Precipitation enhancement involves seeding clouds with silver iodide to promote rainfall. Such programs are generally located within areas where the rainfall is lower than in Region C. The impact of cloud seeding on rainfall is difficult to measure, but it is thought to increase the amount of rainfall received. The greatest benefits of cloud seeding occur during normal to wet years. The impacts of precipitation enhancement on streamflows and reservoir yields have not been studied. The benefits of cloud seeding are highly uncertain for this area. Due to the high cost of cloud seeding and the uncertainty of increased yield, precipitation enhancement should not be a large-scale water management strategy for Region C. However, there may be localized areas in Region C who might benefit from such a management strategy.

Summary of Decision: Do not include precipitation enhancement as a specific management strategy. Allow for studies and localized pilot projects to further investigate precipitation enhancement.

Desalination

The salinity of water in Lake Texoma and the Red River is too high for municipal use, and the water must be desalinated or blended with higher quality water in order to meet drinking water standards. The cost of desalination has decreased in recent years, and the process is being used more frequently. Desalination should be considered as a way to use supplies from Lake Texoma and the Red River.

Summary of Decision: Include desalination as a management strategy in order to utilize supplies from Lake Texoma and the Red River.

Water Right Cancellation

The TNRCC has the power to cancel water rights after ten years of non-use, but this involuntary cancellation authority has seldom been used. The water availability modeling studies being conducted across the state will determine the additional water supply that could be gained from water right cancellation. The Sulphur River Basin is the only Region C basin for which water availability modeling has been completed, and the modeling for the Sulphur Basin shows only a very small gain due to water right cancellation [(51)]. The modeling for the Trinity, Sabine, Red, and Brazos Basins will be completed after this plan is developed. Information on the yield gain from water right cancellation will be available for the update to the plan in 2005. Water right cancellation is not seen as a viable water management strategy to develop additional water supply for Region C.

Summary of Decision: Do not include water right cancellation as a source of water supply for Region C.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) involves storing excess water in aquifers and retrieving this water when needed. The water to be stored can be introduced through enhanced recharge or injected through a well into the aquifer. The excess water to be stored can be treated water or raw water with some pre-treatment.

ASR has the potential to store large volumes of water at lower costs than traditional surface storage. Other benefits of aquifer storage and recovery include elimination of evaporation losses, minimization of environmental impacts, and elimination of storage loss due to sedimentation. ASR requires suitable geological conditions for implementation and can cause contamination of groundwater. The water injected into the aquifer must be treated so that it will not cause damage to the existing groundwater system.

The Tarrant Regional Water District is currently studying ASR. It is premature to determine the suitability of ASR as a source of supply for Region C at this time. Studies of ASR should continue, and pilot projects should be implemented if the strategy appears to be promising.

Summary of Decision: Studies of ASR should continue, and pilot projects should be implemented if the strategy appears promising.

Other Measures - Renewal of Contracts

Many of the water suppliers in Region C purchase water from a major water provider or from another water supplier. TWDB guidelines for Senate Bill One planning efforts indicate that such purchased supplies should be assumed to cease to be available to the purchaser after the expiration of the existing contracts. Renewal of the contract is then treated as a specific management strategy that must be adopted by the regional water planning group. Renewal of contracts is a decision that will be made by the parties involved. In most cases in Region C, both the seller and the purchaser plan to renew existing contracts, and their long-term plans are based on the renewal of contracts. In general, contracts for the purchase of water in Region C will be assumed to be renewed upon their expiration.

Summary of Decision: Include the renewal of existing contracts as a major source of water supply in Region C.

Other Measures – Temporary Overdrafting

In many counties in Region C, the current use of groundwater exceeds TWDB's estimate of long-term reliable groundwater supplies. In order to reduce the demand on overused groundwater resources, water suppliers will need to develop alternate sources of supply. However, the development of alternate sources will take some time. Temporary overdrafting of some groundwater supplies will continue in order to provide water in the interim. Temporary overdrafting of surface water reservoirs may also occur on a short-term basis while water suppliers are connected to other supply sources.

Summary of Decision: Temporary overdrafting of groundwater resources and surface water reservoirs can be used as an interim measure while other water supplies are developed.

Other Measures – Groundwater Management Districts

Texas law allows for the establishment of groundwater management districts to help control the development and use of groundwater resources. Groundwater districts can control well size and use, well spacing, and groundwater pumping. There are currently no groundwater management districts in Region C, although there are many in other parts of the state. Groundwater districts may be an appropriate way to share a limited resource in areas where groundwater use exceeds or approaches the long-term reliable supply. The formation of such districts is a local decision, and they should be considered by water suppliers and government officials in areas of heavy groundwater use. Table 5.5 shows counties and aquifers in Region C where the current groundwater use exceeds TWDB's estimate of the long-term reliable groundwater supply.

Summary of Decision: Local water suppliers and government officials should consider the formation of groundwater management districts in areas of heavy groundwater use.

Table 5.5					
Areas in Which 1996 Groundwater Use Exceeds Texas Water Development Board Projections of Water Availability					
County	**Aquifer**	**River Basin (s)**	**1996 Use**	**Projected Availability in Acre-Feet per Year**	
			(Ac-Ft)	**2000**	**2050**
Cooke	Trinity	Red & Trinity	6,809	4,529	3,753
Denton	Trinity	Trinity	10,006	6,114	5,123
Denton	Woodbine	Trinity	1,845	1,010	1,010
Ellis	Woodbine	Trinity	2,656	1,832	1,832
Grayson	Trinity	Red & Trinity	9,325	3,434	3,088
Grayson	Woodbine	Red & Trinity	5,954	5,710	5,710
Kaufman	Nacatoch	Sabine & Trinity	249	184	184
Parker	Trinity	Trinity	5,500	2,633	2,172
Tarrant	Trinity	Trinity	14,616	4,996	4,996

Other Measures – Assumed Reallocation of Groundwater

As suppliers currently using groundwater convert to surface water supplies, which will happen in many parts of Region C, they may reduce their current use of groundwater. Although some suppliers will continue to use groundwater to meet a portion of their peak demand or to supply a part of their service area, many will eventually convert entirely to surface water supplies. The resulting decrease in groundwater use may make a portion of the limited groundwater supply available to other water suppliers. It should be emphasized that the water plan does not require a water supplier to change their use of groundwater supplies. Rather, the gradual decrease of groundwater use after a surface water supply is developed is a predicted result that is consistent with past experience in many cases.

Summary of Decision: In some cases, assume a gradual decrease in groundwater use as other supplies are made available and assume that groundwater supplies will become available to other water suppliers.

Other Measures - Wellhead Management

Wellhead management is a means to protect groundwater quality. It involves making an analysis of potential threats to water quality in the vicinity of wells and protecting water quality by regulations, zoning, land purchase, physical changes to the well, or other measures.

Summary of Decision: Wellhead protection is a potential tool for local suppliers to protect groundwater quality.

5.4 Methodology for Evaluating Water Management Strategies

The TWDB guidelines set forth certain factors that are to be considered by the regional water planning groups in the evaluation of water management strategies [(1)]:

- Evaluation of quantity, reliability, and cost of water delivered and treated
- Environmental factors including:
  - Environmental water needs
  - Wildlife habitat
  - Cultural resources
  - Bays and estuaries
- Impacts on other water resources
- Impacts on threats to agricultural and natural resources
- Other factors deemed relevant by the planning group
- Equitable comparison of all feasible strategies
- Consideration of interbasin transfer requirements in the Texas Water Code
- Consideration of third party social and economic impacts of voluntary redistributions of water.

This subsection discusses the specific evaluation factors selected by the Region C Water Planning Group for the potentially feasible water management strategies, the environmental evaluation of alternatives, and the development of costs. Additional details on the environmental evaluations, the development of costs, and the evaluation of strategies are included in various appendices.

Factors Considered in Evaluation

Table 5.6 sets out the factors specifically considered by the Region C Water Planning Group in the evaluation of potential water management strategies. Most factors are evaluated qualitatively, with a rating of low, medium, or high. The quantity of water made available and the unit cost of delivered and treated water are evaluated quantitatively. Consistency with plans of Region C water suppliers is an important evaluation criterion. It has always been the intent of the Region C Water Planning Group to build the Region C Water Plan on the existing plans of the water suppliers in the region, especially the major water providers. Appendix P includes the evaluation of the potentially feasible water management strategies for Region C.

Table 5.6
Factors Used to Evaluate Water Management Strategies for Region C
Quantity of Water Made Available
Reliability of Supply
Unit Cost of Delivered and Treated Water
Difficulty of Addressing Environmental Issues
- Instream Flows
- Bay and Estuary Flows
- Wildlife Habitat
- Cultural Resources
- Wetlands
- Water Quality
- Other
Impacts on Water Resources and Other Management Strategies
Impacts on Agricultural and Natural Resources
Consistency with Plans of Region C Water Suppliers
Consistency with Other Regions

Equitable comparison of all feasible strategies is not included as an explicit evaluation factor because it describes the way that the entire evaluation was conducted. Interbasin transfer requirements in the Texas Water Code were considered in the development of strategies. Consideration of third party social and economic impacts of voluntary redistributions of water was not included as a factor because voluntary redistributions of water were not considered as management strategies.

Environmental Evaluation

Appendix Q contains more detailed information on the environmental evaluation of the management strategies. Existing information was used to assign a high, moderate, or low rating in terms of the difficulty of avoidance or mitigation for each of the environmental categories listed in Table 5.6 for each water management strategy. These evaluations were summarized in an overall environmental evaluation for the strategy. Certain management strategies were evaluated as a category rather than individually because their environmental effects do not vary greatly. Examples of evaluation by category include renewal of existing contracts for water, development of new wells in aquifers with additional water available, and temporary overdrafting of aquifers.

Costs of Water Management Strategies

Appendix R contains more detailed information on the development of cost estimates for individual water management strategies. Existing cost estimates were used where available and updated to 1999 prices. Development of cost estimates followed guidelines provided by the Texas Water Development Board. The costs include a 30 percent allowance for engineering and contingencies for pipelines and a 35 percent engineering and contingency allowance for other projects.

Recommended Water Management Strategies

The Texas Water Development Board requires the regional water planning group to develop several tables dealing with potential and recommended water management strategies. These tables are included in the following appendices:

- Appendix S – Texas Water Development Board Table 11 - potential water management strategies
- Appendix T – Texas Water Development Board Table 12 - recommended water management strategies by water user group
- Appendix U – Texas Water Development Board Table 13 – recommended water management strategies by major water provider

- Appendix V – demands, existing supplies, and supplies from recommended strategies by water user group and major water provider.

Appendix V presents the clearest picture of how the plan addresses the projected demands of each water user group.

5.5 Recommended Water Management Strategies for Major Water Providers

The majority of the water supplied in Region C is provided by the five major water providers in the region: Dallas Water Utilities, Tarrant Regional Water District, North Texas Municipal Water District, Fort Worth, and Trinity River Authority. These five entities will continue to provide the majority of the water supply for Region C through 2050, and they will also develop most of the new supply developed in that time period. Other suppliers, such as the Upper Trinity Regional Water District, are increasing the amount of water they supply and may join the five listed above as major water providers in the next few years.

Regional Supplies - Marvin Nichols I Reservoir

The proposed Marvin Nichols I Reservoir is located on the Sulphur River in the Sulphur River Basin in Senate Bill One Planning Region D, the North East Texas Region. The reservoir is shown in Figure 5.3. Appendix W summarizes the analysis conducted for potential new reservoirs that might provide water for Region C. That analysis led to the recommended development of three new reservoirs for water supply in Region C: Marvin Nichols I, Muenster, and Lower Bois d'Arc Creek (formerly known as New Bonham). Three other reservoirs (Upper Bois d'Arc Creek, Ralph Hall, and Tehuacana) are recommended as potential alternative sources of supply that might be developed after 2030.

Marvin Nichols I Reservoir is by far the largest of these proposed new reservoirs, and it would provide 36 percent of the new supply planned to be developed or connected for the region. The estimated yield of Marvin Nichols I is 619,100 acre-feet per year after allowing for downstream water rights and environmental releases as required by the Texas Water Development Board's environmental flow criteria. Assuming that 20 percent of the yield is used to provide water in Region D and 80 percent is made available to Region C, Marvin Nichols I will provide 495,300 acre-feet per year of additional water supply for Region C. The water would be made available to Dallas Water Utilities, Tarrant Regional Water District, and North Texas Municipal Water District and through them to their customers (including Fort Worth and the Trinity River Authority). Irving and Dallas County Other demands would also be met from Marvin Nichols I Reservoir. It is possible that some other water suppliers with independent water supplies may choose to participate individually in the Marvin Nichols I project rather than buying water from the major water providers. Examples of such suppliers include Denton, Dallas County Park Cities Municipal Utility District, and Upper Trinity Regional Water District.

The Region C yield for Marvin Nichols I Reservoir (619,100 acre-feet per year) differs from the value given in the North East Texas Region's report, which is 550,842 acre-feet per year. The difference in yields is caused by different assumptions regarding the operation of the project:

- The North East Texas Region's yield of 550,842 acre-feet per year is based on the assumption that Marvin Nichols I will impound inflows only when Lake Wright Patman, a senior water right downstream, is full and spilling.

- Region C's yield of 619,100 acre-feet per year is based on the assumption that Marvin Nichols I could impound inflows so long as the ability to divert water from Lake Wright Patman is protected.

In effect, the yield used in this report assumes cooperative operation of Marvin Nichols I Reservoir and Lake Wright Patman. This cooperative operation will greatly increase the total yield available from the basin, which provides motivation for cooperation. The cooperative operation assumed in this report will require negotiations between the operators of Marvin Nichols I and the City of Texarkana, which controls water rights in Lake Wright Patman.

Over the next planning period, Region C and the North East Texas Region will continue to cooperate on studies leading to the development of Marvin Nichols I Reservoir. As part of this cooperative effort, the regions will examine potential operation of Marvin Nichols I Reservoir and reach agreement on a method of operation and the resulting yield.

Development of the Marvin Nichols I Reservoir will require cooperation between Region C and the North East Texas Region, and such cooperation has been discussed and support developed during the planning process. It would also require an interbasin transfer permit to bring the water from the Sulphur Basin to the Trinity Basin. The project would include a major water transmission system to bring the new supply to the Metroplex.

The proposed interbasin transfer from the Sulphur Basin to the Trinity Basin will require an analysis of the need for water in the basin of origin and the proposed receiving basin. According to figures developed in Senate Bill One planning by Region C and the North East Texas Region (Region D), the supplies available to Region D from Marvin Nichols I Reservoir will exceed the projected need for new supplies in the Sulphur Basin. As this report shows, the Trinity Basin in Region C is in need of substantial new supplies over the next 50 years. This need will be partially met by supplies from Marvin Nichols I Reservoir.

Table 5.7 shows the estimated cost of the reservoir and the water transmission facilities to deliver the water to Region C suppliers. The table also shows how the cost would be apportioned among the users of the supply. A portion of the Marvin Nichols I supply is designated to meet demands for Dallas County Other uses, which are projected to grow substantially through the planning period. Those demands may in fact be met through one of the existing major water providers. Table 5.7 is based on the assumption that Dallas Water Utilities share of the Marvin Nichols I supply will be delivered to Lake Lewisville, where it can be used to supply Dallas Water Utilities' and their customers including Upper Trinity Regional Water District and Denton. Independent participation in Marvin Nichols I by these suppliers is also a possibility. Irving's share of Marvin Nichols I Reservoir will also be delivered to Lake Lewisville.

As a major reservoir project, Marvin Nichols I will have a number of environmental impacts. Permitting the project and developing appropriate mitigation for the unavoidable impacts will require several years, and it is important that water suppliers in Region C and Region D start that process well in advance of the need for water from the project.

Table 5.7							
Summary of Capital Costs and Supplies for the Marvin Nichols I Reservoir Project - Based on 1999 Construction Costs -							
Part of Project	**Costs**	**Cost Apportioned to Users**					
		Region D	**Dallas WU**	**TRWD**	**NTMWD**	**Irving**	**Dallas Co. Other**
Dam and Reservoir	$426,818,000	$85,364,000	$77,169,000	$107,558,000	$112,679,000	$17,073,000	$26,975,000
Pump Stations (2) – Marvin Nichols I to Lavon (includes booster pump and intake structures)	$75,060,000	$0	$16,963,000	$23,644,000	$24,770,000	$3,753,000	$5,930,000
Pipeline – Marvin Nichols I to Lavon (2-120")	$684,110,000	$0	$154,608,000	$215,495,000	$225,756,000	$34,205,000	$54,045,000
Pump Station - Lavon to Dallas County	$5,061,000	$0	$0	$0	$0	$0	$5,061,000
Pipeline - Lavon to Dallas County (2-42”)	$28,410,000	$0	$0	$0	$0	$0	$28,410,000
Pump Station - Lavon to Lewisville	$29,186,000	$0	$11,150,000	$15,555,000	$0	$2,481,000	$0
Pipeline - Lavon to Lewisville (2-90”)	$175,087,000	$0	$66,883,000	$93,321,000	$0	$14,883,000	$0
Pump Station - Lewisville to Eagle Mountain	$29,565,000	$0	$0	$29,565,000	$0	$0	$0
Pipeline - Lewisville to Eagle Mountain (2-78”)	$139,393,000	$0	$0	$139,393,000	$0	$0	$0
Interest During Construction (Region C only)	$117,864,000	$0	$25,552,000	$48,835,000	$28,400,000	$5,661,000	$9,416,000
Total Costs	$1,710,554,000	$85,364,000	$352,326,000	$673,366,000	$391,605,000	$78,056,000	$129,837,000
Yield Available to Supplier (Ac-Ft/Yr)		123,800	112,000	156,000	163,300	25,000	39,000

Note: Pump station costs include local storage.

Water Management Strategies for Dallas Water Utilities

It is assumed that Dallas Water Utilities will renew contracts with its existing customers as they expire. Table 5.8 and Figure 5.4 show the current sources of supply for Dallas Water Utilities and the recommended water management strategies for development of additional supplies. The text below summarizes the existing sources included in Table 5.8. *Existing sources are in italics*:

- ***Lake Ray Hubbard.*** The yield of this existing source is from Appendix I.
- ***Lake Tawakoni.*** The yield of this existing source is from Appendix I.
- ***Lakes Ray Roberts/Lewisville.*** The yield of this existing source is from Appendix I.
- ***Elm Fork Channel Dams.*** The yield of this existing source is from Appendix I.
- ***Lake Grapevine.*** The yield of this existing source is from Appendix I.
- ***Elm Fork Term Permit.*** DWU has a ten-year term permit to use excess flows from the Elm Fork of the Trinity River when they occur. The yield of this existing source is from Appendix I.
- ***TXU Industrial.*** The yield of this existing source is from Appendix I.
- ***Additional Dry-Year Supply.*** DWU's existing permits allow overdrafting of several of their lakes. The overdrafting can be used to meet demands in the driest years, and that is Dallas Water Utilities' planned mode of operation in a drought. The yield of this existing source is from Appendix I.

The recommended management strategies for development of additional water supplies for Dallas Water Utilities are summarized below:

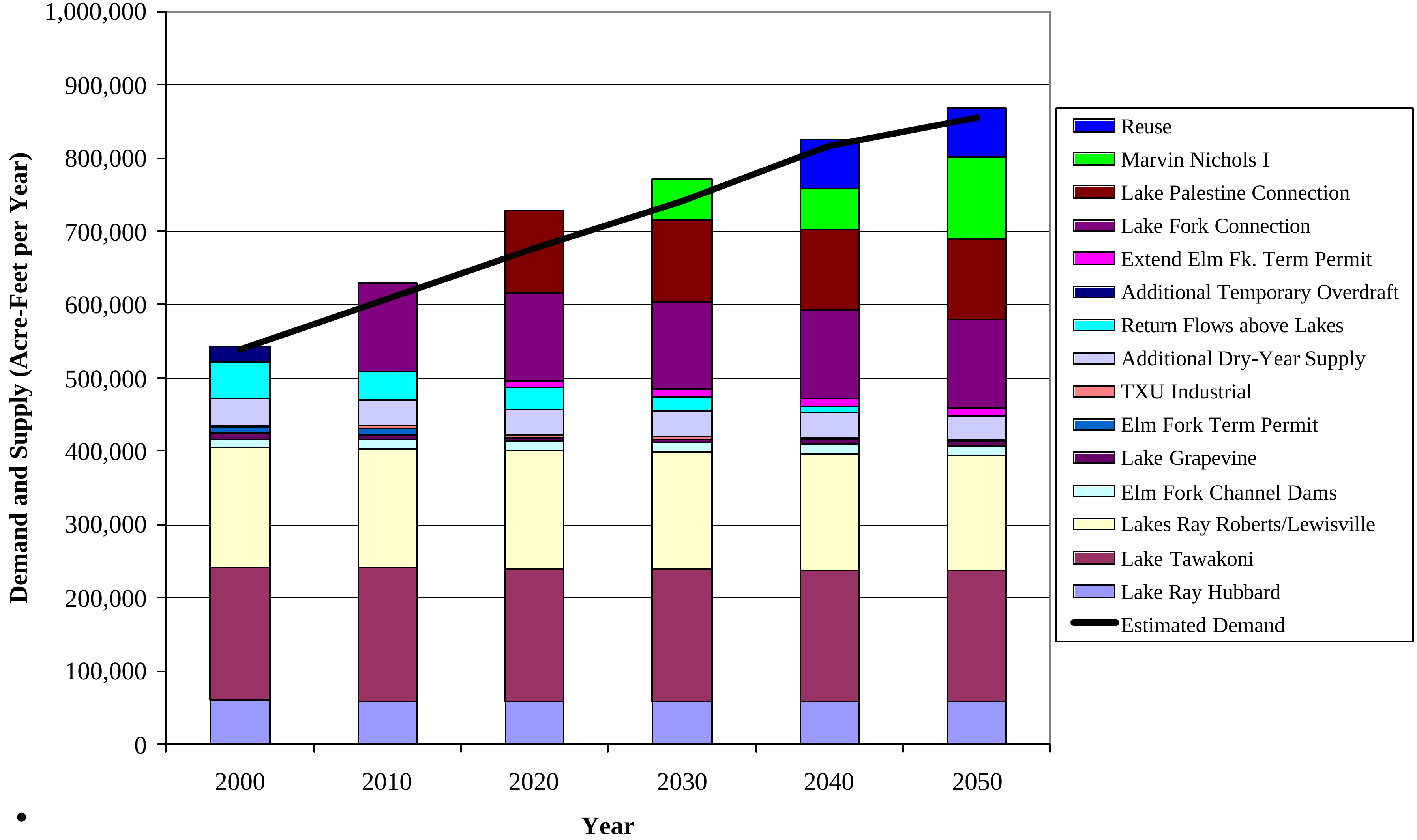
- **Return Flows above Lakes.** Under its existing permits, DWU can make use of return flows to its lakes. In 2000, those return flows are estimated to be about 50,000 acre-feet per year. However, the increasing pressure to reuse treated wastewater makes this source of supply uncertain in the long term. It is assumed that return flows to Dallas' lakes will decrease by 10,000 acre-feet per year per decade. One of the alternative management strategies for Dallas Water Utilities would be to contract with dischargers into the watersheds of its lakes to assure the continued availability of return flows.
- **Additional Temporary Overdraft.** DWU and its customers are currently developing additional delivery capacity to meet the temporary shortage in connected supplies. Until those facilities are completed, DWU will rely on temporary overdrafting of its existing supplies to meet needs.

Table 5.8						
Dallas Water Utilities Water Management Strategies						
Source	**Supply by Source and Demand in Acre-Feet per Year**					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**
Lake Ray Hubbard	*59,500*	*59,100*	*58,700*	*58,400*	*58,000*	*57,600*
Lake Tawakoni	*181,800*	*181,300*	*180,800*	*180,200*	*179,700*	*179,100*
Lakes Ray Roberts/Lewisville	*164,300*	*163,100*	*161,800*	*160,600*	*159,300*	*158,100*
Elm Fork Channel Dams	*11,200*	*11,200*	*11,200*	*11,200*	*11,200*	*11,200*
Lake Grapevine	*6,400*	*6,400*	*6,400*	*6,400*	*6,400*	*6,400*
Elm Fork Term Permit	*10,000*	*10,000*				
TXU Industrial	*2,915*	*2,915*	*2,915*	*2,915*	*2,915*	*2,915*
Additional Dry-Year Supply	*34,530*	*34,290*	*34,035*	*33,810*	*33,555*	*33,315*
Return Flows above Lakes	50,000	40,000	30,000	20,000	10,000	
Additional Temporary Overdraft	22,000					
Extend Elm Fork Term Permit			10,000	10,000	10,000	10,000
Lake Fork Connection		120,000	120,000	120,000	120,000	120,000
Lake Palestine Connection			111,500	110,900	110,200	109,600
Marvin Nichols I				56,000	56,000	112,000
Reuse Project					68,300	68,300
Total Connected Supply	**542,645**	**628,305**	**727,350**	**770,425**	**825,570**	**868,530**
Estimated Demand	538,477	606,517	675,625	741,669	816,204	855,485
Surplus (Shortage)	**4,168**	**21,788**	**51,725**	**28,756**	**9,366**	**13,045**

Notes: (a) *Supplies in italics are already available and connected.*
(b) Other options for Dallas Water Utilities include additional reuse and development of additional yield from return flows above its lakes.

- **Extend Elm Fork Term Permit.** DWU plans to extend its Elm Fork term permit when it expires.
- **Lake Fork Connection.** DWU is currently designing facilities to connect its existing Lake Fork water supply to its system.
- **Lake Palestine Connection.** DWU plans to develop facilities to connect its existing Lake Palestine water supply to its system.
- **Marvin Nichols I.** The Marvin Nichols I project would be jointly developed with other Region C and Region D water suppliers. It is assumed that transmission facilities to Region C will be developed in phases. The Dallas Water Utilities share of Marvin Nichols I is assumed to be delivered to Lake Lewisville.

Figure 5.4
Dallas Water Utilities Supply and Demand



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- **Reuse Project.** DWU plans to develop a reuse program including a project to supplement its water supply from its Central and/or Southside Wastewater Treatment Plants.

The **Total Connected Supply** is the total by decade of all of the existing and recommended supplies above. The **Estimated Demand** is for Dallas Water Utilities' existing customers assuming that all current contracts are renewed. The demand also assumes the addition of several customers in Denton County that will in the future be supplied by Upper Trinity Regional Water District, which gets part of its supply from Dallas Water Utilities. The **Surplus (Shortage)** is the difference between the supply and demand.

Other water supply options for Dallas Water Utilities include development of additional reuse and seeking additional yield from return flows above its lakes. Dallas Water Utilities has a great deal of return flow from its own treatment plants and could develop additional reuse projects. DWU could seek to develop a larger reliable supply from return flows above its lakes, perhaps by contracting with communities in the watersheds to continue discharging their return flows.

Table 5.9 shows the estimated capital costs (in 1999 dollars) for the water management strategies recommended for Dallas Water Utilities. The recommended strategies would develop additional supplies of 419,900 acre-feet per year at a total capital cost of $1,492,649,000 over the next 50 years. The estimated capital costs include expanding water treatment plant capacity, but they do not include the effects of inflation internal water distribution system improvements, the replacement of aging facilities, or upgrading treatment plants to meet changing regulatory requirements.

Water Management Strategies for Tarrant Regional Water District

The Tarrant Regional Water District (TRWD) bases its water supply planning on the safe yield of its water supply system. The safe yield is less than the firm yield because the safe yield reflects reduced demands that would leave a reserve supply available at the end of the critical period. (Firm yield is the yield with no reserve at the end of the critical period.) Thus, TRWD's safe yield planning provides an extra margin of safety for its water supply.

Table 5.9			
Capital Costs for Dallas Water Utilities Water Management Strategies			
- Based on 1999 Construction Costs -			
Project	**Approximate Year**	**Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Lake Fork Connection	2004	$288,000,000	120,000
Extend Elm Fork Permit	2010	$500,000	10,000
Lake Palestine Connection	2015	$332,600,000	109,600
Marvin Nichols I (DWU share)	2030	$352,326,000	112,000
Reuse Project	2040	$124,000,000	68,300
Treatment Plant Expansions	Various	$395,223,000	- [(a)]
Total		$1,492,649,000	419,900
Note: (a) Water treatment plant expansions do not provide additional supply but are needed to make use of supplies provided by other projects.			

It is assumed that Tarrant Regional Water District will renew contracts with its existing customers as they expire. Table 5.10 and Figure 5.5 show the current sources of supply for TRWD and the recommended water management strategies for development of additional supplies. The existing sources included in Table 5.10 are summarized below. *Existing sources are in italics*:

- ***West Fork System.*** The yield of this existing source is from Appendix I (West Fork less Bridgeport Local).
- ***Lake Bridgeport Local.*** The yield of this existing source is from Appendix I.
- ***Lake Benbrook.*** The yield of this existing source is from Appendix I.
- ***Cedar-Richland Connected.*** The supply available from of this existing source is from Appendix K (TWDB Table 6).

The recommended management strategies for development of additional water supplies for TRWD are summarized below:

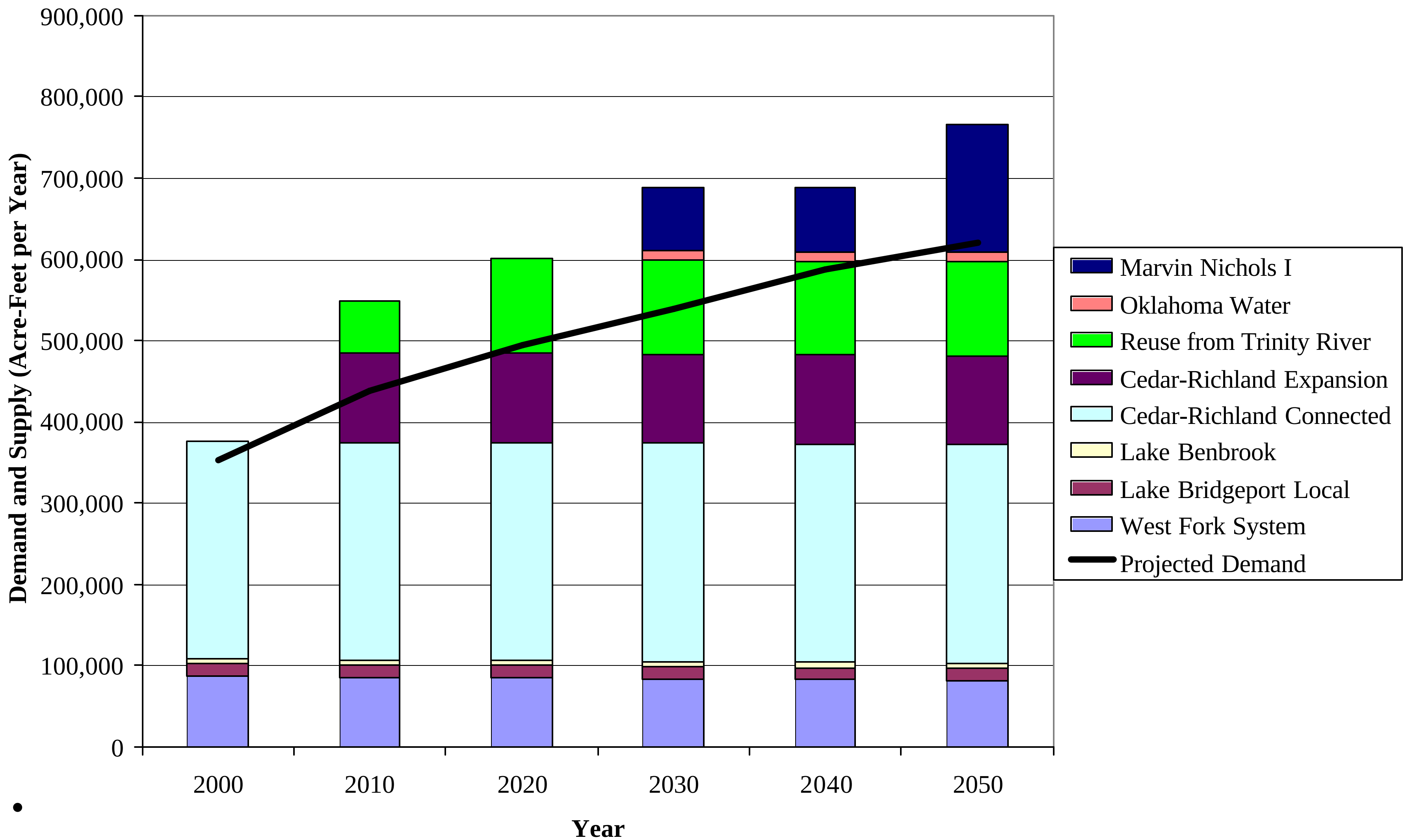
- **Cedar-Richland Capacity Expansion.** TRWD plans to expand its pump stations and build a new booster pump station in order to increase the delivery capacity from the Cedar-Richland system to Tarrant County.

Table 5.10						
Tarrant Regional Water District Recommended Water Management Strategies						
Source	**Supply by Source and Demand in Acre-Feet per Year**					
	2000	**2010**	**2020**	**2030**	**2040**	**2050**
West Fork System	*86,600*	*85,600*	*84,600*	*83,600*	*82,600*	*81,700*
Lake Bridgeport Local	*15,000*	*15,000*	*15,000*	*15,000*	*15,000*	*15,000*
Lake Benbrook	*6,833*	*6,833*	*6,600*	*6,400*	*6,200*	*6,000*
Cedar-Richland Connected	*267,392*	*267,962*	*268,445*	*268,742*	*268,779*	*268,809*
Cedar-Richland Capacity Expansion		110,000	110,000	110,000	110,000	110,000
Reuse from Trinity River		63,000	115,500	115,500	115,500	115,500
Oklahoma Water				12,000	12,000	12,000
Marvin Nichols I				78,000	78,000	156,000
Total Connected Supply	**375,825**	**548,395**	**600,145**	**689,242**	**688,079**	**765,009**
Estimated Demand	352,437	437,991	494,475	539,095	587,480	619,632
Firm Yield Surplus (Shortage)	**23,388**	**110,404**	**105,670**	**150,147**	**100,599**	**145,377**
Reduction to Supply for Safe Yield	22,600	57,020	66,588	77,371	87,893	98,509
Safe Yield Supply	**353,225**	**491,375**	**533,557**	**611,871**	**600,186**	**666,500**
Safe Yield Surplus (Shortage)	**788**	**53,384**	**39,082**	**72,776**	**12,706**	**46,868**

Notes: (a) *Water supplies in italics are already available and connected.*
(b) Other options for Tarrant Regional Water District include developing Lake Tehuacana and obtaining water from Lake Texoma.

- **West Fork Connection.** TRWD is planning to construct a transmission system connecting Lake Benbrook and Eagle Mountain Lake on the West Fork of the Trinity River. This will increase TRWD's system reliability and flexibility, as well as saving pumping costs by allowing use of the West Fork reservoirs for terminal storage.
- **Reuse from Trinity River.** TRWD is currently pursuing permitting to divert water from the Trinity River into Richland-Chambers and Cedar Creek Lakes to supplement the supply available from the lakes. This project will be developed in phases.
- **Third East Texas Pipeline.** In order to move additional supplies from East Texas to Tarrant County, TRWD will construct a third pipeline and associated pump stations.

Figure 5.5
Tarrant Regional Water District Supply and Demand



- **Marvin Nichols I.** The Marvin Nichols I project would be jointly developed with other Region C and Region D water suppliers. It is assumed that transmission facilities to Region C will be developed in phases.

The **Total Connected Supply** is the total by decade of all of the existing and recommended supplies above. The **Estimated Demand** is for TRWD's existing customers assuming that all current contracts are renewed. The demand also assumes the addition of customers in Parker County and Wise County who are planning to develop regional surface water systems and the addition of some steam electric power water users. The **Firm Yield Surplus (Shortage)** is the difference between the firm yield supply and the demand. The **Reduction to Supply for Safe Yield** is the difference between the firm yield supply (used for Senate Bill 1 planning) and the safe yield supply that TRWD prefers to use. The amount is based on safe yields in the 1999 *Water Management Plan* developed for Tarrant Regional Water District by HDR Engineering, Inc [41]. The **Safe Yield Supply** is the total connected supply minus the reduction to supply for safe yield. The **Safe Yield Surplus (Shortage)** is the difference between the safe yield supply and the estimated demand.

Other water supply options for Tarrant Regional Water District include developing Lake Tehuacana and obtaining water from Lake Texoma.

Table 5.11 shows the estimated capital costs (in 1999 dollars) for the water management strategies recommended for TRWD, including the development of the West Fork Connection. (The West Fork Connection does not develop any additional supplies, but it does improve the flexibility of TRWD's water delivery system.) The recommended strategies would develop 393,500 acre-feet per year of additional supplies at a total capital cost of $1,167,652,000 over the next 50 years. The estimated capital cost does not include the effects of inflation or replacement of aging facilities.

Water Management Strategies for North Texas Municipal Water District

Table 5.12 and Figure 5.6 show the current sources of supply for North Texas Municipal Water District and the recommended water management strategies for development of additional supplies. The text below summarizes the existing sources included in Table 5.12. *Existing sources are in italics:*

Table 5.11			
Capital Costs for Tarrant Regional Water District Water Management Strategies			
- Based on 1999 Construction Costs -			
Project	**Approximate Year**	**Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Cedar - Richland Pipeline Capacity Expansion	2005	$24,681,000	110,000
West Fork Connection	2010	$60,539,000	- (a)
Trinity River Reuse	2010	$75,168,000	115,500
Oklahoma Water	2010	$99,931,000	12,000
Third East Texas Pipeline	2015	$233,967,000	- (b)
Marvin Nichols I	2030	$673,366,000	156,000
Total		$1,167,652,000	393,500

Notes: (a) This project does not provide additional water supplies, but it does provide flexibility in the TRWD System.
(b) This project delivers the supply developed by the Trinity River Reuse project.

- ***Lake Lavon.*** The yield of this existing source is from Appendix I.
- ***Lake Texoma.*** The yield of this existing source is from Appendix I.
- ***Lake Chapman.*** The yield of this existing source is from Appendix I.
- ***Current Reuse.*** This is NTMWD's current permit for reuse as given in Appendix I. The permitted reuse equals the permitted wastewater discharge from the Wilson Creek Wastewater Treatment Plant in the Lake Lavon watershed.

The recommended management strategies for the development of additional water supplies for the North Texas Municipal Water District are summarized below:

- **Future Additional Reuse.** NTMWD plans to expand the Wilson Creek Wastewater Treatment Plant in the Lake Lavon Watershed from 32 mgd to 64 mgd and to apply for a permit to reuse the additional flow. It is assumed that the plant will reach a discharge of 64 mgd by 2030.
- **Additional Texoma Water.** NTMWD could obtain some additional water rights from Lake Texoma and use its existing water transmission facilities to deliver water to Lake Lavon. This would require conversion of water from hydropower use to municipal use by the Corps of Engineers and obtaining a Texas water right (including interbasin transfer).

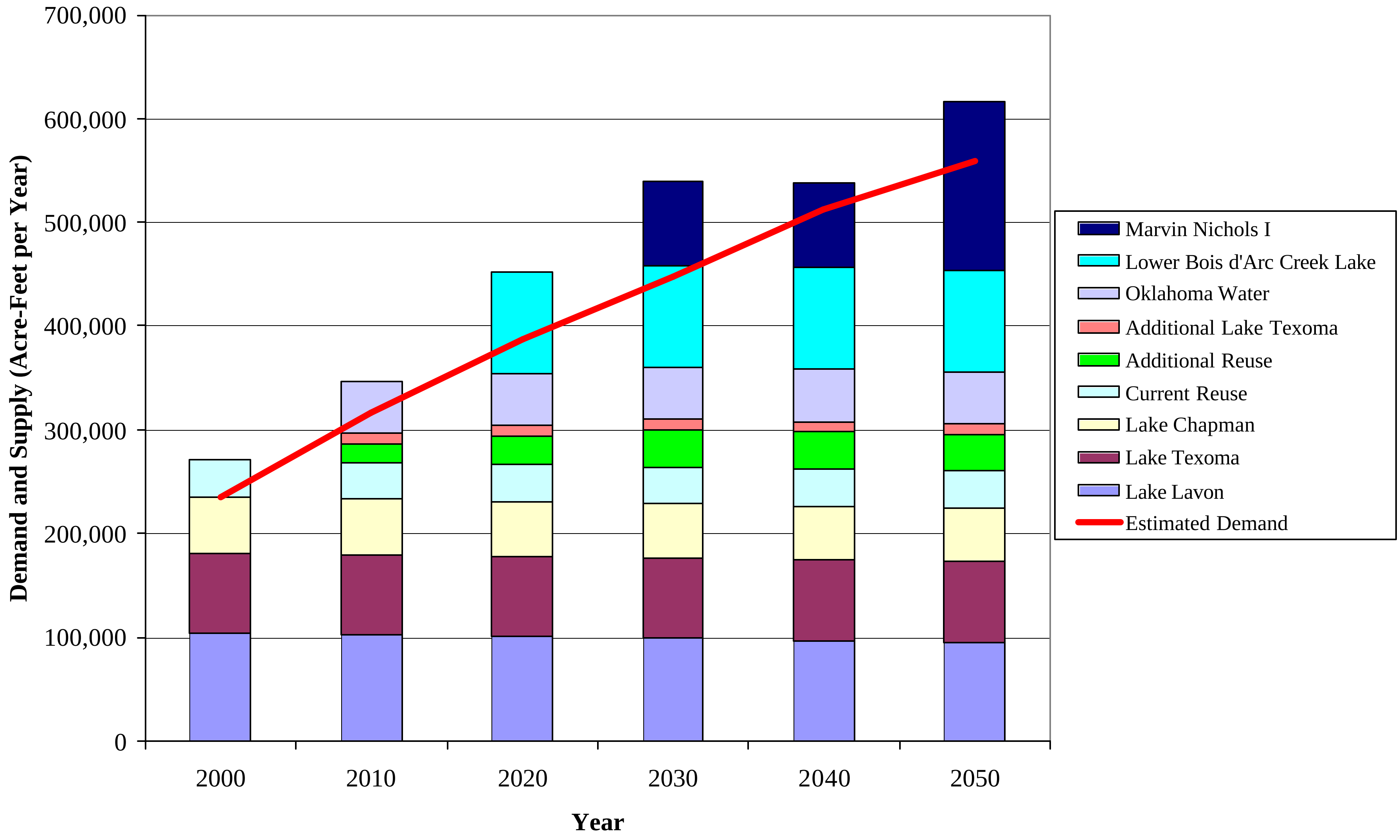
Table 5.12						
North Texas Municipal Water District Recommended Water Management Strategies						
Source	Supply by Source and Demand in Acre-Feet per Year					
	2000	2010	2020	2030	2040	2050
Lake Lavon	*103,900*	*102,200*	*100,600*	*98,800*	*97,000*	*95,200*
Lake Texoma	*77,300*	*77,300*	*77,300*	*77,300*	*77,300*	*77,300*
Lake Chapman	*53,600*	*53,200*	*52,800*	*52,400*	*52,000*	*51,600*
Current Reuse	*35,925*	*35,925*	*35,925*	*35,925*	*35,925*	*35,925*
Future Additional Reuse		17,936	26,904	35,872	35,872	35,872
Additional Lake Texoma		10,000	10,000	10,000	10,000	10,000
Oklahoma Water		50,000	50,000	50,000	50,000	50,000
Lower Bois d'Arc Creek Lake			98,000	98,000	98,000	98,000
Marvin Nichols I				81,650	81,650	163,300
Total Connected Supply	**270,725**	**346,561**	**451,529**	**539,947**	**537,747**	**617,197**
Estimated Demand	234,884	316,092	387,346	448,164	512,509	560,043
Surplus (Shortage)	**35,841**	**30,469**	**64,183**	**91,783**	**25,238**	**57,154**

Notes: (a) *Water supplies in italics are already available and connected.*
(b) Other options for NTMWD include the development of substantial additional Lake Texoma supplies and extending the Lake Texoma pipeline to Lake Lavon.

- **Oklahoma Water.** NTMWD has been engaged in negotiations to purchase water from Oklahoma. This would require water transmission facilities to deliver the water to NTMWD.
- **Lower Bois d'Arc Creek Lake.** NTMWD has previously studied this source of supply (also known as New Bonham Reservoir). The assumption is that NTMWD would use 80 percent of the reservoir's yield of 123,000 acre-feet per year, leaving 25,000 acre-feet per year for local use in the area of the lake. This would require a water right and interbasin transfer permit from TNRCC and water transmission facilities as well as development of the dam and reservoir. Lower Bois d'Arc Creek Lake is shown in Figure 5.3.
- **Marvin Nichols I.** The Marvin Nichols I project would be jointly developed with other Region C and Region D water suppliers. It is assumed that transmission facilities to Region C would be developed in two phases.

The **Total Connected Supply** is the total by decade of all of the existing and recommended supplies above. The **Estimated Demand** is for North Texas Municipal Water Districts' existing customers. The demand also assumes the addition of Little Elm and Prosper as customers of NTMWD, with Prosper also purchasing water from Upper

Figure 5.6
North Texas Municipal Water District Supply and Demand



Trinity Regional Water District. The **Surplus (Shortage)** is the difference between supply and demand.

Other water supply options for North Texas Municipal Water District include developing substantial additional Lake Texoma water. Any substantial increase to use from Lake Texoma would require:

- Conversion of hydropower storage in Lake Texoma to municipal use by the Corps of Engineers.
- A TNRCC permit, including interbasin transfer
- Development of transmission facilities
- Development of desalination treatment facilities.

The development of supplies for the North Texas Municipal Water District from the proposed Lower Bois d'Arc Creek Lake and from additional use of Lake Texoma water will require interbasin transfer water rights from TNRCC. To get an interbasin transfer water right, it is necessary to develop information on the need for water in the basin of origin and the proposed receiving basin. It is difficult to make a detailed analysis of water supplies and needs in the Red River Basin because the basin includes parts of Senate Bill One Planning Regions A, B, C, and D. However, Lake Texoma and Lower Bois d'Arc Creek Lake are most likely to serve Red River Basin needs in counties near the lake - Fannin, Grayson and Lamar. The part of the yield proposed to be left for local use from Lake Texoma and Lower Bois d'Arc Creek Lake exceeds the projected need for new supplies in those counties. As this report shows, the Trinity Basin in Region C is in need of substantial new supplies over the next 50 years. This need can be partially met by supplies from Lake Texoma and Lower Bois d'Arc Creek Lake.

North Texas Municipal Water District could also increase its yield by extending its pipeline leading from Lake Texoma to the Lake Lavon watershed. NTMWD's permit to use water from Lake Texoma includes an allowance of 6,700 acre-feet per year for transmission losses. The losses occur because water pumped from Lake Texoma is released into Sister Grove Creek in the Lake Lavon watershed and allowed to flow to Lake Lavon. NTMWD could study the actual losses in the creek to see if the allowance for channel losses is valid. If the allowance is excessive, NTMWD could seek the right to use the water. If the losses are real, NTMWD might extend its existing pipeline to

Lake Lavon to eliminate the channel losses and make an additional 6,700 acre-feet per year available.

Table 5.13 shows the estimated capital costs (in 1999 dollars) for the water management strategies recommended for the North Texas Municipal Water District.

Table 5.13
Capital Costs for North Texas Municipal Water District Water Management Strategies
- Based on 1999 Construction Costs -

Project	Approximate Year	Capital Cost		Additional 2050 Supply (Acre-Feet/Year)
Future Additional Reuse	2005	$1,000,000	(a)	35,900
Water Treatment Plant Expansions and Treated Water Transmission System Improvements	Various	$801,455,000		- (b)
Additional Lake Texoma	2006	$5,286,000	(c)	10,000
Oklahoma Water	2007	$68,777,000		50,000
Lower Bois d'Arc Creek Lake and Transmission system	2014	$167,324,000	(d)	98,000
Marvin Nichols I	2030	$391,605,000		163,300
Total		$1,435,447,000		357,200

Notes:
(a) The cost for future additional reuse does not include construction costs for wastewater treatment plant expansions, which would have to be built anyway.
(b) Water treatment plant expansions and treated water transmission system improvements do not provide additional supply but are needed to make use of supplies provided by other projects.
(c) Facilities are already constructed.
(d) This represents cost to NTMWD. It is assumed that approximately 20% of the total reservoir cost will be assumed by local interests in Fannin County.

Water Management Strategies for Fort Worth

The City of Fort Worth obtains essentially all of its raw water from the Tarrant Regional Water District. Fort Worth provides treated water for its citizens and a number of water suppliers in Tarrant County and surrounding counties. Fort Worth water management strategies include renewing existing contracts with its water customers as they expire and developing additional treatment capacity as needed. The estimated capital costs for Fort Worth's water treatment plant expansions between now and 2050 total $221,475,000. Fort Worth is also in the planning stages of developing potential reuse projects for its return flows of treated wastewater.

Water Management Strategies for Trinity River Authority

In Region C, the Trinity River Authority needs to develop additional supplies for its Tarrant County Water Supply Project and the Ellis County Water Project. The Tarrant County Water Project uses raw water supplied by Tarrant Regional Water District and provides treated water to Bedford, Colleyville, Euless, Grapevine, and North Richland Hills in northeast Tarrant County. TRA will need to expand its water treatment plant capacity and increase raw and treated water pumping capacity for this system. The Ellis County Water Project will also use raw water from Tarrant Regional Water District to supply users in Ellis County. Current plans call for TRA to construct additional pipelines to deliver water to users in Ellis County.

Other Trinity River Authority water supply efforts in Region C include Lake Bardwell, Joe Pool Lake, Navarro Mills Lake, treated water sales to Coppell and Grand Prairie, and several indirect reuse projects. There are no recommended management strategies for TRA associated with these projects. TRA has submitted an application to TNRCC for reuse of return flows from the Authority's wastewater treatment plants. The specific strategies for use of the reclaimed water include the following:

- Additional reuse for golf course and landscape irrigation in the Las Colinas area (7,000 acre-feet per year)
- Reuse for steam electric power generation in Dallas and Ellis Counties (23,000 acre-feet per year)
- Reuse for golf course and landscape irrigation in Denton and Tarrant Counties (7,500 acre-feet per year)
- Reuse through Lake Grapevine and Joe Pool Lake for Dallas County Other use (44,000 acre-feet per year).

Table 5.14 shows the estimated capital costs for the TRA water management strategies.

5.6 Discussion of Management Strategies by County

Appendix V includes a summary of the projected demands, current supplies, and recommended water management strategies to provide additional supplies by water user group. The recommended strategies for each county in Region C are summarized below.

Table 5.14 Capital Costs for Trinity River Authority Water Management Strategies - Based on 1999 Construction Costs -			
Project	**Capital Cost**	**Additional 2050 Supply (Acre-Feet per Year)**	
Tarrant County Water Project	$52,785,000	0	(a)
Plant and Pump Station Expansions			
Ellis County Water Project	$65,945,000	0	(a)
Pipelines and Pump Stations			
TRA Effluent Reuse Projects	$47,351,000	81,500	
Total	$166,081,000	81,500	

Note: (a) These water treatment plant expansions, pipelines, and pump stations do not make additional supplies available to the region but are needed to make use of supplies already developed.

Collin County

Table 5.15 presents a summary of the projected need for additional supplies, the current sources, and the sources of additional supply for each water user group in Collin County. The North Texas Municipal Water District supplies most of the water used in Collin County, and this will continue to be the case in the future. Water user groups that currently get water from NTMWD will use NTMWD to meet future increases to their needs. Water suppliers that will obtain additional water from sources other than NTMWD include the following:

- Blue Ridge will add new wells and use the Woodbine aquifer to meet its slight increase in demand.
- Celina will overdraft the Trinity aquifer in 2000 and will be supplied by Upper Trinity Regional Water District in 2010 and thereafter.

Table 5.15			
Recommended Management Strategies for Collin County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Allen	18,020	North Texas MWD	North Texas MWD
Anna	0	Trinity aquifer	None
Blue Ridge	24	Woodbine aquifer	- Add new well & overdraft Woodbine aquifer (2000) - Reallocate Woodbine aquifer (2010-2050)
Celina	8,297	Trinity aquifer Woodbine aquifer	- Overdraft Trinity aquifer (2000) - UTRWD - Lake Chapman, reuse, & DWU (2010-2050)
Dallas (part)	1,708	DWU	DWU
Fairview	973	North Texas MWD	North Texas MWD
Farmersville	643	North Texas MWD	North Texas MWD
Frisco (part)	45,157	North Texas MWD	North Texas MWD
Garland (part)	4	North Texas MWD	North Texas MWD
Lucas	829	North Texas MWD	North Texas MWD
McKinney	46,021	North Texas MWD	North Texas MWD
Melissa	76	Woodbine aquifer North Texas MWD	North Texas MWD
Murphy	2,014	North Texas MWD	North Texas MWD
New Hope	50	North Texas MWD	North Texas MWD
Parker	5,746	North Texas MWD	North Texas MWD
Plano (part)	42,371	North Texas MWD	North Texas MWD
Princeton	625	North Texas MWD	North Texas MWD
Prosper	5,349	Woodbine aquifer	- Overdraft Woodbine aquifer (2000) - North Texas MWD (2010-2050) - UTRWD - Lake Chapman, reuse, & DWU (2010-2050)
Richardson (part)	2,761	North Texas MWD	North Texas MWD
Royse City (part)	103	North Texas MWD	North Texas MWD
Sachse (part)	87	North Texas MWD	North Texas MWD

Table 5.15, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Wylie (part)	5,839	North Texas MWD	North Texas MWD
County-Other	17,456	Trinity aquifer Woodbine aquifer North Texas MWD	North Texas MWD
Manufacturing	2,069	Woodbine aquifer North Texas MWD	North Texas MWD
Steam Electric Power	7,102	Trinity aquifer North Texas MWD	- Reuse from NTMWD wastewater
Mining	0	Other local supplies	None
Irrigation	0	Irrigation local supplies	None
Livestock	0	Other aquifer Livestock local supplies	None

- The small part of Dallas in Collin County will continue to be supplied by Dallas Water Utilities.
- Prosper will overdraft the Woodbine aquifer in 2000 and will be supplied by North Texas Municipal Water District and Upper Trinity Regional Water District in 2010 and thereafter.
- Steam electric power demands will be met by reuse.

Table 5.16 shows the estimated capital costs for Collin County water management strategies not covered under the major water providers.

Table 5.16		
Capital Costs for Recommended Water Management Strategies for Collin County Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
New Groundwater Well	$260,000	100
Reuse for Steam Electric Power	$14,111,000	7,200
Total	$14,371,000	7,300

Cooke County

The Trinity aquifer provides almost all of the current water use in Cooke County, but the current use from the aquifer is significantly greater than the estimated long-term reliable supply. Table 5.17 presents a summary of water management strategies to meet demands in Cooke County, which include the following:

- Development of a 1 mgd raw water pipeline and water treatment plant by Gainesville to make use of a portion of the city's raw water in Moss Lake.
- Construction of Muenster Lake and associated transmission and treatment facilities by the City of Muenster.
- Development of the Cooke County Water Supply System consisting of a raw water pipeline from Moss Lake, a treatment plant, and treated water pipelines to deliver water to users throughout the county.
- Supply from Upper Trinity Regional Water District for the City of Valley View and a portion of County Other.

Table 5.18 shows the estimated capital costs for the recommended water management strategies for Cooke County. Based on the current TWDB estimate of groundwater availability(38), it is assumed that the municipal water suppliers in the county will use 70 percent surface water and 30 percent groundwater, with groundwater used primarily to help meet peak demands. TWDB is scheduled to develop a groundwater availability model for the Trinity aquifer by 2004, and this model should give a better estimate of groundwater supplies in Cooke County. When this additional information is available, the plans for the Cooke County Water Supply System should be revisited and refined.

It should be noted that there is no way to force groundwater users to reduce pumping from the Trinity aquifer. However, if TWDB's current estimate of the long-term reliable supply from the aquifer is correct, users will find it necessary to find other supplies over time. The formation of a groundwater management district for Cooke County might be considered as a way to control use of this limited resource.

Table 5.17			
Recommended Management Strategies for Cooke County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Gainesville	2,715	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Moss Lake (2000 - 2050) - Moss Lake parallel pipeline (2010-2050)
Lindsay	88	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Cooke County water supply project - Moss Lake (2010-2050)
Muenster	172	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Muenster Lake (2010-2050) - Add new wells
Valley View	113	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Reallocate Trinity aquifer (2010-2020) - UTRWD - Lake Chapman and reuse (2030-2050)
County Other	690	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Add new wells & reallocate Woodbine aquifer (2010-2050) - Cooke County water supply project - Moss Lake (2010-2050) - UTRWD – Lake Chapman and reuse (2010-2050)
Manufacturing	464	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Moss Lake (2010-2050) - Muenster Lake (2010-2050)
Mining	89	Trinity aquifer Other local supplies	Overdraft Trinity aquifer (2000)
Irrigation	9	Trinity aquifer Irrigation local supply	- Overdraft Trinity aquifer (2000) - Reallocate Trinity aquifer (2010-2050)
Livestock	499	Trinity aquifer Livestock local supply	- Overdraft Trinity aquifer (2000) - Reallocate Trinity aquifer (2010 - 2050)

Table 5.18		
Capital Costs for Recommended Water Management Strategies for Cooke County Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Gainesville 1 MGD Pipeline and Treatment Plant	$3,937,000	1,100
Muenster Lake and Associated Facilities	$11,023,000	500
New Groundwater Wells	$635,000	100
Cooke County Water Supply Project	$26,785,000	1,100
Total	$42,380,000	2,800

Note: (a) Upper Trinity Regional Water District costs and supplies are listed in Denton County, Table 5.23.

Dallas County

Table 5.19 presents a summary of the anticipated shortages in the planning period, the current supplies, and the sources of additional supply for each water user group in Dallas County. Most of Dallas County's current demands are met by Dallas Water Utilities, with North Texas Municipal Water District also providing major supplies. They will continue to be the largest water providers in the county in the future. Along with additional supplies from DWU and NTMWD, other management strategies for Dallas County include the following:

- Connection of Irving's supply from Lake Chapman, which will bring about 50,000 acre-feet per year of additional raw water to Dallas County.
- Development of Grapevine's direct reuse project.
- Use of a portion of the Marvin Nichols I project to meet growing Dallas County Other demands.
- Development of reuse projects by Trinity River Authority to supply County Other and steam electric power demands.

Table 5.19			
Recommended Management Strategies for Dallas County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Addison	13,650	DWU	DWU
Balch Springs	3,597	DWU	DWU
Carrollton (part)	14,317	Trinity aquifer, DWU	DWU
Cedar Hill (part)	17,706	Trinity aquifer Woodbine aquifer DWU	DWU
Cockrell Hill	688	DWU	DWU
Combine (part)	20	DWU	DWU (thru Combine WSC)
Coppell	11,513	DWU	DWU
Dallas (part)	67,407	DWU	DWU
De Soto	18,039	Trinity aquifer DWU	DWU
Duncanville	9,361	DWU Joe Pool Lake	DWU
Farmers Branch	15,803	DWU	DWU
Garland (part)	19,708	North Texas MWD	North Texas MWD
Glenn Heights (part)	1,386	Woodbine aquifer DWU	DWU
Grand Prairie (part)	15,293	Trinity aquifer DWU TRWD	DWU
Grapevine (part)	10	Lake Grapevine	- DWU - Direct reuse
Highland Park	0	Lake Grapevine	None
Hutchins	2,129	DWU	DWU
Irving	70,026	DWU	- DWU (2000-2030) - Lake Chapman (2010-2050) - Marvin Nichols I (2030-2050) Alternatives: Oklahoma, reuse

Table 5.19, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Lancaster	5,156	Trinity aquifer, DWU	DWU
Lewisville (part)	534	DWU	DWU
Mesquite	19,371	North Texas MWD	North Texas MWD
Ovilla (part)	128	DWU	DWU (through Cedar Hill)
Richardson (part)	15,312	North Texas MWD	North Texas MWD
Rowlett (part)	7,466	North Texas MWD	North Texas MWD
Sachse (part)	2,633	North Texas MWD	North Texas MWD
Seagoville	4,280	DWU	DWU
Sunnyvale	1,233	North Texas MWD	North Texas MWD
University Park	0	Lake Grapevine	None
Wilmer	272	Trinity aquifer	- Overdraft Trinity aquifer (2000) - DWU (2010 - 2050)
County Other	119,173	Trinity aquifer Woodbine aquifer Other aquifer DWU North Texas MWD	- DWU (2000-2050) - Dallas County Marvin Nichols I (2030-2050) - TRA reuse (2010-2050)
Manufacturing	9,255	Trinity aquifer Woodbine aquifer DWU Lake Grapevine North Texas MWD	- North Texas MWD (2010-2050) - DWU (2000-2050) - Lake Chapman (2010 - 2050)
Steam Electric Power	17,978	Trinity aquifer DWU North Texas MWD	- North Texas MWD (2010-2050) - DWU (2000-2050) - TRA reuse (2020-2050)
Mining	4,981	Trinity aquifer Other local supply	- Overdraft Trinity aquifer (2000 - 2010) - DWU (2020-2050)
Irrigation	0	Reuse Other aquifer Irrigation local supplies	None
Livestock	0	Woodbine aquifer Livestock local supply	None

Table 5.20		
Capital Costs for Recommended Water Management Strategies for Dallas County Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Irving's Lake Chapman Supply	$97,500,000	48,800
Irving Marvin Nichols	$78,056,000	25,000
Dallas County Other Marvin Nichols	$129,837,000	39,000
Upper Trinity Regional Water District	- (c)	- (c)
Dallas County Other Treatment and Transmission (130 MGD)	$241,600,000	- (b)
Reuse for Steam Electric Power	$6,808,000	10,300
Total	$553,801,000	123,100

Notes:
(a) Irving's Lake Chapman supply facilities will make 48,800 acre-feet per year available to Irving in Dallas County and 14,600 acre-feet per year available to UTRWD in Denton County. Costs cover both supplies but do not include facilities already constructed.
(b) Treatment plant expansions do not make additional water available, but they are needed to make use of supplies developed by other projects
(c) UTRWD costs and supplies are listed in Denton County on Table 5.23.

The City of Irving intends to develop its own water supply. The alternative management strategies for Irving to accomplish this include:

- Use of Lake Chapman water. Irving is in the process of developing a pipeline to transfer water from Lake Chapman to Lake Lewisville. Until those facilities are complete, Irving will continue to rely on DWU for its existing supply.

- Marvin Nichols I. The Marvin Nichols project would be jointly developed with other Region C and Region D suppliers. It is assumed that transmission facilities to Region C will be developed in phases. Appropriate agreements with other entities need to be developed to accommodate storage and diversions.

- Oklahoma water. The Kiamichi River Basin in southeastern Oklahoma represents a potentially viable and economic source of supply for the City of Irving. Potential political hurdles make this supply uncertain. Therefore, Oklahoma water is considered an alternative source. Appropriate agreements with other entities would need to be developed to accommodate storage and diversions.

- Reuse. Irving plans to develop a reuse program for water originating in Lake Chapman. Indirect reuse of Irving's Lake Chapman water will require future

TNRCC authorization. The amount of water that will be available for reuse is uncertain at this time.

- Dallas Water Utilities. Irving may need to continue a contract with Dallas Water Utilities to provide for storage and treatment of water in Lake Lewisville for any newly developed sources and for use of DWU water when Lake Chapman or other sources are unavailable. Irving may also need to participate with DWU or others in expanding water treatment plant capacity.

Irving is willing to commit to an appropriate share of the costs of whichever of the above management strategies are ultimately implemented.

Table 5.20 shows the estimated capital costs for the Dallas County water management strategies not associated with the major water providers.

Denton County

Current groundwater use from the Trinity and Woodbine aquifers in Denton County exceeds the estimated reliable long-term supply determined by the Texas Water Development Board [38]. Water suppliers in Denton County are increasing their use of surface water from the Upper Trinity Regional Water District and other sources. Water management strategies for Denton County include the following:

- Many water suppliers have already begun to purchase water from Upper Trinity Regional Water District or will begin to do so in the new future. UTRWD's sources of water include the following:
    - Raw water from Lake Chapman, delivered to Lake Lewisville through pipelines developed by Irving.
    - Raw water from reuse of the water delivered for UTRWD from Lake Chapman.
    - Raw water purchased from Dallas Water Utilities, including future supplies from the proposed Marvin Nichols I Reservoir.
- The City of Denton will provide its own water supply, using its existing raw water sources and purchasing additional raw water from Dallas Water Utilities.
- Dallas Water Utilities will continue to provide raw and treated water to water suppliers in Denton County. (Dallas Water Utilities is planning to connect their supply from Marvin Nichols I to Lake Lewisville. Renewal of contracts will require approval by Dallas City Council.)

- Fort Worth will continue to provide treated water to some suppliers in southwestern Denton County. (Renewal of contracts will require approval by Fort Worth City Council.)

- North Texas Municipal Water District will provide treated water to certain water suppliers in eastern Denton County.

- Reuse by UTRWD and TRA will supply demands for golf course and landscape irrigation.

- A reuse project will be developed by the City of Denton to supply increases to steam electric power demand.

A substantial portion of the water needed for Denton County will be supplied by raw and treated water sales from Dallas Water Utilities. DWU's current supplies for Denton County are provided from its share of the yields of Lake Ray Roberts and Lewisville Lake. As demands in Denton County and the part of Dallas County served by these lakes grow, additional supplies will be provided by delivering raw water to Lewisville Lake. The planned delivery of raw water from Chapman Lake to Lewisville Lake by Irving and Upper Trinity Regional Water District and the planned delivery from Marvin Nichols I Reservoir to Lewisville Lake by Dallas Water Utilities will provide needed supplies for Denton County. (See footnotes (f) and (g) in Table 5.21.) Table 5.21 is a summary of supply and demand for the Upper Trinity Regional Water District, which will provide water for many of the water user groups in Denton County.

Table 5.22 presents a summary of the anticipated needs during the planning period, the current supplies, and the sources of additional supply for each water user group in Denton County. Table 5.23 presents the estimated capital costs associated with water management strategies not covered under the major water providers.

Ellis County

Table 5.24 summarizes current supply sources, shortages with current supplies, and sources of additional supplies for Ellis County. Current use from the Woodbine aquifer in Ellis County exceeds TWDB's estimated long-term reliable supply [38]. Ellis County water suppliers have signed contracts with the Trinity River Authority to obtain raw

Table 5.21
Supply and Demand for Upper Trinity Regional Water District

Source	Supply by Source and Demand in Acre-Feet per Year					
	2000	2010	2020	2030	2040	2050
Dallas Water Utilities [(b)]	*13,702*	*25,752*	*46,970*	*0*	*0*	*0*
Denton [(c)]	*3,560*	*1,401*	*0*	*0*	*0*	*0*
Lake Chapman [(d)]	0	15,000	14,900	14,800	14,700	14,600
Reuse of Lake Chapman [(e)]	0	14,200	14,200	14,100	14,000	13,900
Renewed Contract Dallas Water Utilities [(f)]	0	0	0	68,800	73,500	76,400
Additional Dallas Water Utilities [(g)]	0	0	0	5,890	16,666	32,484
Total Connected Supply	16,967	56,353	76,070	103,590	118,866	137,384
Estimated Demand	16,967	38,610	70,329	97,286	112,537	125,696
Surplus (Shortage)	0	17,743	5,741	6,304	6,329	11,688

Notes:

(a) *Supplies in italics are already available and connected*.

(b) UTRWD has contracted with DWU for long-term raw water supply, the amount of which is equal to the needs of certain specified cities plus an additional 11,200 acre-feet per year (10 mgd) for other customers within UTRWD's service area. The values listed will be increased as necessary to meet the needs of the specified cities, subject to the terms of the contract.

(c) UTRWD has contracted to purchase excess raw water for an interim period from the City of Denton. Denton also supplies treated water to UTRWD for Sanger.

(d) UTRWD has a contract and permit to import water from Chapman Lake in the Sulphur River Basin to the Trinity River Basin. The infrastructure to deliver this supply to Denton County is scheduled to be completed in 2003 under contract with the City of Irving.

(e) UTRWD plans to obtain a permit to reuse treated effluent based on the water that the district will import from Chapman Lake.

(f) Renewed contract DWU represents an assumed renewal of the current contract and additional supply development by DWU. This additional water may come from existing local lakes (Lewisville and Ray Roberts), the proposed Marvin Nichols I Reservoir, other supply sources, or a combination thereof. The water from the Nichols project is to be delivered by pipeline into Ray Roberts Lake or Lewisville Lake. As provided elsewhere in this report, UTRWD may choose to participate directly in the Nichols project, in lieu of purchasing such additional water from DWU. UTRWD's contract with Dallas is currently limited to a total of 10 MGD to UTRWD for cities not specifically named in the contract. DWU has made no commitment for future service to cities not specifically named in the contract, and future service will require future city council action.

(g) Additional DWU represents supply from DWU in addition to the amount supplied under current contract provisions. This supply may be developed independently by UTRWD. UTRWD's contract with Dallas is currently limited to a total of 10 mgd to UTRWD for cities not specifically named in the contract. DWU has made no commitment for future service to cities not specifically named in the contract, and future service will require future city council action.

Table 5.22			
Recommended Management Strategies for Denton County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Argyle	4,060	Trinity aquifer UTRWD	UTRWD
Aubrey	1,229	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Bartonville	2,681	Trinity aquifer UTRWD	UTRWD
Carrollton (part)	13,976	Trinity aquifer DWU	DWU
Copper Canyon	1,501	Trinity aquifer UTRWD	UTRWD
Corinth	6,715	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Crossroads	2,964	UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Dallas (part)	1,254	DWU	DWU
Denton	35,269	Lake Lewisville Lake Ray Roberts DWU UTRWD	DWU
Double Oak	933	Trinity aquifer UTRWD	UTRWD
Flower Mound	31,448	DWU UTRWD	- UTRWD (2000-2050) - DWU (2000-2050)
Frisco (part)	387	North Texas MWD	North Texas MWD
Hebron	780	Woodbine aquifer	- Overdraft Woodbine aquifer (2000) - UTRWD - Lake Chapman, reuse, & DWU (2010-2050)
Hickory Creek	1,539	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU

Table 5.22, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Highland Village	3,370	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Justin	2,497	Trinity aquifer	- Overdraft Trinity aquifer (2000) - UTRWD (2010-2050)
Krugerville	362	Trinity aquifer	- Add new well & overdraft Trinity aquifer (2000) - UTRWD - Lake Chapman, reuse, & DWU (2010-2050)
Krum	1,167	Trinity aquifer	- Overdraft Trinity aquifer (2000) - UTRWD - Lake Chapman, reuse, & DWU (2010-2050)
Lake Dallas	1,659	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Lewisville	42,254	DWU	- UTRWD - Lake Chapman, reuse, & DWU (2010-2050) - DWU (2000-2050)
Lincoln Park	384	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Little Elm	1,835	Woodbine aquifer	- Add new well & overdraft Woodbine aquifer (2000) - North Texas MWD (2010-2050)
Northlake	7,354	TRWD (through Fort Worth) Woodbine aquifer	TRWD (through Fort Worth) UTRWD - Lake Chapman, reuse, & DWU
Oak Point	1,830	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Pilot Point	1,465	Trinity aquifer	- Overdraft Trinity aquifer (2000) - UTRWD - Lake Chapman, reuse, & DWU (2010-2050)

Table 5.22, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Plano (part)	27	North Texas MWD	North Texas MWD
Ponder	1,337	Trinity aquifer	UTRWD
Roanoke	893	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
Sanger	3,807	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Shady Shores	732	Trinity aquifer UTRWD	UTRWD - Lake Chapman, reuse, & DWU
Southlake (part)	745	TRWD (through Fort Worth)	TRWD (through Fort Worth)
The Colony	10,694	Trinity aquifer DWU	DWU
Trophy Club	6,288	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
County Other	37,323	Trinity aquifer Woodbine aquifer Other aquifer UTRWD TRWD (through Fort Worth)	- UTRWD - Lake Chapman, reuse, & DWU (2000-2050) - TRWD (2010-2050) - TRA reuse (2010-2050)
Manufacturing	1,647	Trinity aquifer Lake Ray Roberts UTRWD DWU	UTRWD - Lake Chapman, reuse, & DWU
Steam Electric Power	5,500	Reuse (Denton)	Reuse (Denton)
Mining	16	Trinity aquifer Other local supply	Increase other local supply
Irrigation	0	Woodbine aquifer Irrigation local supply	None
Livestock	0	Trinity aquifer Woodbine aquifer Livestock Local Supply	None

Table 5.23		
Estimated Capital Costs for Recommended Denton County Water Management Strategies Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
UTRWD Delivery of Lake Chapman Supply	- [(b)]	14,600 [(c)]
UTRWD Reuse of Lake Chapman Supply	$1,000,000 [(b)]	13,900
UTRWD Treated Water Transmission Improvements and Water Treatment Plant Expansions (2000-2050)	$479,157,000	- [(a)]
Denton Ray Roberts Water Treatment Plant	$29,983,000	- [(a)]
Denton Water Treatment Plant Expansions through 2050	$59,966,000	- [(a)]
New Groundwater Wells	$1,856,000	2,300
Reuse Project for Steam Electric Power	$9,315,000	5,500
Total	$581,277,000	36,300

Notes:
(a) Treatment plant expansions and treated water transmission improvements do not make additional water available, but they are needed to make use of supplies developed by other projects.
(b) The capital cost of delivery facilities is included in Irving's cost in Table 5.20. UTRWD will pay Irving to transport their water.
(c) UTRWD Lake Chapman supply is at least 10,900 acre-feet per year under the District's agreement with Commerce. The 14,600 acre-feet per year supply assumes that Commerce will not exercise its option to acquire back 25 percent of its Lake Chapman supply from UTRWD.

water from the Tarrant Regional Water District pipelines that run through Ellis County. Current plans call for that raw water to be treated by Waxahachie and provided as treated water to other Ellis County users. Management strategies to provide additional water for Ellis County include the following:

- Development of the Ellis County Water Supply System for Ferris, Italy, Maypearl, Palmer, Red Oak, Waxahachie, county other, and manufacturing.
- Additional DWU supplies for Cedar Hill, Glenn Heights, Grand Prairie, Oak Leaf, and Ovilla.
- Temporary overdrafting of groundwater for some users while new supplies are developed.
- Additional TRWD supplies to Ennis.

Table 5.24			
Recommended Management Strategies for Ellis County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Cedar Hill (part)	47	Trinity aquifer Woodbine aquifer DWU	DWU
Ennis	876	TRA - Lake Bardwell	- TRWD – new customer (2010-2050)
Ferris	54	Woodbine aquifer Joe Pool Lake	Ellis County system (2010-2050) Possibly DWU
Glenn Heights (part)	278	Woodbine aquifer DWU	DWU
Grand Prairie (part)	32	Trinity aquifer DWU TRWD	DWU
Italy	454	Trinity aquifer Woodbine aquifer	- Overdraft Trinity aquifer (2000) - Ellis County system (2010-2050)
Mansfield (part)	88	TRWD	TRWD
Maypearl	93	Woodbine aquifer	- Overdraft Woodbine aquifer (2000) - Ellis County system (2010-2050)
Midlothian	535	Trinity aquifer TRA - Joe Pool Lake TRWD	Ellis County system (2010-2050)
Milford	89	Woodbine aquifer Other aquifer Files Valley WSC	- Files Valley WSC (Lake Aquilla)
Oak Leaf	302	DWU	DWU
Ovilla (part)	1,010	DWU (through Cedar Hill)	DWU (through Cedar Hill)
Palmer	390	Woodbine aquifer	- Overdraft Woodbine aquifer - Possibly DWU - Ellis County system (2010-2050)

Table 5.24, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Pecan Hill	44	Other aquifer	Rockett SUD
Red Oak	182	Woodbine aquifer TRA - Joe Pool Lake	- Overdraft Woodbine aquifer - Possibly DWU - Ellis County system (2010-2050)
Waxahachie	655	Lake Waxahachie TRA - Lake Bardwell TRA – reuse	Ellis County system (2010-2050)
County Other	740	Trinity aquifer Woodbine aquifer Other aquifer TRA - Joe Pool Lake TRA - Lake Bardwell	Ellis County system (2010-2050)
Manufacturing	400	Trinity aquifer Woodbine aquifer TRA - Joe Pool Lake Lake Waxahachie TRA - Lake Bardwell	TRA - Lake Bardwell Ellis County system TRA Joe Pool Lake Lake Waxahachie
Steam Electric Power	18,000	None	- TRA reuse - Ennis reuse - TRA (Joe Pool Lake through Midlothian) - TRA (Lake Bardwell through Ennis)
Mining	0	Woodbine aquifer	None
Irrigation	0	Trinity aquifer Irrigation local supply	None
Livestock	0	Woodbine aquifer Livestock local supply	None

- Delivery of raw water from TRWD to Joe Pool Lake for Midlothian (through contract with TRA).
- Additional TRWD supplies to Mansfield.
- Additional supplies from Aquilla Lake in Region G to Milford (through Files Valley WSC).

- Supplies for steam electric power demand from TRA reuse, reuse of Ennis wastewater, TRA Joe Pool Lake water (through Midlothian), and TRA Lake Bardwell water (through Ennis)

Table 5.25 shows the estimated capital costs for water management strategies for Ellis County not covered under major water providers.

Table 5.25

Capital Costs for Recommended Water Management Strategies for Ellis County Not Covered Under Major Water Providers

- Based on 1999 Construction Costs -

Management Strategy	Estimated Capital Cost	Additional 2050 Supply (Acre-Feet/Year)
Ennis Connection to Tarrant Regional Water District	$9,182,000	4,100
Midlothian Transmission and Water Treatment Plant Expansions	$6,050,000	- (a)
Ennis Reuse	$0 (b)	2,400
Total	$15,232,000	6,500

Note: (a) Treatment plant expansions and treated water transmission improvements do not make additional water available, but they are needed to make use of supplies developed by other projects.
(b) No capital cost is included because the project is already constructed and in operation.

Fannin County

Table 5.26 gives a summary of current supply sources, shortages with current supplies, and sources of additional supplies for Fannin County. Because of concerns about long-term groundwater supplies, Fannin County water suppliers are planning to develop a county-wide surface water supply system. Other potential water management strategies for Fannin County include the development of the Lower Bois d'Arc Creek, Ralph Hall, and Upper Bois d'Arc Creek reservoir sites. The North Texas Municipal Water District is planning to develop the Lower Bois d'Arc Creek site, and up to 20 percent of the project's yield could be set aside for use in the Red River Basin in Fannin and surrounding counties. The Ralph Hall and Upper Bois d'Arc Creek sites are being pursued by Fannin County interests, and they are alternative water management strategies that might be developed after 2030. Table 5.27 shows the capital costs for recommended management strategies for Fannin County not covered under major water providers.

Table 5.26 Recommended Management Strategies for Fannin County			
Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Bonham	0	Lake Bonham	Fannin County system
Honey Grove	0	Woodbine aquifer	Fannin County system
Leonard	0	Woodbine aquifer	Fannin County system
Savoy	0	Woodbine aquifer	Fannin County system
Trenton	0	Woodbine aquifer	Fannin County system
County Other	13	Trinity aquifer Woodbine aquifer Lake Bonham	Fannin County system
Manufacturing	0	Woodbine aquifer Lake Bonham	Fannin County system
Steam Electric Power	0	Woodbine aquifer Lake Texoma	None
Mining	0	Other local supply	None
Irrigation	0	Other aquifer Irrigation local supply	None
Livestock	0	Woodbine aquifer Trinity aquifer Livestock local supply	None

Freestone County

Table 5.28 is a summary of the current sources, shortages with no new supplies, and recommended water management strategies for Freestone County. The shortages without development of new supplies would be addressed as follows:

- An additional well would be developed in the Carrizo-Wilcox aquifer for Fairfield.
- Wortham would purchase treated water from Mexia.

Table 5.27		
Capital Costs for Recommended Water Management Strategies for Fannin County Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Fannin County System (including 5,000 acre-feet per Year from Lower Bois d'Arc Creek Reservoir)	$52,358,000	5,000
Fannin County Share of Lower Bois d'Arc Creek Reservoir (not including 5,000 acre-feet per year in system)	$18,300,000[(a)]	20,000
Total	$70,658,000	25,000
Note: (a) Capital cost for Fannin County share of Lower Bois d'Arc Creek Reservoir does not include transmission and treatment.		

Table 5.28			
Recommended Management Strategies for Freestone County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Fairfield	89	Carrizo-Wilcox aquifer	Carrizo-Wilcox aquifer
Teague	0	Teague City Lake Carrizo-Wilcox aquifer	None
Wortham	331	Lake Wortham	Mexia
County Other	0	Carrizo-Wilcox aquifer Wortham Lake	None
Steam Electric Power	14,988	Carrizo-Wilcox aquifer Lake Fairfield TRA Livingston	TRWD
Mining	0	Other local supply Carrizo-Wilcox aquifer	None
Irrigation	0	Carrizo-Wilcox aquifer Irrigation local supply	None
Livestock	0	Carrizo-Wilcox aquifer Queen City aquifer Other aquifer Livestock local supply	None

- Water for steam-electric power generation will be provided from TRWD's Richland-Chambers Lake, and pipelines will be constructed from the lake to deliver the water to power plants.

Table 5.29 shows the capital costs of these water management strategies. (There is no capital cost for Wortham's purchase of water from Mexia because the necessary facilities are already in place.)

There are some alternative water management strategies that may be implemented in Freestone County:

- Development of a surface water supply system for Fairfield using raw water from TRWD's Richland-Chambers Lake.
- Development of a surface water supply system for Wortham using raw water from TRWD's Richland-Chambers Lake.

Table 5.29

Capital Costs for Recommended Water Management Strategies for Freestone County Not Covered Under Major Water Providers

- Based on 1999 Construction Costs -

Management Strategy	Estimated Capital Cost	Additional 2050 Supply (Acre-Feet/Year)
New Groundwater Well	$178,000	100
Transmission to Calpine Power Plant (includes TRWD system buy-in costs)	$4,989,000	- [a]
Transmission to Other Power Plants (includes TRWD system buy-in costs)	$9,828,000	- [a]
Total	$14,995,000	100

Note: (a) These transmission systems move water within Region C but do not make more water available.

Grayson County

The Trinity and Woodbine aquifers provide almost all of the current water use in Grayson County, and the current use from the aquifers is significantly greater than the estimated long-term reliable supply. Table 5.30 presents a summary of water management strategies to meet demands in Grayson County, which include the following:

- Development of a Grayson County water supply system consisting of a raw water pipeline from Lake Texoma, a treatment and desalination plant, and treated water pipelines to deliver water to users throughout the county.
- Temporary overdrafting of the aquifers while the surface water supply system is developed.
- Sale of treated water by Denison to Pottsboro.

Table 5.30
Recommended Management Strategies for Grayson County

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Bells	105	Trinity aquifer Woodbine aquifer	- Overdraft Trinity aquifer (2000) - Overdraft Woodbine aquifer (2000) - Grayson County water supply System (2010-2050)
Collinsville	73	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Grayson County water supply system (2010-2050)
Denison	0	Lake Texoma Lake Randell	None
Gunter	158	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Grayson County water supply system (2010-2050)
Howe	223	Woodbine aquifer	- New well & overdraft Woodbine aquifer (2000) - Grayson County water supply system (2010-2050)
Luella	76	Woodbine aquifer	- Overdraft Woodbine aquifer (2000) - Grayson County water supply system (2010-2050)

Table 5.30, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Pottsboro	198	Woodbine aquifer Lake Randell	Lake Texoma (through Denison)
Sherman	0	Trinity aquifer	None
Southmayd	143	Woodbine aquifer Lake Texoma Woodbine aquifer	- New well & overdraft Woodbine aquifer (2000) - Grayson County water supply system (2010-2050)
Tioga	57	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Grayson County water supply system (2010-2050)
Tom Bean	134	Woodbine aquifer	- Overdraft Woodbine aquifer (2000) - Grayson County water supply system (2010-2050)
Van Alstyne	1,132	Trinity aquifer Woodbine aquifer	- Overdraft Trinity aquifer (2000) - New well & overdraft Woodbine aquifer (2000) - Grayson County water supply system (2010-2050)
Whitesboro	613	Trinity aquifer	- Overdraft Trinity aquifer (2000) - Grayson County water supply system (2010-2050)

Table 5.30, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Whitewright	170	Trinity aquifer Woodbine aquifer	- Overdraft Trinity aquifer (2000) - Overdraft Woodbine aquifer (2000) - New well, Trinity aquifer (2010-2020) - Grayson County water supply system (2010-2050)
County Other	1,646	Trinity aquifer	- New well & overdraft Trinity aquifer (2000) - Overdraft Woodbine aquifer (2000) - Reallocate Trinity aquifer (2010-2030) - Grayson County water supply system (2010-2050)
Manufacturing	3,803	Woodbine aquifer Lake Texoma Lake Randell	Grayson County water supply system
Mining	632	Trinity aquifer Woodbine aquifer	- New well & overdraft Trinity aquifer (2000) - Overdraft Woodbine aquifer (2000) - Reallocate Trinity aquifer (2010-2050) - Reallocate Woodbine aquifer (2010-2050)
Irrigation	542	Trinity aquifer	Reallocate Trinity aquifer
Livestock	0	Woodbine aquifer Livestock local supply	None

Table 5.31 shows the estimated capital costs for the development of the Grayson County water management strategies not covered under major water providers. The Grayson County water supply system could be developed by the Greater Texoma Utility Authority or by another regional entity formed for that purpose. Based on the current

TWDB estimate of groundwater availability [38], it is assumed that the municipal water suppliers in the county will use 70 percent surface water and 30 percent groundwater, with groundwater used primarily to help meet peak demands. TWDB is scheduled to develop a groundwater availability model for the Trinity Aquifer by 2004, and this model should give additional information on groundwater supplies in Grayson County. When this additional information is available, the plans for the Grayson County water supply system should be revisited and refined.

It should be noted that there is no way to force groundwater users to reduce pumping from the aquifers. However, if TWDB's current estimate of the long-term reliable supply from the aquifers is correct, users will find it necessary to find other supplies over time. The formation of a groundwater management district for Grayson County might be considered as a way to control use of this limited resource.

Table 5.31

Capital Costs for Recommended Water Management Strategies for Grayson County Not Covered Under Major Water Providers

- Based on 1999 Construction Costs -

Management Strategy	Estimated Capital Cost	Additional 2050 Supply (Acre-Feet/Year)
Grayson County Surface Water Supply System	$94,316,000	5,000
New Groundwater Wells	$3,479,000	1,300
Pottsboro Water Line	$990,000	3,000
Total	$98,785,000	9,300

Note: (a) Treatment plant expansions and treated water transmission pipelines do not make additional water available, but they are needed to make use of supplies developed by other projects.

Henderson County

Table 5.32 is a summary of the current sources, need for additional supplies, and recommended water management strategies for Henderson County. The currently available supplies are sufficient to meet projected demands in the county except for Malakoff, which is planning to build a surface water supply system based on raw water from the Tarrant Regional Water District's Cedar Creek Reservoir. The estimated capital cost for Malakoff's new water supply system is $7,809,000.

Jack County

Table 5.33 shows the needs for additional supplies, current sources, and new sources of supply for Jack County. As the table shows, current sources of supply appear to be adequate to meet projected demands through 2050 for all water user groups in Jack County. One alternative water management strategy that is included for Jack County is the development of a pipeline to deliver treated water from Jacksboro to Bryson. This strategy could be implemented if Lake Bryson, with its limited drainage area, experiences a shortage.

Table 5.32

Recommended Management Strategies for Henderson County

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Athens	0	Carrizo-Wilcox aquifer Lake Athens	None
Eustace	0	Carrizo-Wilcox aquifer	None
Gun Barrel City	0	East Cedar Creek FWSD	None
Mabank	0	TRWD	None
Malakoff	58	Carrizo-Wilcox aquifer	- Overdraft Carrizo-Wilcox aquifer (2000) - TRWD (2010-2050)
Payne Springs	0	East Cedar Creek FWSD	None
Seven Points	0	West Cedar Creek MUD	None
Tool	0	West Cedar Creek MUD	None
Trinidad	0	Trinidad City Lake	None
County Other	0	Carrizo-Wilcox aquifer Other aquifer TRWD	None
Manufacturing	0	Carrizo-Wilcox aquifer Lake Athens	None

Table 5.32 Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Steam Electric Power	0	Carrizo-Wilcox aquifer TRWD TXU Forest Grove Lake Trinidad	None
Mining	0	Carrizo-Wilcox aquifer Other local supply	None
Irrigation	0	Carrizo-Wilcox aquifer Irrigation local supply	None
Livestock	0	Carrizo-Wilcox aquifer Other aquifer Queen City aquifer Livestock local supply	None

Table 5.33

Recommended Management Strategies for Jack County

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Bryson	0	Lake Bryson	None
Jacksboro	0	Lost Creek/Jacksboro system	None
County-Other	0	Trinity aquifer Lost Creek/Jacksboro system Lake Bryson	None
Mining	0	Other aquifer Other local supply	None
Irrigation	0	Irrigation local supply Jacksboro reuse Other aquifer	None
Livestock	0	Other aquifer Livestock local supply	None

Kaufman County

Table 5.34 summarizes the current supply sources, the need for additional supply, and the recommended sources of additional supply for water user groups in Kaufman County. Sources of additional water supplies for Kaufman County include the following:

- Additional supplies from Dallas Water Utilities for Combine and the portion of Dallas in Kaufman County.
- Additional supplies from North Texas Municipal Water District for Crandall, Forney, Kaufman, Oak Grove, county other, and manufacturing.
- Additional supplies from Terrell (Lake Tawakoni) for county other and manufacturing.
- Reuse of treated wastewater from Garland for steam electric power demand.
- Temporary overdrafting of the Woodbine aquifer and purchase from Tarrant Regional Water District for mining demand.
- Additional irrigation local supplies for irrigation demands.

Table 5.35 gives the estimated capital costs for the management strategies not covered under major water providers. (There is no additional capital cost for additional water from Terrell for manufacturing because the facilities for this management strategy are already in place.)

Navarro County

Table 5.36 summarizes the current supply sources, need for additional supplies, and recommended sources of additional supply for Navarro County. Corsicana supplies treated water for most of the water user groups in Navarro County, and Corsicana has a sufficient water supply if it expands its water treatment plants. The only need for additional supply anticipated is for mining, and that need would be met by an additional well in the Carrizo-Wilcox aquifer. An alternative source of additional supply for Navarro County would be to construct the facilities needed to connect Corsicana's existing supplies from Richland-Chambers Reservoir to its water supply system. Table 5.37 shows the estimated capital costs for Navarro County's recommended water management strategies.

Table 5.34			
Recommended Management Strategies for Kaufman County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Combine (part)	71	DWU	DWU
Crandall (part)	477	North Texas MWD	North Texas MWD
Dallas	1	DWU	DWU
Forney	3,894	North Texas MWD	North Texas MWD
Kaufman	985	North Texas MWD	North Texas MWD
Kemp	0	TRWD	None
Mabank (part)	0	TRWD	None
Oak Grove	64	North Texas MWD	North Texas MWD
Terrell	0	Lake Tawakoni Lake Terrell	None
County Other	3,034	Other aquifer Lake Tawakoni North Texas MWD	- North Texas MWD - Lake Tawakoni
Manufacturing	213	Lake Terrell North Texas MWD	- North Texas MWD - Lake Terrell
Steam Electric Power	15,000	None	Garland reuse
Mining	93	Other local supply	- Add new well & overdraft Woodbine (2000) - TRWD (2010-2050)
Irrigation	397	Nacatoch aquifer Irrigation local supply	- Additional irrigation local supply
Livestock	0	Nacatoch aquifer Woodbine aquifer Livestock local supply	None

Table 5.35		
Capital Costs for Recommended Water Management Strategies for Kaufman County Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Reuse from Garland Wastewater	$18,497,000	15,700
Kemp Water Treatment Plant Expansion	$2,813,000	- [(a)]
Terrell Water Treatment Plant Expansions	$8,439,000	- [(a)]
Woodbine Aquifer Well for Mining	$163,000	<100
Total	$29,912,000	15,700

Note: (a) Treatment plant expansions do not make additional water available, but they are Needed to make use of supplies developed by other projects.

Table 5.36			
Recommended Management Strategies for Navarro County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Blooming Grove	0	Corsicana	None
Corsicana	0	Lake Halbert TRA - Navarrro Mills Res.	None
Dawson	0	Corsicana TRA - Navarro Mills Res.	None
Frost	0	Woodbine aquifer Corsicana	None
Kerens	0	Chatfield WSC Corsicana	None
Rice	0	Rice WSC	None

Table 5.36, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
County Other	0	Trinity aquifer Woodbine aquifer TRWD Corsicana	None
Mining	43	Carrizo-Wilcox aquifer Nacatoch aquifer	- Add new well & pump Carrizo-Wilcox aquifer
Manufacturing	0	Other aquifer Corsicana TRA - Navarro Mills Res.	None
Irrigation	0	Irrigation local supply	None
Livestock	0	Carrizo-Wilcox aquifer Nacatoch aquifer Other aquifer Livestock local Supply	None

Table 5.37

Capital Costs for Recommended Water Management Strategies for Navarro County Not Covered Under Major Water Providers

- Based on 1999 Construction Costs -

Management Strategy	Estimated Capital Cost	Additional 2050 Supply (Acre-Feet/Year)
Corsicana Water Treatment Plant Expansions	$5,626,000	- [(a)]
New Groundwater Well	$44,000	100
Total	$5,670,000	100

Note: (a) Treatment plant expansions do not make additional water available, but they are needed to make use of supplies developed by other projects.

Parker County

Table 5.38 gives a summary of the current supply sources, the need for additional supplies, and recommended sources of additional supply for Parker County. Sources of additional water supply planned for Parker County include the following:

- Weatherford is constructing a pump station and 36-inch pipeline to bring water from Tarrant Regional Water District's Lake Benbrook to Lake Weatherford. That project is planned for completion in 2002.
- Weatherford will treat raw water made available by Tarrant Regional Water District and sell treated water to Aledo, Annetta, Hudson Oaks, and Willow Park, all of which currently use the Trinity aquifer for their water supply.
- TRWD will provide additional water for Azle, Briar, Reno (through Springtown), and Springtown.
- Additional county other and manufacturing supplies will be developed from TRWD through Weatherford.
- Water for steam electric power will be provided by reuse of treated wastewater from Weatherford and by water from TRWD's Lake Benbrook.
- Water for mining will be provided by increased local water supply diversions.
- The Trinity aquifer will be overdrafted on an interim basis while other supplies are developed.

Table 5.39 shows the estimated capital costs of these management strategies for Parker County. The additional supplies from Tarrant Regional Water District for Azle, Briar, Reno, and Springtown are not included because those capital costs are included in Tarrant Regional Water District capital costs.

Like several other Region C counties, Parker County currently has groundwater use from the Trinity aquifer in excess of the long-term reliable supply estimated by TWDB. This problem will be addressed with the development of the proposed pipeline from Tarrant Regional Water District to Weatherford and the development of a regional water supply system from Weatherford to other Parker County water suppliers.

Table 5.38			
Recommended Management Strategies for Parker County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Aledo	732	Trinity aquifer	- Overdraft Trinity aquifer (2000) - TRWD (through Weatherford) (2010-2050)
Annetta	801	Other aquifer	- Add new well & overdraft Other aquifer (2000) - TRWD (through Weatherford) (2010-2050)
Azle (part)	110	TRWD	TRWD
Briar (part)	36	TRWD	TRWD
Hudson Oaks	1,645	Trinity aquifer	- Overdraft Trinity aquifer (2000) - TRWD through Weatherford (2010-2050)
Mineral Wells	0	Lake Mineral Wells Lake Palo Pinto	None
Reno	112	Trinity aquifer TRWD (through Springtown)	TRWD (through Springtown)
Springtown	184	Trinity aquifer TRWD	TRWD
Weatherford	14,497	Lake Weatherford	- Overdraft Lake Weatherford (2000) - TRWD
Willow Park	2,637	Trinity aquifer	- Overdraft Trinity aquifer (2000) - TRWD (through Weatherford) (2010-2050)
County Other	3,822	Trinity aquifer Woodbine aquifer Other aquifer TRWD	-Add new wells and overdraft Trinity aquifer (2000) - TRWD (through Weatherford) (2010-2050)
Manufacturing	277	Trinity aquifer Lake Weatherford Lake Palo Pinto	-Add new wells and overdraft Trinity aquifer (2000) - TRWD (through Weatherford) (2010-2050)

Table 5.38, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Steam Electric Power	11,850	Lake Weatherford	- TRWD - Weatherford Reuse
Mining	3,008	Trinity aquifer Other local supply Possum Kingdom Reservoir	- Increase diversions from other local supply
Irrigation	0	Trinity aquifer Irrigation local supply	None
Livestock	0	Trinity aquifer Livestock local supply	None

Table 5.39

Capital Costs for Recommended Water Management Strategies for Parker County Not Covered Under Major Water Providers

- Based on 1999 Construction Costs -

Management Strategy	Estimated Capital Cost	Additional 2050 Supply (Acre-Feet/Year)
Pipeline and Pump Station from Lake Benbrook to Weatherford	$9,000,000	- (a)
Weatherford Treatment Plant Expansions	$27,221,000	- (b)
Treated Water Delivery Lines from Weatherford To Aledo, Annetta, Hudson Oaks, & Willow Park	$7,164,000	- (b)
Parallel Pipeline and Pump Station from Lake Benbrook to Weatherford	$13,375,000	- (a)
New Groundwater Wells	$5,095,000	2,300
Springtown Water Treatment Plant Expansions	$5,626,000	- (b)
Weatherford Reuse for Steam Electric Power	$3,894,000	6,000
Line from Lake Benbrook for Steam Electric Power	$11,642,000	- (a)
Total	$83,017,000	8,300

Notes:
(a) These transmission systems move water within Region C but do not make more water available.
(b) Treatment plant expansions and treated water transmission improvements do not make additional water available, but they are needed to make use of supplies developed by other projects.

Table 5.40			
Recommended Management Strategies for Rockwall County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Dallas (part)	4	DWU	DWU
Heath	1,594	North Texas MWD	North Texas MWD
Rockwall	12,975	North Texas MWD	North Texas MWD
Rowlett (part)	4,048	North Texas MWD	North Texas MWD
Royse City (part)	3,062	North Texas MWD	North Texas MWD
Wylie (part)	7	North Texas MWD	North Texas MWD
County Other	50	Other aquifer North Texas MWD	North Texas MWD
Manufacturing	3	North Texas MWD	North Texas MWD
Steam Electric Power	6,000	None	North Texas MWD reuse
Mining	0	Other local supply	None
Livestock	0	Other aquifer Livestock local supply	None

Rockwall County

Table 5.40 shows the current water supply sources, the needs for additional water supply, and the recommended sources of additional supply for water user groups in Rockwall County. North Texas Municipal Water District currently supplies the majority of the demand in the county, and NTMWD will meet increases to demands for its customers. Dallas Water Utilities will continue to supply the small portion of the City of Dallas in Rockwall County. The new demand for steam electric power use will be met by reuse of treated wastewater effluent from North Texas MWD. The estimated capital costs for reuse to meet steam electric power demands is $4,795,000. The capital costs for other management strategies are shown under the major water providers.

Tarrant County

Table 5.41 summarizes the current sources of supply, needs for additional supply, and recommended new sources for Tarrant County. Most of Tarrant County's current water supply is from raw water provided by the Tarrant Regional Water District, and this will continue to be the case in the future. Current groundwater use from the Trinity aquifer in Tarrant County is considerably in excess of the long-term reliable supply from the aquifer

Table 5.41
Recommended Management Strategies for Tarrant County

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Arlington	16,236	Lake Arlington, TRWD	TRWD
Azle (part)	633	TRWD	TRWD
Bedford	1,807	Trinity aquifer TRA (from TRWD)	TRA (from TRWD)
Benbrook	0	Trinity aquifer TRWD	None
Blue Mound	67	TRWD	TRWD (Tecon)
Briar (part)	178	TRWD	TRWD
Burleson (part)	528	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Colleyville	2,322	Trinity aquifer TRA (from TRWD)	TRA (from TRWD)
Crowley	2,043	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Dalworthington Gardens	1,177	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Edgecliff Village	551	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Euless	1,739	Trinity aquifer TRA (from TRWD)	TRA (from TRWD)
Everman	631	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
Forest Hill	1,907	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Fort Worth	30,333	TRWD	TRWD

Table 5.41, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Grand Prairie (part)	8,587	Trinity aquifer DWU TRWD (through Fort Worth and TRA)	- DWU - TRWD (through Fort Worth and TRA)
Grapevine (part)	1,982	Lake Grapevine TRA (from TRWD)	- TRA (from TRWD) - DWU - Direct reuse
Haltom City	6,737	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Haslet	457	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
Hurst	6,897	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
Keller	7,882	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Kennedale	3,257	Trinity aquifer	- Add new well & overdraft Trinity aquifer (2000) - TRWD (through Arlington and Fort Worth) (2010-2050)
Lake Worth Village	825	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
Mansfield (part)	3,221	TRWD	TRWD
North Richland Hills	11,841	Trinity aquifer TRWD (through Fort Worth) TRA (from TRWD)	TRWD (through Fort Worth) TRA (from TRWD)
Pantego	423	Trinity aquifer	- Overdraft Trinity aquifer (2000) - TRWD (through Arlington and Fort Worth) (2010-2050)
Pelican Bay	397	Trinity aquifer	- Add new well & overdraft Trinity Aquifer (2000) - Reallocate groundwater (2010-2050)
Richland Hills	2,510	Trinity aquifer, TRWD (through Fort Worth)	TRWD (through Fort Worth)
River Oaks	183	TRWD	TRWD
Saginaw	3,519	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Sansom Park Village	512	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
Southlake (part)	15,383	TRWD (through Fort Worth)	TRWD (through Fort Worth)

Table 5.41, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Watauga	4,757	TRWD (through Fort Worth)	TRWD (through Fort Worth)
Westworth Village	312	TRWD)through Fort Worth)	TRWD (through Fort Worth)
White Settlement	1,993	Trinity aquifer TRWD (through Fort Worth)	TRWD (through Fort Worth)
County Other	20,402	Trinity aquifer Woodbine aquifer Other aquifer TRWD TRWD (through Fort Worth) Lake Grapevine TRWD (throughTRA) Reuse	- TRWD (through Fort Worth) - TRA reuse
Manufacturing	16,783	Trinity aquifer TRWD (through Fort Worth) Lake Arlington Reuse (Lake Worth)	TRWD TRWD (through Fort Worth)
Steam Electric Power	2,436	Trinity aquifer Lake Arlington TRWD	Reuse from Fort Worth TRWD
Mining	0	TRWD Other local supply	None
Irrigation	0	Trinity aquifer Irrigation local supply	None
Livestock	0	Trinity aquifer Livestock local supply	None

Note: This table assumes renewal of Fort Worth's contracts with its customers. Fort Worth has not committed to contract renewal, which will require city council action.

as estimated by TWDB. Many Tarrant County water users have developed surface water supplies in recent years and decreased their reliance on the Trinity aquifer. The trend of decreasing reliance on the Trinity aquifer is assumed to continue in the future. In addition, it is assumed that Kennedale and Pantego will begin to purchase treated surface water from Fort Worth and Arlington in the near future and will decrease their use of water from the Trinity aquifer. Water management strategies to provide additional supply for Tarrant County include the following:

- Development of additional supplies by the Tarrant Regional Water District.
- Water treatment plant expansions by Arlington, Benbrook, Fort Worth, Mansfield and the Trinity River Authority Tarrant County Water Supply system to keep pace with increasing demands.
- Purchase of treated water from Fort Worth and Arlington by Kennedale and Pantego.
- Increasing supplies from Dallas Water Utilities for Grand Prairie and Grapevine.
- Development of direct reuse by Grapevine.
- Development of reuse projects from Fort Worth to meet increasing demands for steam electric power supply and irrigation.
- Development of a TRA reuse project to supply golf course and landscape irrigation needs.

Table 5.42 shows the capital costs of those Tarrant County water management strategies not already covered under the major water providers.

Wise County

Table 5.43 shows the current sources of supply, projected needs for additional supplies, and recommended sources of additional supply for Wise County water user groups. Recommended water management strategies for Wise County include the following:

- Walnut Creek Special Utility District has constructed a 20-inch water line to serve Aurora, Boyd, Newark, and Rhome with treated water using water purchased from Tarrant Regional Water District. Walnut Creek SUD is currently planning a water treatment plant expansion.
- Alvord will add an additional well and continue to use the Trinity aquifer.
- Briar, Bridgeport, and Decatur will obtain additional supplies from the Tarrant Regional Water District.
- Steam electric power needs will be covered by sales from Tarrant Regional Water District. Pipelines and pump stations to three power plants will be required.

Table 5.44 shows the estimated capital costs for the water management strategies planned for Wise County not already covered under the major water providers.

Table 5.42		
Capital Costs for Recommended Water Management Strategies for Tarrant County Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Arlington Water Treatment Plant Expansions	$25,665,000	- [a]
Benbrook Water Treatment Plant Expansions	$4,219,000	- [a]
Mansfield Water Treatment Plant Expansions	$29,532,000	- [a]
Pipeline to Deliver Water from Fort Worth To North Tarrant County Customers	$9,824,000	- [a]
Community Water Supply Corporation Water Treatment Plant Expansions	$5,626,000	- [a]
New Groundwater Wells	$1,674,000	300
Grapevine Direct Reuse	$4,003,000	1,500
Reuse from Fort Worth Wastewater	$2,909,000	2,600
Total	$83,452,000	4,400

Note: (a) Treatment plant expansions and treated water transmission improvements do not make additional water available, but they are needed to make use of supplies developed by other projects.

5.7 Expanded Discussion of Livestock Demands

In 14 out of 16 counties in Region C, the estimated overall county-wide water supply for livestock is sufficient to meet the projected demands over the next 50 years. In 13 of the Region C counties, the estimated overall county-wide water supply for irrigation purposes can meet projected demands for the county as a whole. However, these overall county-wide supply and demand figures do not show areas of shortages that exist within the counties under drought conditions. To address this concern, the Region C Water Planning Group surveyed county agriculture extension agents on livestock water use in their counties. Agents from ten of the sixteen Region C counties responded to the surveys, and the responses are summarized in Appendix X. The following points emerged from the survey responses:

Table 5.43			
Recommended Management Strategies for Wise County			
Water User Group	**Need for Additional Supplies (Ac-Ft/Yr)**	**Current Supply Source(s)**	**Source(s) of Additional Supply**
Alvord	51	Trinity aquifer	- Add new well & overdraft Trinity aquifer (2000) - Reallocate groundwater (2010-2050)
Aurora	86	Other aquifer	- Overdraft other aquifer (2000) - TRWD (through Walnut Creek SUD) (2010-2050)
Boyd	264	Trinity aquifer	- Overdraft Trinity aquifer (2000) - TRWD (through Walnut Creek SUD) (2010-2050)
Briar (part)	40	TRWD	TRWD
Bridgeport	249	TRWD	TRWD
Chico	29	Trinity aquifer TRWD	TRWD
Decatur	277	TRWD	TRWD
Newark	160	Trinity aquifer	- Overdraft Trinity aquifer (2000) - TRWD (through Walnut Creek SUD) (2010-2050)
Rhome	132	Trinity aquifer	- Overdraft Trinity aquifer (2000) - TRWD (through Walnut Creek SUD) (2010-2050)
County Other	4,457	Trinity aquifer TRWD	- TRWD - UTRWD – Lake Chapman and reuse (2020-2050)
Manufacturing	0	Other aquifer TRWD Other local supplies	None
Steam Electric Power	11,200	None	- Contract with Duke (2010-2050) - Contract with Tractebel (2010-2050) - TRWD

Table 5.43, Continued

Water User Group	Need for Additional Supplies (Ac-Ft/Yr)	Current Supply Source(s)	Source(s) of Additional Supply
Mining	0	Trinity aquifer TRWD Bridgeport local Other local supply	None
Irrigation	0	Trinity aquifer Irrigation local supply	None
Livestock	0	Trinity aquifer Livestock local supply	None

Table 5.44		
Capital Costs for Recommended Water Management Strategies for Wise County Not Covered Under Major Water Providers		
- Based on 1999 Construction Costs -		
Management Strategy	**Estimated Capital Cost**	**Additional 2050 Supply (Acre-Feet/Year)**
Walnut Creek Special Utility District Water Treatment Plant Expansions	$34,949,000	- [(a)]
New Groundwater Wells	$544,000	300
Bridgeport Water Treatment Plant Expansions	$5,626,000	- [(a)]
Decatur Water Treatment Plant Expansions	$5,626,000	- [(a)]
Upper Trinity Regional Water District	- [(b)]	- [(b)]
Steam Electric Power Transmission Systems	$21,738,000	- [(a)]
Total	$68,483,000	300

Note: (a) Treatment plant expansions and treated water transmission improvements do not make additional water available, but they are needed to make use of supplies developed by other projects.
(b) UTRWD costs and supplies are listed in Denton County on Table 5.23.

- Most counties experienced localized shortages due to lack of surface water in the recent drought conditions.
- In some counties, declining groundwater levels also create problems for livestock water supply.
- Projections of livestock use from county extension agents are higher than TWDB numbers in some counties and lower in other counties.

- Some livestock water users are using brush control to enhance supplies.

The remainder of this section outlines several methods that could be used to address localized drought shortages for livestock and irrigation supply in Region C.

Overdrafting Aquifers

In most cases, it is not feasible for farmers and ranchers to convert from groundwater to surface water. Such a transition would be very costly and the individuals would be responsible for these costs. It is not reasonable to expect these users to pay for pipelines and pump stations to bring water to their operations from cities. Thus, overdrafting the aquifers during drought conditions should be considered an appropriate solution to providing water for livestock supply. The amount of water pumped from the aquifers in normal years can be reduced when the needs are less and the surface water is more available from streams and stock ponds. In many cases, aquifers in Region C are currently being overdrafted. As cities move away from groundwater toward surface water, the amount of groundwater available for irrigation and livestock use may increase.

Brush Control

Brush control in localized areas may increase water supplies for farmers and ranchers. Removal of water-thirsty brush could make more water available in stock ponds and in aquifers. State funding for brush removal is recommended. Also, assistance with proper removal methods is recommended so that poisonous chemicals are not introduced into existing water sources.

Funding for Maintaining Existing Stock Ponds and Adding New Stock Ponds

Stock ponds are man-made ponds that catch and contain runoff. Stock ponds that are 200 acre-feet or larger require a state water right permit. However, ponds that contain less than 200 acre-feet of water can be constructed for domestic and livestock purposes without a permit. The costs of maintaining and building these ponds can be quite high. Government funding to help build and maintain stock ponds of all sizes is recommended. Funding to assist with improving, dredging, and increasing capacities of stock ponds is also recommended to ensure sufficient water supply for livestock.

Improving and Maintaining Existing NRCS Dams

The Natural Resources Conservation Service (NRCS) (formerly the Soil Conservation Service) installed numerous small dams to help control downstream flooding and sedimentation. These NRCS reservoirs also provide water for livestock and increase streamflows during low flow periods. The design life for the majority of the NRCS dams is 50 years. Most of the projects were built in the 1950s and 1960s and are nearing the end of their design life. Many of the NRCS structures are in need of maintenance or repair in order to extend the life of the dams. The Region C Water Planning Group recommends that the State of Texas seek federal funding to improve and maintain these NRCS structures.

The Tarrant Regional Water District is working with the NRCS to establish erosion control structures in the West Fork watershed. This project calls for 78 erosion control structures, 47 of which have been built. The West Fork Watershed Committee has worked to re-activate the NRCS watershed management program and to secure funding for the project. The committee has added an additional 8 structures to the original management plan. These erosion control structures will serve several purposes. First, they will decrease erosion and sedimentation accumulation downstream in Lake Bridgeport and Eagle Mountain Lake. These structures will also hold water that can be used by livestock and increase downstream flows during low flow periods.

Survey on Agricultural Water Use

The Texas Agricultural Statistics Service sends out a survey to farmers and ranchers across Texas. Currently, no questions regarding water use are asked in this survey. Additional questions could be added to the survey with an explanation as to why they are being added to help quantify the amount of water being used for livestock and irrigation and needed improvements. Potential questions include:

- Do you use groundwater or surface water for your ranch/farm?
- If you are using groundwater:
    - What aquifer(s) are you pumping?
    - What is your total pumping capacity?

    - How deep are your water wells?

- If you are using surface water:

    - How many stock tanks do you have?

    - What is the capacity of each stock tank?

- Are you currently experiencing water shortages?

- How many head of livestock are you watering?

- How many acres of each crop are you irrigating?

These are suggested questions rather than an exhaustive list of questions that could be asked. It should be noted that some people may not know the pumping capacities of their groundwater wells or the storage capacity of their stock tanks. This information will only be useful if the farmers and ranchers answer the questions to the best of their abilities and return the surveys.

5.8 Consistency with the Regional Water Plan

Senate Bill One requires that future projects be consistent with approved regional water plans to be eligible for Texas Water Development Board (TWDB) funding and Texas Natural Resource Conservation Commission (TNRCC) surfacing water permitting. The following factors should be considered by TWDB and TNRCC in making consistency determinations:

- Willing buyer/ willing seller transactions of water rights and treated water should not be controlled by this regulation. Such transactions may be beneficial to all concerned and may simply not have been foreseen in the planning process.

- TWDB and TNRCC should interpret existing legislation to give the maximum possible flexibility to water suppliers as they seek to serve the public and provide new supplies. Changes in the timing of supply development, the order in which supplies are developed, the amount of supply from a management strategy, or the details of a project should <u>not</u> be interpreted as making that project inconsistent with the regional plan.

- Small surface water uses for irrigation, recreation, industrial, or other purposes may be below the level of detail at which this plan was prepared. Such small uses should be regarded as consistent with this plan as long as they do not have an impact on the region's existing water supply or on strategies recommended specifically in the plan.

- Projects to replace or repair existing facilities should be regarded as consistent with this plan.

- Projects for internal water distribution system improvements and other water supply projects that do not involve the development of or connection to a new water source should be regarded as consistent with the regional plan.

- Projects intended to improve water quality or meet regulatory requirements should be regarded as consistent with the regional plan.

- Projects that promote regional cooperation should receive state support and be regarded as consistent with the regional plan.

- In some cases, changing circumstances will require fast action on projects by water suppliers. TWDB and TNRCC should support water suppliers when fast track efforts are required.

5.9 Effect of the Plan on Navigation

Commercial navigation has not been a significant factor in Region C historically, and it is not expected to be significant in the period covered by the plan. Recreational use of streams and reservoirs in Region C has been significant, and this plan is not expected to significantly affect recreational use of reservoirs. The effect of the Region C water plan on navigation is expected to be negligible.

Table 5.3
Potential New Reservoirs for Region C Water Supply

Name	Region	County	Basin	Stream	Yield in Acre-Feet/Year: Holding All Inflow	Yield: With Releases*	Yield: Source	Estimated Capital Cost: Previous Estimate	Estimated Capital Cost: Base Year	Estimated Capital Cost: 1999 Cost	Year 2000 Cost per Ac-Ft/Yr	Approximate Delivery Distance (Miles)	Environmental Impacts: Acres Flooded	Environmental Impacts: Wetland Impacts	Environmental Impacts: Bottomland Hardwood	Environmental Impacts: Endangered Species	Environmental Impacts: Other Issues	Interbasin Transfer Required?	Region C Entities Interested	Comments
Tehuacana	**C**	**Freestone**	**Trinity**	**Tehuacana Creek**	**68,300**	64,900**	**A, D**	**$113,121,000**	**1989**	**$196,402,000**	**$3,026**	**90**	**14,900**	**Moderate**	**Moderate**	**Low**	**Lignite**	**No**	**TRWD**	
Muenster	**C**	**Cooke**	**Trinity**	**Brushy Elm Creek**	**500**		**B**					**5**		**Low**	**Low**	**Low**		**No**	**Muenster**	
Roanoke	C	Denton	Trinity	Denton Creek	26,800		G					0		Moderate	Low	Low	Urban development	No	None	Yield is from increase to Lake Grapevine yield.
Upper Red Oak	C	Ellis	Trinity	Red Oak Creek		4,700	G					0		Moderate	Low	Low		No	None	
Lower Red Oak	C	Ellis	Trinity	Red Oak Creek		7,200	G					0		Moderate	Low	Low		No	None	
Boyd	C	Wise	Trinity	West Fork Trinity								0		Low	Low	Low		No	None	
Italy	C	Ellis	Trinity	Chambers Creek	56,000	7,200	A, G					10	12,900	Moderate	Low	Moderate	Downstream water rights	No	None	Yield limited by prior rights.
Tennessee Colony	C	Anderson/Freestone/ Henderson/Navarro	Trinity	Trinity River	300,100+	285,100**	A, D	$621,112,000	1989	$838,501,000	$2,941	100	85,100	High	High	Moderate	Lignite, mitigation land	No	None	
Lower Bois d'Arc Creek	**C**	**Fannin**	**Red**	**Bois d'Arc Creek**	**124,700**	**123,000**	**C**	**$95,961,000**	**1995**	**$114,846,000**	**$934**	**80**	**16,400**	**Moderate**	**Moderate**	**Low**	**National grassland**	**Yes**	**NTMWD**	
Upper Bois d'Arc Creek	**C**	**Fannin**	**Red**	**Bois d'Arc Creek**								**10**		**Low**	**Low**	**Low**		**No**	**Fannin Co.**	
Ralph Hall	**C**	**Fannin**	**Sulphur**	**North Sulphur River**								**15**		**Low**	**Low**	**Low**	**National grassland**	**Yes**	**Fannin Co.**	
Ringgold	B	Clay	Red	Little Wichita River	27,600		A, D					90	15,000	Low	Low	Low		Yes		
Big Pine	D	Lamar	Red	Big Pine Creek	35,900		A, D					120	5,100	Moderate	Moderate	Low		Yes	None	Yield includes diversions from Red River.
Pecan Bayou	D	Red River	Red	Pecan Bayou	82,000		A					130	16,200	Moderate	Low	Moderate		Yes	None	Yield includes diversions from Red River.
George Parkhouse I (South)	**D**	**Delta/Hopkins**	**Sulphur**	**North Sulphur River**	**122,900**	**119,100**	**A, C, D**	**$167,598,000**	**1995**	**$186,034,000**	**$1,562**	**100**	**29,700**	**Moderate**	**Moderate**	**Low**	**Mitigation land**	**Yes**	**Several**	
George Parkhouse II (North)	**D**	**Delta/Lamar**	**Sulphur**	**South Sulphur River**	**141,200**	**129,700**	**A, C, D**	**$112,095,000**	**1995**	**$126,667,000**	**$977**	**100**	**12,300**	**Moderate**	**Low**	**Low**	**Prime farmland**	**Yes**	**Several**	
Marvin Nichols I (North)	**D**	**Red River/Morris/ Titus**	**Sulphur**	**Sulphur River**	**641,700**	**619,100**	**A, C, D**	**$384,521,000**	**1995**	**$426,818,000**	**$689**	**130**	**62,100**	**High**	**High**	**Low**	**Lignite**	**Yes**	**Several**	
Marvin Nichols II (South)	**D**	**Morris/Titus**	**Sulphur**	**White Oak Creek**	**294,800**	280,100**	**A**	**$191,081,000**	**1989**	**$250,316,000**	**$894**	**130**	**35,900**	**High**	**Moderate to high**	**Low**	**Mitigation land, oil wells**	**Yes**	**Several**	
Little Cypress	D	Marion/Upshur	Cypress	Little Cypress Bayou	129,000		A, D					150	14,000	High	Moderate	Moderate		Yes	None	
Upper Little Cypress	D	Upshur	Cypress	Little Cypress Bayou	71,700		A					130	24,500	High	Moderate	Moderate		Yes	None	
Black Cypress	D	Marion/Cass	Cypress	Black Cypress Bayou	192,000		A					150	32,200	High	High	Moderate		Yes	None	
Marshall	D	Marion/Upshur	Cypress	Little Cypress Bayou	284,100		A					150	32,300	High	Moderate	Moderate		Yes	None	
Waters Bluff	D	Smith/Upshur/Wood	Sabine	Sabine River	324,000	307,800**	A, F	$489,532,000	1998	$514,009,000	$1,670	120	36,400	High	High	High	Wildlife mangement area, wetland banks	Yes	None	
Carl Estes	D	Van Zandt	Sabine	Sabine River	94,000	89,300**	D, F	$373,815,000	1998	$392,506,000	$4,395	80	24,900	Moderate	Moderate	Moderate	Lignite	Yes	None	
Big Sandy	D	Wood	Sabine	Big Sandy Creek	46,600	44,300**	A, D, F	$82,818,000	1998	$86,959,000	$1,963	110	4,400	Moderate	Moderate to high	Moderate		Yes	None	
Carthage	D	Harrison/Panola/Rusk	Sabine	Sabine River	537,000	510,200**	A, F	$495,838,000	1998	$520,630,000	$1,020	160	41,200	High	High	High		Yes	None	
South Bend	G	Stephens/Young	Brazos	Brazos River	106,700		A, D					100	29,700	Moderate	Low	Moderate	Oil wells	Yes	None	Yield is increase to BRA system.
Bedias	H	Grimes/Madison/Walker	Trinity	Bedias Creek	78,500	74,600**	D, H	$147,245,000	1989	$198,781,000	$2,665	170	24,700	Moderate	Low	Moderate		No	TRA	Not for Region C.
Ponta	I	Cherokee/Nacogdoches/Rus	Neches	Angelina River	163,700		A					150	36,800	High	Moderate	Moderate		Yes	None	
Eastex	I	Cherokee	Neches	Mud Creek	85,500		A, D					140	10,000	Moderate	Moderate	Moderate		Yes	None	Has TNRCC permit.
Weches	I	Anderson/Cherokee	Neches	Neches River	193,000		A, D					140	33,100	High	High	Moderate		Yes	None	
Rockland	I	Angelina/Polk/Trinity	Neches	Neches River	555,400		A, D					200	101,100	High	High	Moderate to high	Timber	Yes	None	

Sources: A. Freese and Nichols, Inc., and Alan Plummer Associates, Inc.: *Regional Water Supply Plan,* prepared for the Tarrant County WCID #1 in conjunction with the Texas Water Development Board, Fort Worth, 1990.
B. Texas Water Development Board Yield Estimates.
C. Freese and Nichols, Inc.: *Preliminary Study of Sources of Additional Water Supply,* prepared for North Texas MWD, Fort Worth, 1996.
D. Texas Parks and Wildlife Department: *An Assessment of Direct Impacts to Wildlife Habitat from Future Water Development Projects,* Austin, 1990.
E. U.S. Fish and Wildlife Service: *Texas Bottomland Hardwood Preservation Program,* Albuquerque, 1984.
F. Freese and Nichols, Inc., Brown and Root, Inc., and LBG-Guyton Associates: *Comprehensive Sabine Watershed Management Plan,* prepared for Sabine River Authority of Texas in conjunction with the Texas Warer Development Board, Fort Worth, 1999.
G. Espey-Houston and Associates, Inc., Alan Plummer Associates, Inc., and Rone Engineering: *Regional Water Study for Ellis County and Southern Dallas County,* prepared for Trinity River Authority in conjunction with Texas Water Development Board, Austin, 1989.
H. Burns and McDonnell: *Bedias Project Inventory, Texas, Plan Formulation Working Document,* prepared for the U.S. Bureau of Reclamation, Kansas City, 1989.

Notes: * Releases are to allow full diversions for downstream water rights and to satisfy TWDB consensus criteria for instream flows. Releases were assumed to reduce yield by 5% if data were not available.
** Releases were assumed to reduce yield by 5% for these reservoirs.
+ Yield for Tennessee Colony does not include return flows.
Reservoirs shown in bold were retained for further study.

Figure 5.1

ct of Conservation on Projected Municipal Demand in Region C

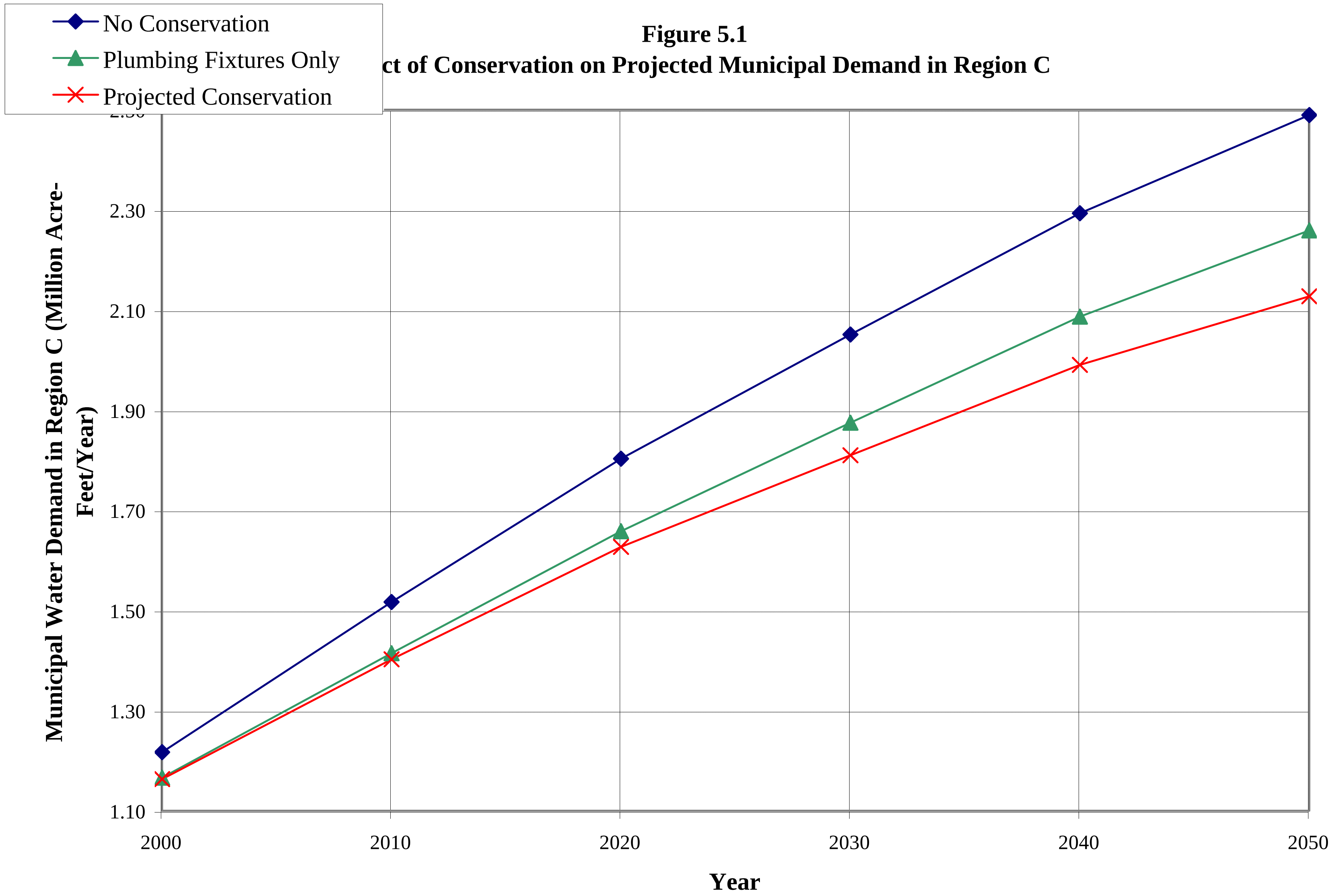


Figure 5.2
Potential Savings from Various Conservation Measures

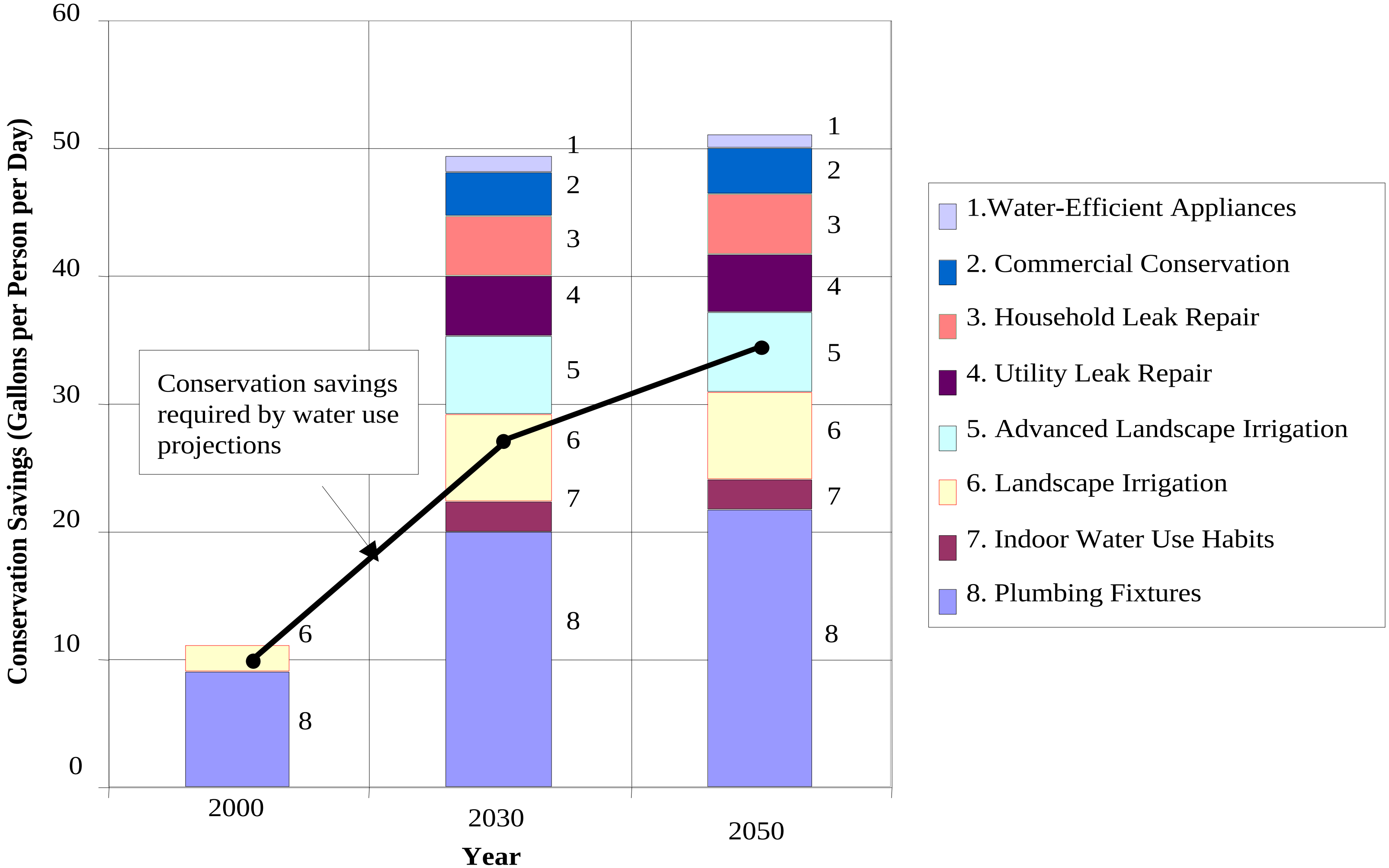


Figure 5.4
Dallas Water Utilities Supply and Demand

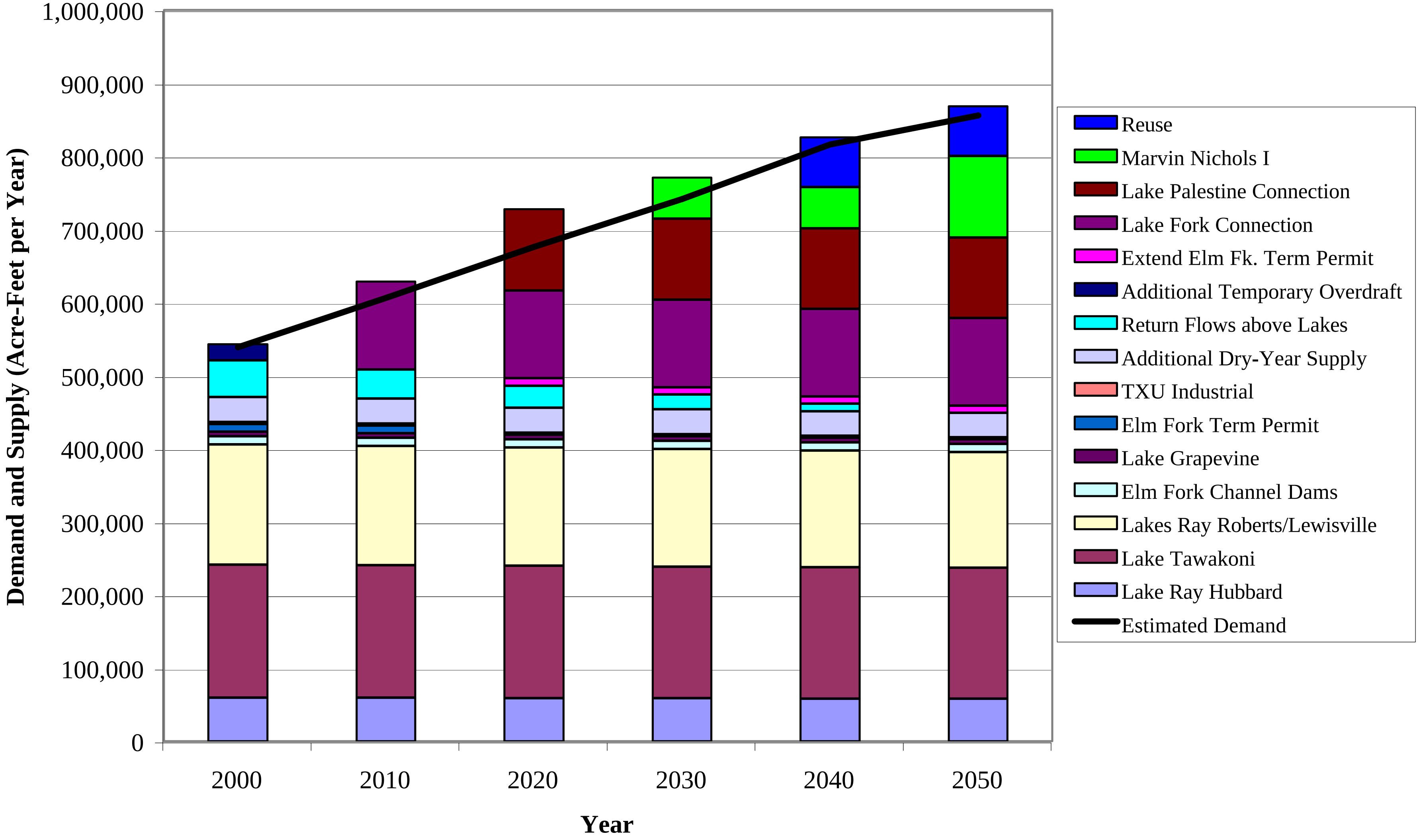


Figure 5.5
Tarrant Regional Water District Supply and Demand

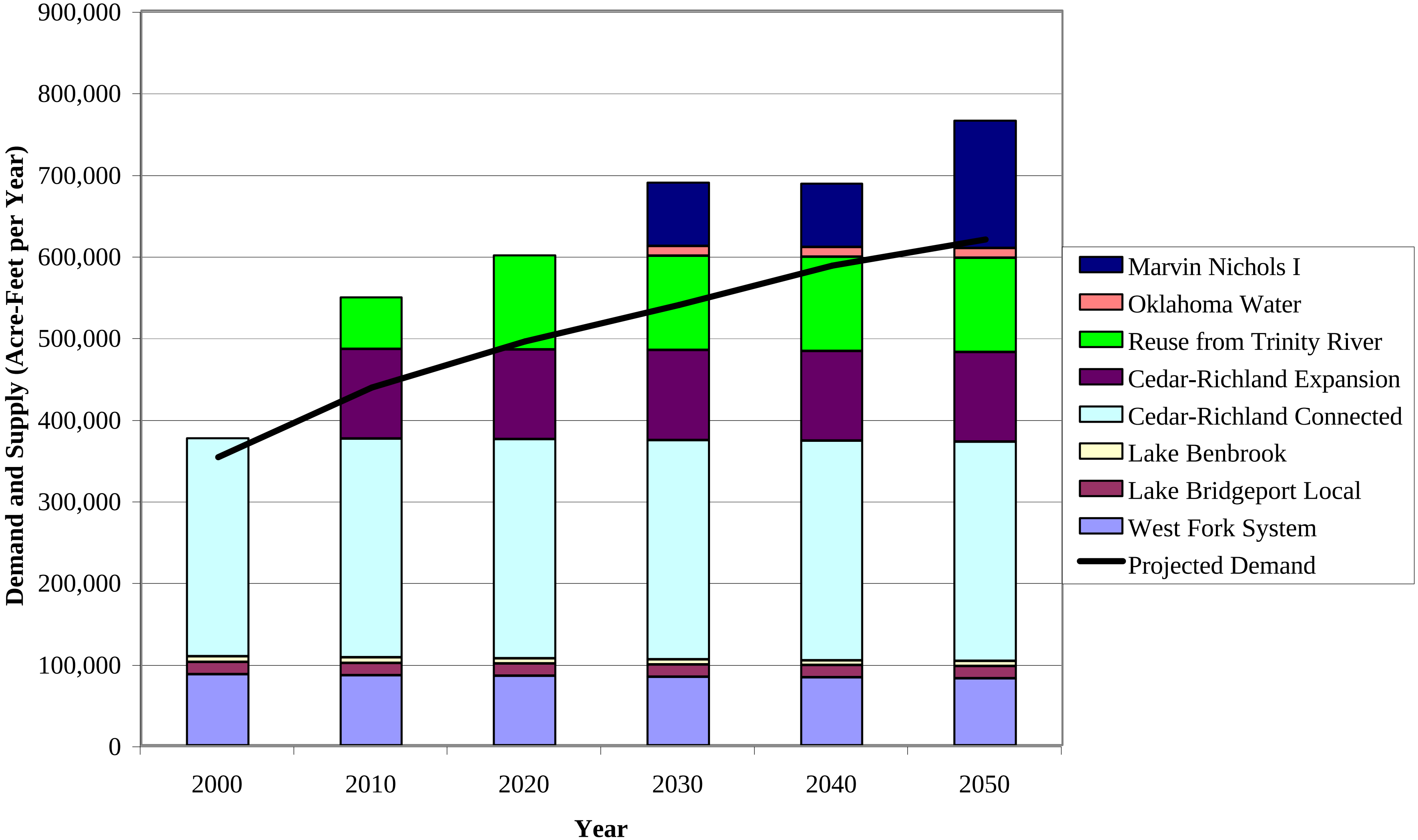
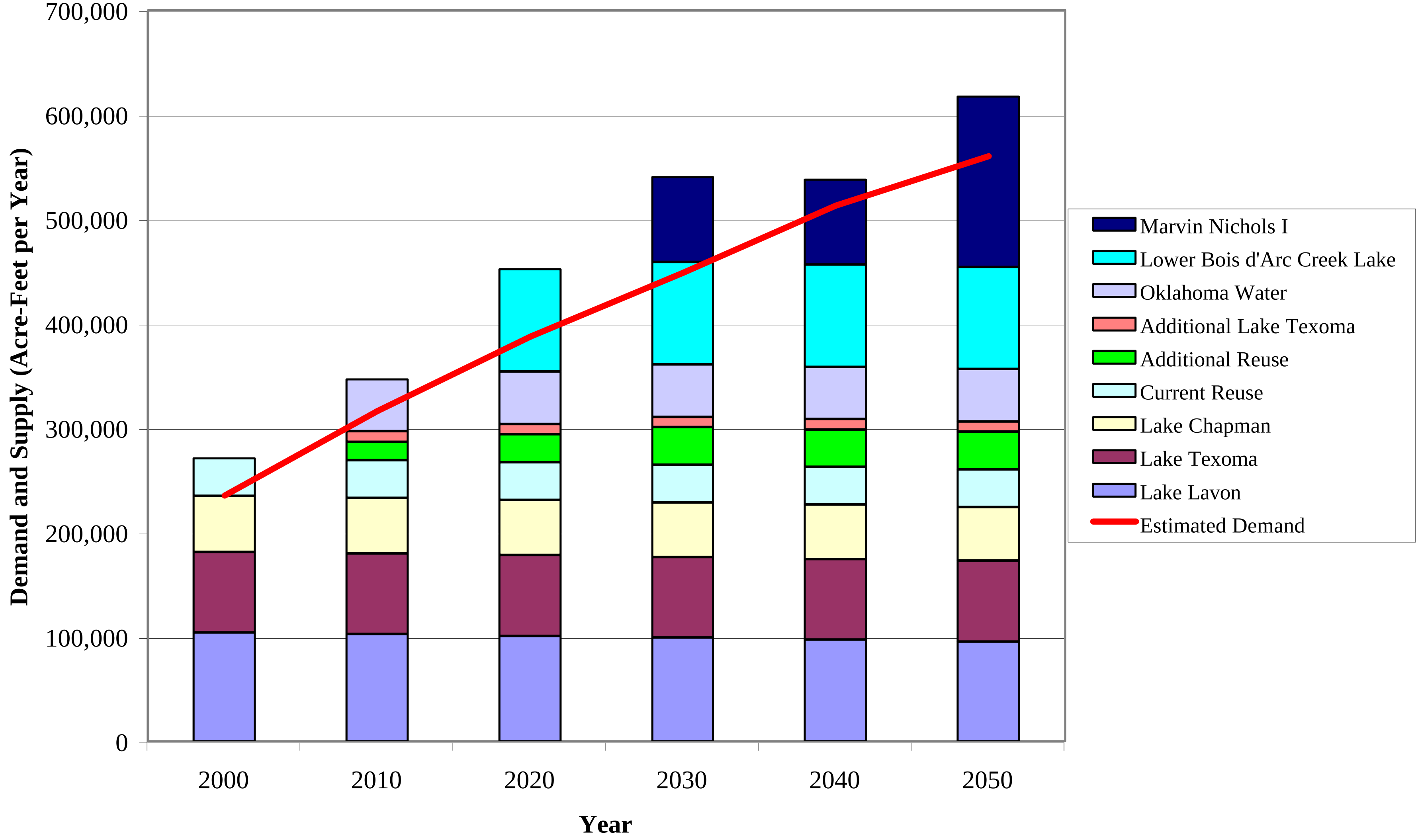


Figure 5.6
North Texas Municipal Water District Supply and Demand



6. Regulatory, Administrative, Legislative, and Other Recommendations

The Texas Water Development Board (TWDB) regional water planning guidelines [(1)] require that a regional water plan include recommendations for regulatory, administrative, and legislative changes that will facilitate water resource development and management:

> "357.7 (a) Regional water plan development shall include the following…
> (9) regulatory, administrative, or legislative recommendations that the regional water planning group believes are needed and desirable to: facilitate the orderly development, management, and conservation of water resources and preparation for and response to drought conditions in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of the state and regional water planning area. The regional water planning group may develop information as to the potential impact once proposed changes in law are enacted."

The guidelines also call for regional water planning groups to make recommendations on the designation of ecologically unique river and stream sites and unique sites for reservoir construction. This section presents the regulatory, administrative, legislative, and other recommendations of the Region C Water Planning Group and the reasons for the recommendations. The recommendations are presented in the following order:

- Summary of recommendations
- Recommendations related to the Senate Bill One planning process
- Recommendations related to TNRCC policy and water rights
- Recommendations for state and federal programs to address water supply issues
- Recommendations for ecologically unique river and stream segments
- Recommendations for unique sites for reservoir development

6.1 Summary of Recommendations

The Region C Water Planning Group makes the following recommendations:

- Recommendations related to the Senate Bill One planning process
    - Allow alternative strategies to be designated for near and long term planning needs.

- Encourage TWDB to exercise discretion in the consideration and approval of funding for alternatives not presented as part of the regional water plan.
    - Encourage TNRCC to exercise discretion in the consideration and approval of water right permit applications not part of the regional water plan.
    - Allow regional water planning groups to assume that contracts for water supply will be renewed when they expire.
    - Provide clarification of the impacts of designating a unique stream segment.
- Recommendations related to TNRCC policy and water rights
    - Make certain water rights exempt from cancellation for ten years of non-use.
    - Reduce the regulatory and legislative obstacles to indirect reuse of treated wastewater.
    - Remove barriers to interbasin transfers of water.
- Recommendations for state and federal programs to address water supply issues
    - Increase funding for Texas Water Development Board loans and the state participation program to assist with the development of water supply projects.
    - Accelerate studies of groundwater availability for the Trinity aquifer in North Texas.
    - Increase state participation in water conservation efforts.
    - Provide a program for education of board members of Water Supply Corporations, Special Utility Districts, and Municipal Utility Districts.
    - Increase state participation in watershed protection planning.
    - Encourage federal funding for development, maintenance, and upgrading of NRCS structures.
    - Provide state assistance with maintenance and construction of stock ponds.
    - Encourage Texas Department of Agriculture to include water supply questions on its survey of farmers and ranchers.
- Recommendations for ecologically unique river and stream segments
    - Provide clarification of the impacts of designating a unique stream segment.
- Recommendations for unique sites for reservoir construction
    - Marvin Nichols I
    - Lower Bois d'Arc Creek
    - Muenster

- o Tehuacana

These recommendations are discussed in greater detail below.

6.2 Recommendations Related to the Senate Bill One Planning Process

Alternative Strategies for Near and Long Term Needs

Section 357.7(a)(8) of the TWDB Regional Water Planning guidelines requires "specific recommendations of water management strategies to meet near term needs…". As we understand the TWDB interpretation of this requirement:

- Needs through 2030 are near-term needs.
- Listing of a number of alternative strategies among which a water supplier can choose is not allowed for near-term needs.

This requirement decreases the local control and flexibility that have been an important part of the successful efforts to meet water needs in Region C and throughout Texas. Water suppliers need to have a full range of options as they seek to provide new water supplies for Texas' future. It is impossible to foresee all the possibilities for new water supplies in a planning process such as this, and changing circumstances can change the preferred alternative for new supplies very quickly. New laws, court decisions, regulatory changes, permitting decisions, changes in growth patterns, and other factors may make a recommended strategy impossible and require a supplier to develop other alternatives. Limiting the options of water suppliers will make negotiations to obtain needed land or water more difficult and drive up the cost of new water supplies. The following steps should be taken to address these concerns:

- Willing buyer/willing seller transactions of water rights and treated water should not be controlled by this regulation. Such transactions may be beneficial to all concerned and may simply not have been foreseen in the planning process.
- The TWDB and the Texas Natural Resource Conservation Commission (TNRCC) should interpret existing legislation to give the maximum possible flexibility to water suppliers as they seek to serve the public and provide new supplies. Changes in the timing of supply development, the order in which strategies are implemented, the amount of supply from a management strategy, or the details of a project should <u>not</u> be interpreted as making that project inconsistent with the regional plan.

- The TWDB and TNRCC should make liberal use of their ability to waive consistency requirements if local water suppliers elect strategies that differ from those in the regional plan.
- Legislative and regulatory changes should be made to allow plans to present alternative sources of supply where appropriate.

Requirement that a Project Must Be Consistent with the Regional Water Plan to Receive Funding from TWDB

The Senate Bill One legislation requires that a project must be consistent with an approved regional plan in order to receive funding from TWDB. The TWDB has changed its rules to reflect this legislative mandate.

This requirement raises many of the concerns cited above in the discussion of alternative strategies for near and long term needs:

- It decreases local control and flexibility.
- It deprives water suppliers of options.
- It deprives TWDB in flexibility in funding desirable and needed projects.
- Plans must change over time because it is impossible to foresee changing circumstances.
- Limiting the options of water suppliers will make negotiations to obtain needed land or water supplies more difficult and drive up the price of water.

The following steps should be taken to address these concerns:

- Willing buyer/willing seller transactions of water rights and treated water should not be controlled by this regulation. Such transactions may be beneficial to all concerned and may simply not have been foreseen in the planning process.
- The TWDB should interpret existing legislation to give the maximum possible flexibility to water suppliers as they seek to serve the public and provide new supplies. Changes in the timing of supply development, the order in which strategies are implemented, the amount of supply from a management strategy, or the details of a project should <u>not</u> be interpreted as making that project inconsistent with the regional plan.
- The TWDB should make liberal use of its ability to waive consistency requirements where local water suppliers elect strategies that differ from those in the regional plan.
- Legislative and regulatory changes should be made to allow the TWDB to exercise discretion in the consideration and approval of funding for alternatives not presented as part of the regional water plan.

Requirement that a Project Must Be Consistent with the Regional Water Plan to Receive a Water Right Permit from TNRCC

The Senate Bill One legislation requires that a project must be consistent with an approved regional plan in order to receive a water right permit from TNRCC. The TNRCC has adopted rules to reflect this legislative mandate. Section 297.41(a)(3)(E) of TNRCC regulations indicates that "(a) Except as otherwise provided by this chapter, the commission shall grant an application for a water right only if…(3) the proposed application…(E) addresses a water supply need in a way that is consistent with the state water plan and an approved regional water plan for any area in which the proposed appropriation is located, unless the commission determines that new, changed, or unaccounted for conditions warrant waiver of this requirement…." Section 297.41(b) further indicates that the commission shall not issue a municipal water right after September 1, 2001, in any region that does not have an approved regional water plan unless the commission waives the requirement.

This requirement raises many of the same concerns cited in the two discussions above:

- It decreases local control and flexibility
- It deprives water suppliers of options.
- It limits TNRCC's ability to permit the best alternative to meet water supply needs.
- Plans must change over time because it is impossible to foresee changing circumstances.
- Limiting the options of water suppliers will make negotiations to obtain needed land or water supplies more difficult and drive up the price of water.

The following steps should be taken to address these concerns:

- Willing buyer/willing seller transactions of water rights and treated water should not be controlled by this regulation. Such transactions may be beneficial to all concerned and may simply not have been foreseen in the planning process.
- The TNRCC should interpret existing legislation and regulations to give the maximum possible flexibility to water suppliers as they seek to serve the public and provide new supplies. Changes in the timing of supply development, the order in which strategies are implemented, the amount of supply from a

management strategy, or the details of a project should not be interpreted as making that project inconsistent with the regional plan.

- The TNRCC should make liberal use of its ability to waive consistency requirements where local water suppliers elect strategies that differ from those in the regional plan.
- Legislative and regulatory changes should be made to allow TNRCC to exercise discretion in the consideration and approval of water right permit applications not part of the regional water plan.

TWDB Regulations Regarding the Treatment of Contract Expiration in Senate Bill One Planning

TWDB has interpreted its current regulations to require regional water planning groups to assume that water will not be made available from one entity to another after the expiration of current contracts. A water management strategy to renew the contract is required to make the water available after the expiration of the current agreement. If the buyer and seller of the water currently plan to renew their commitment (which they usually do), this requirement forces Senate Bill One planning to be unrealistic and to depart from other planning conducted by water providers. The future supplies available to purchasers of water are underestimated, and the future commitments of those providing the water are also underestimated.

The TWDB should change its regulations to allow regional water planning groups to assume that current contracts will be extended beyond the current expiration date if that reflects the current intention of both parties to the contract.

Clarification of Impacts of Designating a Stream Segment as a Unique Stream Segment

As part of the Senate Bill One planning process, regional water planning groups are asked to make recommendations for designation of unique stream segments. It is difficult to make such recommendations because of the uncertain implications of designation of unique stream segments. The legislature should clarify the intent and impact of the unique stream segment designation. Specific questions that should be answered include the following:

- What is the objective of designating a unique stream segment?
- How would adjacent private properties be affected by the designation?

- How will future water rights be affected? For example, would instream flow requirements be imposed on future water rights upstream?
- How will designation affect regulatory programs to protect water quality?
- What types of activities would be restricted as a result of the designation?
    - Reservoirs on the segment
    - Reservoirs upstream from the segment
    - Wastewater treatment plant discharge permits
    - Power lines
    - Municipal separate storm sewer system permits
    - Pipelines
    - Roads
    - Bridges across the segment
    - Landfills
    - Septic systems
    - Other activities
- What area is affected by the designation? The stream? The entire watershed? An area surrounding the stream?
- Can the designation be reversed?

6.3 Recommendations Related to TNRCC Policy and Water Rights

Cancellation of Water Rights for Non-Use

The Texas Water Code currently allows TNRCC to cancel any water right, in whole or in part, for ten consecutive years of non-use. This rule inhibits long-term water supply planning and is particularly undesirable in the case of major reservoirs constructed for municipal water supply. In order to take full advantage of the yield available at a given site, reservoirs are often constructed to meet needs far into the future. In many cases, only part of the supply is used in the first ten years, with the remainder allocated to meeting future growth.

This should be addressed by changing the water code to exempt certain projects from cancellation for ten years of non-use. The exemption might extend to:

- Municipal water rights

- Water rights for steam electric power generation
- Water rights associated with major reservoirs
- Water rights included as long-term supplies in an approved regional water plan.

Policies Limiting Indirect Reuse of Treated Wastewater

The TNRCC has recently implemented policies, some in response to legislative requirements in Senate Bill One, that limit TNRCC's ability to permit projects for indirect reuse, in which water is returned to a reservoir or watercourse before being rediverted for reuse. The policy of discouraging indirect reuse has a number of negative impacts on water suppliers in Region C and throughout the state:

- The policies are logically inconsistent with policies encouraging direct reuse of treated wastewater.
- The policies inhibit reuse for municipal purposes by prohibiting the most effective approach to municipal reuse, which incorporates "multiple barriers" between wastewater discharge and eventual reuse. Streams and reservoirs are among the most effective of such multiple barriers.
- The policies encourage reuse for irrigation and industrial purposes, where direct reuse is appropriate, while discouraging reuse to meet municipal needs, where indirect reuse is a preferred approach.
- It is poor public policy to discourage indirect reuse, which is a water supply alternative with relatively low environmental impacts.
- It is poor public policy to require the construction of infrastructure for direct reuse in cases when natural watercourses can deliver water much more economically.
- Indirect reuse of treated wastewater is an important element of water supply planning in Region C. In many cases, it provides new water supplies with significantly less environmental impact than would alternative sources, such as new reservoirs.

The legislature should revisit the issue of indirect reuse of treated wastewater using the bed and banks of state watercourses, with a view to reducing the obstacles to indirect reuse. In particular, reuse of water that originates from interbasin transfers should be regarded as developed water and regulated under Section 11.042 of the water code, which currently applies only to reuse of water that originated as groundwater. The historical discharge of treated wastewater effluent should not make the indirect reuse of wastewater more difficult.

Requirements for Interbasin Transfers Introduced in Senate Bill One

Senate Bill One introduced a number of new requirements for applications for water right permits to allow interbasin transfers. The requirements are in Section 11.085 of the water code, and they include many provisions not required for any other type of water right. Requirements imposed on interbasin transfers and not on any other water right include the following:

- Analysis of the impact of the transfers on user rates by class of ratepayer
- Public meetings in the basin of origin and the receiving basin
- Extra notice to county judges, mayors, and groundwater districts in the basin of origin
- Extra notice to legislators in the basin of origin and the receiving basin
- TNRCC request for comments from each county judge in the basin of origin
- Proposed mitigation to the basin of origin
- Demonstration that the applicant has prepared plans that will result in the "highest practicable water conservation and efficiency achievable…"

Exceptions to these extra requirements placed on interbasin transfers were made for emergency transfers, small transfers (less than 3,000 acre-feet under one water right), transfers to an adjoining coastal basin, transfers to a county partially in the basin of origin, and transfers to a municipality whose retail service area is partially within the basin of origin.

The effect of these changes is to make obtaining a permit for interbasin transfer significantly more difficult than it was under prior law and thus to discourage the use of interbasin transfers for water supply. This is undesirable for several reasons:

- Current supplies greatly exceed projected demands in some basins, and the supplies already developed in those basins can only be used by interbasin transfers.
- Interbasin transfers have been used extensively in Texas and are an important part of the state's current water supply. For example, current permits allow interbasin transfers of over 600,000 acre-feet per year from the Red, Sulphur, Sabine, and Neches Basins to meet needs in the Trinity Basin in Region C. This represents almost 1/3 of the region's reliable water supply.
- Emerging Senate Bill One water supply plans for major metropolitan areas in Texas (Dallas-Fort Worth, Houston, and San Antonio) rely on interbasin transfers

as a key component of their plans. It is difficult to envision developing a water supply plan for these areas without significant new interbasin transfers.

- Texas water law has always regarded surface water as belonging to the people of the state, to be used for the benefit of the state as a whole. It is important that the law on interbasin transfers reflect this basic approach.
- The current requirements for permitting interbasin transfers provide an unnecessary barrier to development of the best, most economical, and most environmentally acceptable water supplies.
- Since no interbasin transfer permits have been granted under these new requirements, the meaning of some of the provisions and the way in which they will be applied by TNRCC are undefined.

The legislature should revisit the current law on interbasin transfers and remove some of the unnecessary and counterproductive barriers to such transfers that now exist.

6.4 Recommendations for State and Federal Programs to Address Water Supply Issues

Increased State Funding for Texas Water Development Board Loans and the State Participation Program

The Senate Bill One regional water planning studies are showing significant needs for new water supply projects to allow Texas to grow and prosper. The loan and state participation programs of the Texas Water Development Board have been important tools in the development of existing supplies. These programs need to be continued and extended with additional funding to assist with the development of the next generation of projects as the state seeks to implement the Senate Bill One regional plans.

Studies of Groundwater Availability

The TWDB is currently conducting a series of studies of groundwater availability for major aquifers in Texas. Studies of the Trinity aquifer in North-Central Texas, a major source of water for Region C, are currently scheduled for 2004. For several Region C counties, the current use from the Trinity aquifer is much greater than the available reliable supply from the aquifer, as previously estimated by the TWDB. This would indicate that alternative sources of supply should be developed quickly in those counties. However, in at least some of the counties with substantial overdrafts from the aquifer, water suppliers are not encountering significant water supply problems and are reluctant to invest in alternative supplies. It is important that updated water availability estimates be developed as soon as possible to help determine whether development of expensive alternative sources of supply is justified.

TWDB should continue its program of developing new groundwater availability models for major aquifers in Texas. If possible, TWDB should accelerate development of the model and of new availability estimates for the Trinity aquifer in North Texas.

Increased State Participation in Water Conservation Efforts

The current TWDB-approved projections of water demand assume significant reductions in per capita municipal use and industrial and irrigation use due to water conservation measures. In Region C, the projected reductions in per capita use result in a 15 percent reduction in projected municipal water use as of 2050. A major portion of that reduction is projected to come from the requirements for low-flow plumbing fixtures in current state and federal law. However, there are other factors tending to increase per capita use in Region C and elsewhere (smaller household size, development of new housing with large lots in many cities, increasing prosperity). It is important that programs be developed to help local water suppliers achieve the conservation savings included in the current water demand projections.

The legislature should provide funding to allow TWDB and other state agencies to undertake or expand the following programs:

- A study of the effectiveness of municipal water conservation programs in Texas and how state agencies can assist local suppliers in achieving conservation goals.
    - What are the trends in per capita use in the state, in various regions, and for various suppliers, after adjusting for climate?
    - Where has conservation been particularly effective?
    - What are the elements of effective programs, and how might they be applied elsewhere in the state?
    - What other factors besides conservation programs affect per capita municipal use (positively or negatively)?
    - Are conservation-oriented water rates effective? If so, how might they be implemented?

    - How can state agencies most effectively assist water suppliers in implementing conservation programs?

- Similar studies of the effectiveness of conservation in industrial and irrigation water use and how state agencies can assist in achieving conservation goals.
- State funding for educational programs on water conservation in the schools (such as the Major Rivers program and others).
- State funding for seminars on water conservation and conservation issues to educate policy makers, including elected officials, community leaders, board members of water supply entities, and water utility managers.

Development of a Program to Educate Board Members of Water Supply Entities

The state should develop a program for the education of board members of Water Supply Corporations, Special Utility Districts, and Municipal Utility Districts on water supply issues. The program could include seminars on various issues offered across the state, perhaps in conjunction with the Texas Rural Water Association and other groups. It may be appropriate to consider requirements for accreditation of board members to ensure that they understand water supply issues so that they can govern appropriately.

Increased State Participation in Watershed Protection

One key element of water supply planning is the protection of the quality and usability of supplies we have already developed. The state should develop a program to encourage the development and implementation of watershed protection plans for existing supplies by the owners of the supplies. Elements of such a program could include:

- State grants or matching funding for studies.
- Development of guidance in the development and implementation of watershed protection plans.
- Technical assistance with the development and implementation of watershed protection plans.
- Seminars on watershed protection.
- Development of statewide databases of information that might be useful in watershed protection plans in a standard and consistent format. Such information might include:

- Land use
- Water quality data
- Roads
- Petroleum product pipelines
- Oil and gas wells
- Landfills
- Superfund sites and other potential sources of pollution
- Permitted wastewater discharges

Funding for NRCS Structures

Over the past 50 years, the U.S. Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) has built a great many small dams for sediment control and flood control in Texas. The NRCS reservoirs also provide water for livestock and increase streamflows during low flow periods. The design life for the majority of the NRCS watershed dams is 50 years. Most of the projects were built in the 1950s and 1960s and are nearing the end of their design life. Many of the NRCS structures are in need of maintenance or repair in order to extend the life of the dams. There is legislation under consideration in the U.S. Congress to provide federal funding for renovating and upgrading NRCS flood control structures. The Region C Water Planning Group recommends that the State of Texas seek federal funding to improve and maintain NRCS structures.

In addition, there are some watersheds where local agencies can work with NRCS to develop additional sediment and flood control structures and implement other measures to control erosion. For example, the Tarrant Regional Water District is working with the NRCS to establish erosion control structures in the West Fork watershed. The West Fork Watershed Committee has worked to re-activate the NRCS watershed management program and to secure funding for the project. The state of Texas should seek to extend existing NRCS programs to assist with the development of erosion and sediment control programs.

Maintenance and Construction of Stock Ponds

The dry conditions of recent years have resulted in localized shortages of water for livestock across the state. One way to address these shortages is to develop stock ponds to capture runoff and hold it to provide water in dry periods. The costs of maintaining and building stock ponds can be quite high. State assistance and funding should be made available to help build and maintain stock ponds eligible for agricultural exemption status. Funding for building, improving, dredging, and increasing capacities of stock ponds can help ensure sufficient water supply for livestock.

Survey on Agricultural Water Use

The Texas Agricultural Statistics Service sends out a survey to farmers and ranchers across Texas. Currently, no questions regarding water supply are asked in this survey. Questions could be added to the survey to help quantify the amount of water being used for livestock and irrigation and to identify needed water supply improvements. Potential questions include:

- Do you use groundwater or surface water for your ranch/farm?
- If you are using groundwater:
    - What aquifer(s) are you pumping?
    - What is your total pumping capacity?
    - How deep are your water wells?
- If you are using surface water:
    - How many stock tanks do you have?
    - What is the capacity of each stock tank?
- Are you currently experiencing water shortages?
- How many head of livestock are you watering?
- How many acres of each crop are you irrigating?

Including questions on water supply in the Texas Agricultural Statistics Service survey could improve the basic data available on water use for agriculture and help with future water supply planning.

6.5 Recommendations for Ecologically Unique River and Stream Segments

As part of the Senate Bill One planning process, regional water planning groups are asked to make recommendations for designation of unique stream segments. The Texas Parks and Wildlife Department (TPWD) recommended certain specific stream segments in Region C for designation as unique stream segments. Table 6.1 lists segments recommended by TPWD in *Ecologically Significant River and Stream Segments of Region C, Regional Water Planning Area*[73] .That report included information intended to support designation of the recommended segments. TPWD also submitted a list of other segments recommended for designation with limited supporting information[74]. Those segments are listed in Table 6.2.

The Region C Water Planning Group recommends against designation of any unique stream segments in Region C because of the uncertain implications of such designation. The legislature should clarify the intent and impact of the unique stream segment designation. Specific questions that should be addressed by the legislature are outlined in Section 6.2 above.

6.6 Recommendations for Unique Sites for Reservoir Construction

Section 357.9 of the Texas Water Development Board (TWDB) regional water planning guidelines [1] allows a regional water planning group to recommend unique sites for reservoir construction:

> **"357.9. Unique Sites for Reservoir Construction.** A regional water planning group may recommend sites of unique value for construction of reservoirs by including descriptions of the sites, reasons for the unique designation and expected beneficiaries of the water supply to be developed at the site. The following criteria shall be used to determine if a site is unique for reservoir construction:
>
> (1) site-specific reservoir development is recommended as a specific water management strategy or in an alternative long-term scenario in an adopted regional water plan; or

Table 6.1

Texas Parks and Wildlife Department Recommendations for Designation as Ecologically Unique River and Stream Segments from *Ecologically Significant River and Stream Segments of Region C, Regional Water Planning Area*[73]

River or Stream Segment	Description	Basin	County	TPWD Reasons for Designation[a]: Biological Function	Hydrologic Function	Riparian Conservation Area	High Water Quality/Aesthetic Value	Endangered Species/ Unique Communities
Bois d'Arc Creek	Entire length	Red	Fannin	X	X	X		
Brazos River	Parker/Palo Pinto county line to F.M. 2580	Brazos	Parker	X			X	X
Buffalo/Linn Creek	Vicinity of confluence	Trinity	Freestone	X	X			
Clear Creek	Denton/ Cooke county line to confluence with Elm Fork Trinity River	Trinity	Denton				X	
Coffee Mill Creek	Entire length	Red	Fannin			X		
Elm Fork Trinity River (Denton County)	Lake Ray Roberts to U.S. 380	Trinity	Denton			X	X	
Elm Fork Trinity River (Dallas County)	California Crossing Road to confluence with West Fork Trinity River	Trinity	Dallas			X	X	
Lost Creek	Entire length	Trinity	Jack			X	X	
Purtis Creek[b]	Upstream from Henderson county line	Trinity	Henderson			X		
Trinity River	MacArthur Boulevard to Interstate 45	Trinity	Dallas			X	X	

[a] The criteria listed are from Texas Administration Code Section 357.8. The Texas Parks and Wildlife feels that their recommended reaches meet the criteria marked with an X.
[b] The reach of Purtis Creek recommended for designation by TPWD is in Region D rather than Region C.

Table 6.2

Other Texas Parks and Wildlife Department Suggestions for Designation as Ecologically Unique River and Stream Segments

River or Stream Segment	Basin	County
Red River - Fannin County	Red	Fannin
Red River - Grayson County	Red	Grayson
Red River - Cooke County	Red	Cooke
North Fish Creek	Red	Cooke
South Fish Creek	Red	Cooke
North Sulphur River	Sulphur	Fannin
Beans Creek	Trinity	Jack
Big Creek	Trinity	Wise
Red Oak Creek	Trinity	Ellis
Rowlett Creek	Trinity	Collin

(2) the location, hydrologic, geologic, topographic, water availability, water quality, environmental, cultural, and current development characteristics, or other pertinent factors make the site uniquely suited for :

(A) reservoir development to provide water supply for the current planning period; or

(B) where it might reasonably be needed to meet needs beyond the 50-year planning period."

This section presents the Region C Water Planning Group's recommendations for unique sites for reservoir development and the reasons for the recommendations. The Region C Water Planning Group recommends designation of the following four unique sites for reservoir development:

- Marvin Nichols I site on the Sulphur River in Red River, Bowie, Titus, and Franklin Counties
- Lower Bois d'Arc Creek (New Bonham) site on Bois d'Arc Creek in Fannin County
- Muenster site on Brushy Elm Creek in Cooke County
- Tehuacana site on Tehuacana Creek in Freestone County.

These sites and the reasons for designating them as unique reservoir sites are discussed below.

Marvin Nichols I

Description of the Site. The Marvin Nichols I site is located on the Sulphur River upstream from its confluence with White Oak Creek. The dam would be in Titus, Red River, and Bowie Counties, and the reservoir would also impound water in Franklin County. The proposed reservoir has been studied in the past and was included in the most recent Texas Water Plan as a source of water supply for Region C and Region D. The reservoir has been studied with a conservation pool elevation of 312.0, although a reservoir could be built at this location with conservation storage as high as 320.0.

With the top of conservation storage at elevation 312.0, the proposed reservoir would have a yield of 619,100 acre-feet per year and would flood 62,100 acres. The reservoir has a very large yield compared with other potential projects. The most significant environmental impact of the Marvin Nichols I project would be the inundation of habitat, including wetlands and bottomland hardwoods. The lake would inundate a portion of the Sulphur River Bottom West/Cuckoo Pond bottomland hardwoods area, which is designated as a Priority 1 area in the 1984 U.S. Fish and Wildlife Service *Bottomland Hardwood Protection Plan* [65]. (A Priority 1 area is an "excellent quality bottomlands of high value to the key waterfowl species.") There are also lignite deposits and some oil and gas wells in the pool area of the lake.

Reasons for Unique Designation. Marvin Nichols I would provide a substantial portion of the projected water needs of Region C and Region D. It is included in the Region C water plan as a source of water for all of the major water providers in the region. North Texas Municipal Water District, Dallas Water Utilities, and Tarrant Regional Water District would participate in the project directly, with Fort Worth and the Trinity River Authority acquiring water from Tarrant Regional Water District. Through those major water providers, the reservoir would supply many of the water user groups in Region C.

Compared to the alternative of developing a number of other reservoirs in the Sulphur Basin (George Parkhouse I, George Parkhouse II, and Marvin Nichols II), Marvin Nichols I provides more water at a lower cost and with less environmental impact. The location, geologic, hydrologic, topographic, water availability, water quality, and current development characteristics make this site uniquely suited to provide a major water supply for Regions C and D.

Expected Beneficiaries of Water Supply. The expected beneficiaries of this project in Region C include the following water providers and water user groups:

- *Dallas Water Utilities and its customers*
    - *Multi-County* - Dallas, Carrollton, Cedar Hill, Combine, Glenn Heights, Grand Prairie, Grapevine, Lewisville, Ovilla
    - *Dallas County* - Addison, Balch Springs, Cockrell Hill, Coppell, De Soto, Duncanville, Farmers Branch, Hutchins, Irving, Lancaster, Seagoville, Wilmer, Dallas County Other, Dallas County Manufacturing, Dallas County Steam Electric Power, Dallas County Mining
    - *Denton County* - Denton, Flower Mound, The Colony, Denton County Other, Denton County Manufacturing
    - *Ellis County* - Oak Leaf
    - *Upper Trinity Water District and its current and potential customers*
        - *Multi-County* - Lewisville (also directly from Dallas)
        - *Collin County* - Celina, Prosper
        - *Cooke County* - Valley View, Cooke County Other
        - *Denton County* - Argyle, Aubrey, Bartonville, Copper Canyon, Corinth, Crossroads, Double Oak, Flower Mound (also directly from Dallas), Hebron, Hickory Creek, Highland Village, Justin, Krugerville, Krum, Lake Dallas, Lincoln Park, Northlake, Oak Point, Pilot Point, Ponder, Sanger, Shady Shores, Denton County Other (also directly from Dallas), Denton County Manufacturing (also directly from Dallas)
- *North Texas Municipal Water District and its customers*
    - *Multi-County* - Frisco, Garland, Plano, Richardson, Rowlett, Royse City, Sachse, Wylie
    - *Collin County* - Allen, Fairview, Farmersville, Lucas, McKinney, Melissa, Murphy, New Hope, Parker, Princeton, Prosper (also from UTRWD), Collin County Other, Collin County Manufacturing, Collin County Steam Electric Power
    - *Dallas County* - Mesquite, Sunnyvale, Dallas County Other (also from Dallas), Dallas County Manufacturing (also from Dallas), Dallas County Steam Electric Power (also from Dallas)
    - *Denton County* - Little Elm

- *Kaufman County* – Crandall, Forney, Kaufman, Oak Grove, Kaufman County Other, Kaufman County Manufacturing
- *Rockwall County* – Heath, Rockwall, Rockwall County Other, Rockwall County Manufacturing

- *Tarrant Regional Water District and its current and potential customers in Tarrant, Denton, Parker, Wise, and Johnson Counties*
  - *Multi-County* – Burleson (part in Region G, through Fort Worth), Mansfield (part in Region G), Azle, Briar, Grapevine (through TRA, also from Dallas), Newark, Grand Prairie (through Fort Worth, also from Dallas), Southlake (through Fort Worth)
  - *Denton County (through Fort Worth)* – Northlake (also from UTRWD), Roanoke, Trophy Club, Denton County Other
  - *Parker County* - Reno, Springtown, Weatherford, Parker County Steam Electric Power
    - *Through Weatherford* – Aledo, Annetta, Hudson Oaks, Willow Park, Parker County Other, Parker County Manufacturing
  - *Tarrant County* – Arlington, Benbrook, Blue Mound, Fort Worth, River Oaks, Tarrant County Irrigation, Tarrant County Mining, Tarrant County Steam Electric Power
    - *Through Fort Worth* – Benbrook (also direct from TRWD), Crowley, Dalworthington Gardens, Edgecliff Village, Everman, Forest Hill, Haltom City, Haslet, Hurst, Keller, Kennedale, Lake Worth Village, North Richland Hills, River Oaks (also direct from TRWD), Pantego, Richland Hills, Saginaw, Sansom Park Village, Watauga, Westworth Village, White Settlement, Tarrant County Other, Tarrant County Manufacturing
    - *Through Trinity River Authority* - Bedford, Colleyville, Euless, North Richland Hills (also through Fort Worth), Watauga (also through Fort Worth), Tarrant County Other (also through Fort Worth), Tarrant County Manufacturing (also through Fort Worth)
    - *Through Arlington* – Kennedale (also through Fort Worth), Pantego (also through Fort Worth)
  - *Wise County* - Aurora, Boyd, Bridgeport, Chico, Decatur, Rhome, Wise County Other, Wise County Manufacturing, Wise County Mining, Wise County Steam Electric Power.

Lower Bois d'Arc Creek (New Bonham)

Description of the Site. Lower Bois d'Arc Creek Reservoir would be located on Bois d'Arc Creek in Fannin County, immediately upstream from the Caddo National

Grassland. The proposed reservoir has been studied in the past with a conservation pool elevation of 534.0, and the Red River Compact gives Texas unlimited use of the waters of Bois d'Arc Creek upstream from the Lower Bois d'Arc Creek site.

With the top of conservation storage at elevation 534.0, the proposed reservoir would have a yield of 123,000 acre-feet per year and would flood 16,400 acres. The most significant environmental impacts of Lower Bois d'Arc Creek Reservoir would be the inundation of habitat, including wetlands and bottomland hardwoods. The lake would inundate the Bois d'Arc Creek bottomland hardwoods area, which is designated as a Priority 4 area in the 1984 U.S. Fish and Wildlife Service *Bottomland Hardwood Protection Plan* [(65)]. (A Priority 4 area is a "moderate quality bottomlands with minor waterfowl benefits.") The lake would have no direct impacts on the Caddo National Grasslands, but changes in flow patterns on Bois d'Arc Creek could have an indirect impact on the grasslands. In order to protect the grasslands, the Texas Parks and Wildlife Department nominated Bois d'Arc Creek for designation as an ecologically unique stream segment. Meeting the release requirements from the Texas Water Development Board consensus criteria for releases would minimize the downstream impacts of Lower Bois d'Arc Creek Reservoir.

Reasons for Unique Designation. The North Texas Municipal Water District would be the primary developer of the Lower Bois d'Arc Creek Reservoir, and it is assumed that the District would use 80 percent of the yield of the project. The remaining 20 percent of the yield would be reserved for use in the Red River Basin in the area of the project, particularly Fannin County. The North Texas Municipal Water District needs a major new supply by 2020, approximately 10 years earlier than the other major water providers in Region C. Because Lower Bois d'Arc Creek is smaller, costs less, and has less environmental impact than Marvin Nichols I, it could be developed by NTMWD alone and developed more quickly than the larger reservoir. Water in Lower Bois d'Arc Creek Reservoir would be relatively inexpensive in the lake and would also be relatively inexpensive delivered to the North Texas Municipal Water District.

The location, geologic, hydrologic, topographic, water availability, water quality, environmental, and current development characteristics make this site uniquely suited to provide water supply for Region C.

Expected Beneficiaries of Water Supply. The expected beneficiaries of this project include North Texas Municipal Water District and its customers and water user groups in Fannin County:

- *North Texas Municipal Water District and its customers*
  - *Multi-County* - Frisco, Garland, Plano, Richardson, Royse City, Sachse, Wylie, Rowlett
  - *Collin County* - Allen, Fairview, Farmersville, Lucas, McKinney, Melissa, Murphy, New Hope, Parker, Princeton, Prosper, Collin County Other, Collin County Manufacturing, Collin County Steam Electric Power
  - *Dallas County* - Mesquite, Sunnyvale, Dallas County Other (also from Dallas), Dallas County Manufacturing (also from Dallas), Dallas County Steam Electric Power (also from Dallas)
  - *Denton County* – Little Elm
  - *Kaufman County* – Crandall, Forney, Kaufman, Oak Grove, Kaufman County Other, Kaufman County Manufacturing
  - *Rockwall County* – Heath, Rockwall, Rockwall County Other, Rockwall County Manufacturing
- *Water User Groups in Fannin County* – Bonham, Honey Grove, Leonard, Savoy, Trenton, Fannin County Other, Fannin County Manufacturing.

Muenster

Description of the Site. Muenster Reservoir would be located on Brushy Elm Creek in Cooke County. The proposed reservoir has been permitted by the Texas Natural Resource Conservation District for impoundment of 4,700 acre-feet and diversion of 500 acre-feet per year for municipal use. The reservoir would flood 418 acres at the top of conservation storage. Because of its small size, the reservoir would have little environmental impact.

Reasons for Unique Designation. The Muenster Water District and the Natural Resource Conservation Service are developing Muenster Lake for municipal water supply, flood control, and recreation. The project has been permitted by the Texas Natural Resource Conservation Commission and approved by local voters. Muenster Lake would reduce Muenster's dependence on the Trinity aquifer, which is overused in Cooke County.

The location, geologic, hydrologic, topographic, water availability, water quality, environmental, and current development characteristics make this site uniquely suited to provide water supply for Region C.

Expected Beneficiaries of Water Supply. The expected beneficiaries of this project include Muenster, Cooke County Manufacturing, and Cooke County Other. The project would indirectly benefit other water user groups in Cooke County by reducing use from the Trinity aquifer.

Tehuacana

Description of the Site. Tehuacana Reservoir would be located on Tehuacana Creek in Freestone County, south of Richland-Chambers Reservoir. The proposed reservoir was included in the last state water plan as a source of supply for the Tarrant Regional Water District. The project has been part of TRWD's planning for many years, and it fits well with the District's system. The reservoir would have a conservation pool elevation of 315.0, the same as Richland-Chambers, and the two lakes would be connected by a channel.

With the top of conservation storage at elevation 315.0, the proposed reservoir would have a yield of 68,300 acre-feet per year and would flood 14,900 acres. The most significant environmental impacts of Tehuacana Reservoir would be the inundation of habitat, including wetlands and bottomland hardwoods. There are also lignite resources and oil and gas wells in the area that would be inundated by Tehuacana Reservoir.

Reasons for Unique Designation. Tehuacana Reservoir has been in the plans of the Tarrant Regional Water District for decades. The lake would be connected to Richland-Chambers Reservoir by a channel, allowing the water supply provided by Tehuacana to be pumped from Richland-Chambers. Development of Tehuacana could allow extension of the Tarrant Regional Water District project of diversions from the Trinity for additional water supply. Although this reservoir is not recommended for development before 2050 if other sources can be developed, it remains desirable as an alternative project and as a source of supply for growth after 2050.

The location, geologic, hydrologic, topographic, water availability, water quality, and current development characteristics make this site uniquely suited to provide water supply for Region C.

Expected Beneficiaries of Water Supply. The expected beneficiaries of this project would be Tarrant Regional Water District and its existing and potential customers as well as water user groups in Freestone County:

- *Multi-County* – Burleson (part in Region G, through Fort Worth), Mansfield (part in Region G), Azle, Briar, Grand Prairie (through Fort Worth), Grapevine (through TRA), Southlake (through Fort Worth), Mabank, Newark
- *Denton County (through Fort Worth)* – Northlake, Roanoke, Trophy Club, Denton County Other
- *Ellis County (through TRA)* – Ennis, Ferris, Italy, Maypearl, Midlothian, Palmer, Red Oak, Waxahachie, Ellis County Other, Ellis County Manufacturing
- *Freestone County* – Fairfield, Teague, Wortham, Freestone County Other, Freestone County Steam Electric Power
- *Henderson County* – Gun Barrel City, Malakoff, Payne Springs, Seven Points, Tool, Henderson County Other, Henderson County Steam Electric Power
- *Kaufman County* – Kemp, Kaufman County Other, Kaufman County Mining
- *Navarro County* – Corsicana
    - *Through Corsicana* – Blooming Grove, Dawson, Frost, Navarro County Other, Navarro County Manufacturing
- *Parker County* - Reno, Springtown, Weatherford, Parker County Steam Electric Power
    - *Through Weatherford* – Aledo, Annetta, Hudson Oaks, Willow Park, Parker County Other, Parker County Manufacturing
- *Tarrant County* – Arlington, Benbrook, Blue Mound, Fort Worth, River Oaks, Tarrant County Irrigation, Tarrant County Mining, Tarrant County Steam Electric Power
    - *Through Fort Worth* – Benbrook (also directly from TRWD), Crowley, Dalworthington Gardens, Edgecliff Village, Everman, Forest Hill, Haltom City, Haslet, Hurst, Keller, Kennedale, Lake Worth Village, North Richland Hills, Pantego, Richland Hills, River Oaks (also directly from TRWD), Saginaw, Sansom Park Village, Watauga, Westworth Village, White Settlement, Tarrant County Other, Tarrant County Manufacturing
    - *Through Trinity River Authority* - Bedford, Colleyville, Euless, North Richland Hills (also through Fort Worth), Watauga (also through Fort

Worth), Tarrant County Other (also through Fort Worth), Tarrant County Manufacturing (also through Fort Worth)

    - *Through Arlington* – Kennedale (also through Fort Worth), Pantego (also through Fort Worth)

- *Wise County* - Aurora, Boyd, Bridgeport, Chico, Decatur, Rhome, Wise County Other, Wise County Manufacturing, Wise County Mining, Wise County Steam Electric Power.

7. Plan Approval Process and Public Participation

This section describes the plan approval process for the Region C Water Plan and the efforts made to inform the public and encourage public participation in the planning process. Special efforts were made to inform the general public and water suppliers and others with special interest in the planning process and to seek their input.

7.1 Regional Water Planning Group

The original legislation for Senate Bill One and the Texas Water Development Board planning guidelines establish regional water planning groups to control the planning process [(1)]. The regional water planning groups were to include representatives of eleven specific interests:

- General public
- Counties
- Municipalities
- Industrial
- Agricultural
- Environmental
- Small businesses
- Electric generating utilities
- River authorities
- Water districts
- Water utilities

Table 7.1 lists the members of the Region C Water Planning Group, the interests they represent, their organizations, and their counties. The Region C Water Planning Group held regular meetings during the development of the plan, receiving information from the region's consultants and making decisions on planning efforts. These meetings were open to the public, and proper notice was made under Senate Bill One guidelines [(1)]. All but one of the Region C Water Planning Group meetings were held at the Trinity River Authority Central Wastewater Treatment Plant in Grand Prairie, a central location in the

Table 7.1

Members of the Region C Water Planning Group

Member	Organization	Interest	County	
Terrace W. Stewart, Chairman	Dallas Water Utilities	Municipalities	Dallas	*
James Parks, Vice-Chairman	North Texas Municipal Water District	Water Districts	Collin	*
Roy F. Eaton, Secretary	Wise County Messenger	Small Businesses	Wise	
Brad Barnes	Rancher	Agricultural	Jack	
A. Leroy Burch	Retired	Industries	Dallas	
Jerry W. Chapman	Greater Texoma Utility Authority	Water Districts	Grayson	*
Dale Fisseler	City of Fort Worth	Municipalities	Tarrant	
Howard Martin	City of Denton	Municipalities	Denton	
Jim McCarter	Navarro Mills WSC	Water Utilities	Navarro	
Elaine Petrus	Streams and Valleys	Environmental	Tarrant	
Paul Phillips	City of Weatherford	Municipalities	Parker	
Irvin M. Rice	Retired	Public	Dallas	
Robert O. Scott	Tarrant Coalition for Environmental Awareness	Environmental	Tarrant	
George Shannon	Tarrant Regional Water District	Water Districts	Tarrant	*
Connie Standridge	Winkler WSC	Water Utilities	Freestone	
Danny Vance	Trinity River Authority	River Authorities	Tarrant	*
Judge Tom Vandergriff	Tarrant County	Counties	Tarrant	
Mary E. Vogelson	League of Women Voters	Public	Dallas	
Paul Zweiacker	TXU	Electric Generating Utilities	Dallas	*

Note: * The organizations these members represent extend into other counties in Region C.

region. The only meeting held elsewhere was a joint meeting with the Region D Water Planning Group, held in Greenville. The water planning group generally met monthly, skipping a few months and holding more frequent meetings when the intensity of the planning effort required. The committee held nine meetings in 1998, 11 meetings in 1999, and 15 meetings in 2000.

7.2 Outreach to Water Suppliers and Regional Planning Groups

The Region C Water Planning Group made special efforts to contact water suppliers in the region and obtain their input in the planning process. The five major water providers in the region (Dallas Water Utilities, Tarrant Regional Water District, North Texas Municipal Water District, Fort Worth, and Trinity River Authority) are all represented on the water planning group. In addition, the planning group encouraged the Region C consultants to keep in close touch with the major water providers and other water suppliers as planning proceeded. Water suppliers were included on the mailing list for Region C newsletters (discussed below under outreach to the public). Other specific measures to obtain input from water suppliers and from other regional water planning groups are discussed below.

Questionnaires

Appendix C includes copies of the questionnaires that were sent out early in the Region C planning process to all Region C counties, cities with populations over 1,000, regional water suppliers, retail water suppliers (supplying over 0.2 mgd), and large industries. The questionnaires sought information on population and water use projections and other water supply issues. The response rate for all questionnaire recipients was 51 percent, and 61 percent of the cities, counties, and regional water suppliers responded.

Technical Review Committee

As part of the development of population and water use projections for Region C, the water planning group appointed a technical review committee composed of experienced water resource planners. This committee worked with the Region C consultants to develop recommended population and water use projections and reported to the planning group. The report of the Technical Review Committee is included as Appendix E. Members of the Technical Review Committee included:

- Tom Taylor (Chair) – Upper Trinity Regional Water District
- Robert McCarthy – Dallas Water Utilities

- Richard Browning – Trinity River Authority
- Wayne Owen – Tarrant Regional Water District
- Dale Fisseler – Fort Worth
- Robert Mansell – North Texas Municipal Water District

The Technical Review Committee met with the consultants six times, and all of the meetings were posted as public meetings.

Sulphur River Task Group

The Region C and Region D water planning groups formed the Sulphur River Task Group, including members of both water planning groups. The task group coordinated water supply planning involving the Sulphur River Basin, which was seen as a likely source of water supply for both Region C and Region D. The Sulphur River Task Group has met eleven times during the planning process, and the two regions have cooperated in their planning efforts for the Sulphur Basin. Both planning groups support the development of Marvin Nichols I Reservoir on the Sulphur River in Region D. The Marvin Nichols I project will provide water supplies for both regions.

7.3 Outreach to the Public

Newsletters

The Region C Water Planning Group published newsletters as needed to inform the public of the progress of the planning process. The newsletters were sent to:

- Water right holders
- County judges
- Mayors and officials of cities in the region
- Other water planning regions
- TWDB staff
- Approximately 675 media
- Any person who requested to be on the mailing list.

A total of four newsletters have been distributed in Region. An additional newsletter may be distributed in late September or early October 2000. Appendix Y includes copies of the Region C newsletters, as well as a brochure on the regional water planning process produced by TWDB.

Public Awareness Presentations

Members of the Region C Water Planning Group have made a number of presentations on the planning process to interested groups throughout the region. Table 7.2 is a partial list of the presentations made by planning group members before September 2000.

Table 7.2

Public Awareness Presentations Made During the Region C Planning Process

Date	Location	Speaker	Audience
November 24, 1998	Weatherford	Paul Phillips	Rotary Club
March 31, 1999	Decatur	Roy Eaton/Terrace Stewart	Public / Water Suppliers
April 14, 1999	Gainesville	Jerry Chapman	Rotary Club
April 30, 1999	Arlington	Mary Vogelson Terrace Stewart Danny Vance Bill Meadows	League of Women Voters Symposium (350-400 people)
May 4, 1999	Nacogdoches	Danny Vance	Region I Water Planning Group
May 5, 1999	Sherman	Jerry Chapman	Lions Club
June 29, 1999	Weatherford	Paul Phillips/Terrace Stewart	Public
June 30, 1999	Denton County	Howard Martin	Public
June 30, 1999	Fort Worth	Danny Vance	Professional Networking Club
July 2, 1999	Bonham	Jerry Chapman	Fannin County Commissioners Court
August 9, 1999	Plano	Jim Parks	Plano City Council
August 9, 1999	Corsicana	Connie Standridge	Public / Water Suppliers
August 10, 1999	Fort Worth	Bill Meadows	Fort Worth City Council
August 11, 1999	Arlington	John Jadrosich	Optimist Club
August 19, 1999	Dallas	Jim Parks	Society of Professional Engineers

Table 7.2, Continued

Date	Location	Speaker	Audience
August 19, 1999	Sherman	Jerry Chapman	Texoma Council of Governments
August 23, 1999	Bonham	Jerry Chapman	Fannin County Commissioners Court
September 7, 1999	Muenster	Jerry Chapman	Muenster City Council
September 18, 1999	Fort Worth	Robert Scott	Tarrant Coalition for Environmental Awareness
October 5, 1999	Sherman	Jerry Chapman	Rotary Club
October 20, 1999	Allen	Jim Parks	Rotary Club
December 1, 1999	Wylie	Jim Parks	Leadership Rowlett
February 8, 2000	The Colony	Jim Parks	Rotary Club
February 10, 2000	Plano	Jim Parks	Rotary Club
March 25, 2000	Plano	Jim Parks	City of Plano
April 4, 2000	Mesquite	Jim Parks	Exchange Club
May 9, 2000	Farmersville	Jim Parks	Farmersville City Council
June 14, 2000	Denton County	Roy Eaton/George Shannon	Northwest Communities Partnership
July 6, 2000	Fort Worth	George Shannon	Optimist Club
July 10, 2000	Grayson County	Jerry Chapman	Cooke and Grayson County Water Suppliers
July 24, 2000	Plano	Jim Parks	City of Plano - City Manager's Staff
August 4, 2000	Plano	Jim Parks	Rotary Club
August 8, 2000	Fort Worth	George Shannon	Rotary Club
August 11, 2000	Austin	Danny Vance	Texas Coalition of Cities
August 17, 2000	Rockwall	Jim Parks	Rotary Club
August 24, 2000	Euless	Danny Vance	North Central Texas Council of Governments

Media Outreach

The media outreach plan for Region C called for using a number of communication vehicles to keep the media, and hence the public, informed of the progress and activities of the Region C Water Planning Group:

- **Newsletters –** Newsletters were sent to approximately 675 media as well as to members of the general public on the mailing list.

- **Public meetings –** The media were invited via a printed Public Meeting Notice to attend the public hearing on September 14, 1999. Media were also invited to attend the five county meetings and the public hearing in September 2000 via a press release.
- **Press materials –** A complete press kit was issued to the media in September 1999. It included frequently asked questions and answers, a six-page summary of the planning process, impact and opportunities of regional water planning, copies of the newsletter, and a press release on the state's mandated water planning. An updated press kit were later distributed to select media. The revised press kit included a summary of the plan, revised questions and answers, recommended water management strategies by county and water supply source, a roster of board member contacts, and a list of the libraries and county clerks offices where the entire plan was on file for review by the public
- **Press releases and media advisories –** Press releases were issued on April 9, 1999, August 10 and 30, 1999, August 23, 2000, and September 19, 2000 to inform the media of ongoing activities of the Region C Water Planning Group. A media advisory was issued on August 8, 1999 to inform the public of the Public Meeting held in Corsicana on August 10. A media advisory was sent to remind the media of the public meetings on September 6, 11, 13, 18, and 20, 2000. A media advisory was sent to remind the media of the public hearing on September 25, 2000.
- **Ongoing media relations** - Reporters from *The Dallas Morning News*, including Staff Writer Terri Langford and Associate Editorial Editor William McKenzie, have been proactive in attending the board meetings and have diligently covered the issues and activities surrounding the Region's water planning efforts. Relationships with the *Star-Telegram* have resulted in coverage in the western section of the region.
- **Editorial board meetings –** An editorial board meeting was held with *The Dallas Morning News* on September 5, 2000. An editorial board meeting was held on September 11, 2000 with the *Fort Worth Star-Telegram*.

The Region C Water Planning Group and its efforts have netted a significant amount of press coverage since August 1999. Appendix Z includes copies of the press clippings for Region C. In 1999, the following publications produced articles on the Region C planning process:

- *Arlington Morning News*
- *Azle News* (2 articles)
- *Bridgeport Index*
- *Cedar Creek Pilot* (3 articles)
- *Corsicana Daily Sun*

- *Dallas Morning News* (3 articles)
- *DeSoto Focus* (2 articles)
- *Fort Worth Star-Telegram*
- *Greenville Herald Banner*
- *Herald Democrat*
- *Lewisville Leader*
- *Oak Cliff Tribune*
- *Wise County Messenger* (2 articles)
- *Wylie News* (2 articles)

In 2000, the following publications produced articles on the Region C planning process:

- *Amarillo Globe-News*
- *Dallas Business Journal*
- *The Community News* (2 articles)
- *Longview News Journal*
- *Azle News*
- *Rockwall Success*
- *Dallas Morning News* (16 articles)
- *Greenville Herald Banner*
- *Sherman Herald Democrat (*2 articles)
- *Mount Pleasant Daily Tribune (*2 articles)
- *Bonham Daily Favorite (*2 articles)
- *Nacogdoches Daily Sentinel*
- *Fort Worth Star-Telegram* (10 articles)
- *Wise County Messenger* (2 articles)
- *News-Mirror*
- *Herald Democrat* (2 articles)
- *Bridgeport Index*
- *Wylie News*
- *Upstream/Downstream*
- *Denton Record-Chronicle*

Publication on the Web

In order to make the draft of the *Initially Prepared Region C Water Plan* more accessible to the public, it was available on the Freese and Nichols web page, at http://www.freese.com/senbill1/regionc/index.htm. Freese and Nichols and the Texas Water Development have both maintained web sites with information on the Region C planning process as planning proceeded.

7.4 Public Meetings and Public Hearings

Initial Public Meeting

As required by Senate Bill One rules, the Region C Water Planning Group held an initial public meeting to discuss the planning process and the scope of work for the region on June 30, 1998.

Public Hearing on Population and Water Use

The Region C Water Planning Group held a public hearing in Grand Prairie on September 14, 1999, to present the recommended population and water demand projections for the region and to receive public input before the projections were delivered to the Texas Water Development Board for approval.

Public Meetings on Water Needs and Potential Strategies

In March of 2000, the water planning group held an additional set of public meetings to discuss the planning effort, present population and water use projections, discuss possible water management strategies for each county, and encourage public feedback. These meetings were held throughout the region, and each meeting concentrated on certain counties:

- March 7, Springtown (Jack, Parker, Tarrant, and Wise Counties)
- March 20, Grand Prairie (Dallas and Denton Counties)
- March 21, Mesquite (Collin, Kaufman, and Rockwall Counties)
- March 23, Grayson County (Cooke, Fannin, and Grayson Counties)
- March 28, Ennis (Ellis, Freestone, Henderson, and Navarro Counties)

Public Meetings and Public Hearing on Draft Initially Prepared Plans

In September of 2000, the Region C Water Planning Group held a series of public meetings around the region to present the draft *Initially Prepared Region C Water Plan* and seek public input. As with the meetings in March of 2000, the meetings concentrated on water management strategies for nearby counties. The meetings were scheduled as follows:

- September 7, 2:00-4:00, Ennis Public Library (Ellis, Freestone, Henderson, and Navarro Counties)
- September 12, 6:00-8:00, North Texas Municipal Water District in Wylie (Collin, Kaufman, and Rockwall Counties)
- September 14, 2:00-4:00, Trinity River Authority Central Wastewater Treatment Plant in Grand Prairie (Dallas and Denton Counties)
- September 19, 6:00-8:00, Grayson County Community College (Cooke, Fannin, and Grayson Counties)
- September 21, 4:00-6:00, Springtown Fire Hall (Jack, Parker, Tarrant, and Wise Counties)

The public hearing on the draft *Initially Prepared Region C Water Plan* was held at 1:30 on September 26 at the Trinity River Authority Central Wastewater Treatment Plant in Grand Prairie. The Region C Water Planning Group accepted written comments on the report until October 3, 2000. Comments on the *Initially Prepared Region C Water Plan* and responses to the comments are included in Appendices AA and BB.

7.5 Implementation Strategies

Most of the water supply strategies in the Region C plan are basically uncomplicated and should not require special or unusual implementation strategies. All of the strategies will require additional planning and environmental analysis as they are implemented, and most will require permitting. In addition, four of the key supply efforts - (a) conservation, (b) reuse of reclaimed wastewater, (c) development of the Marvin Nichols I Reservoir, and (d) obtaining water from Oklahoma, and - are more complex and will call for relatively sophisticated implementation strategies for effective mitigation of inter-regional and/or intra-regional conflicts. The following strategies have been identified as potentially useful in those cases.

Conservation

We have proposed a more detailed study of water conservation in Region C as a part of the next five-year cycle of Senate Bill One planning. In addition, we recommend the following efforts by Region C suppliers:

- Set up a continuing Committee for Study of Water Conservation Techniques, to strengthen the understanding of various conservation alternatives and their potential effectiveness.
- Identify avenues of research in water conservation that would justify State funding and seek sponsorship by the TWDB or TNRCC.

Reuse of Reclaimed Wastewater

As part of the next five-year cycle of Senate Bill One planning, we recommend that the Region C Water Planning Group make a further analysis of plans for reuse in Region C:

- Prepare a comprehensive summary of the historical and current amounts and locations of reclaimed wastewater in Region C.
- Project the future volumes and locations of reclaimed wastewater in Region C by decade through the year 2050.
- Compare the amount of reuse proposed with reclaimed wastewater volumes to project remaining wastewater flows in Region C streams.
- Seek to develop regional cooperation in the planning and development of reuse projects in Region C.

Marvin Nichols I Reservoir

Development of the proposed Marvin Nichols I Reservoir presents special challenges because of the involvement of two Senate Bill One planning regions and because of the size, cost, and environmental impacts of the project. We recommend the following steps in the development of the Marvin Nichols I project:

- Region C water suppliers should continue communication and coordination with potential partners in the Sulphur Basin for the development of Marvin Nichols I.
- Carry out detailed studies of the environmental factors in the Marvin Nichols I project, with special attention to what can be done to minimize and mitigate the adverse environmental impacts.
- Prepare an engineering report on the Marvin Nichols I Reservoir project.

- Submit an application to the Texas Natural Resource Conservation Commission for a water right permit authorizing construction and operation of the Marvin Nichols I Reservoir. Provide the TNRCC with the needed supporting evidence to support the application and obtain the permit.

- Continue the operation and funding of the Sulphur River Joint Task Group throughout the planning and permitting process, to help identify and resolve inter-regional issues.

- Continue to hold periodic public meetings in Region C and Region D to inform people about the progress of the development process and obtain public input.

Water from Oklahoma

The state of Oklahoma has initiated a Request for Qualifications process to identify potential customers for water from Southeast Oklahoma. Several Region C water suppliers are participating in that process, and they should continue to do so. Working with the state of Oklahoma, the suppliers should seek to:

- Identify sources of water in Oklahoma within reasonable distances of the state line that are not allocated or needed for future use in Oklahoma.
- Evaluate the amounts of water that might be obtained from such sources.
- Explore potential avenues of cooperation between Region C entities and Oklahoma entities for mutually beneficial development and use of one or more of the Oklahoma sources.