PLATEAU REGION WATER PLAN

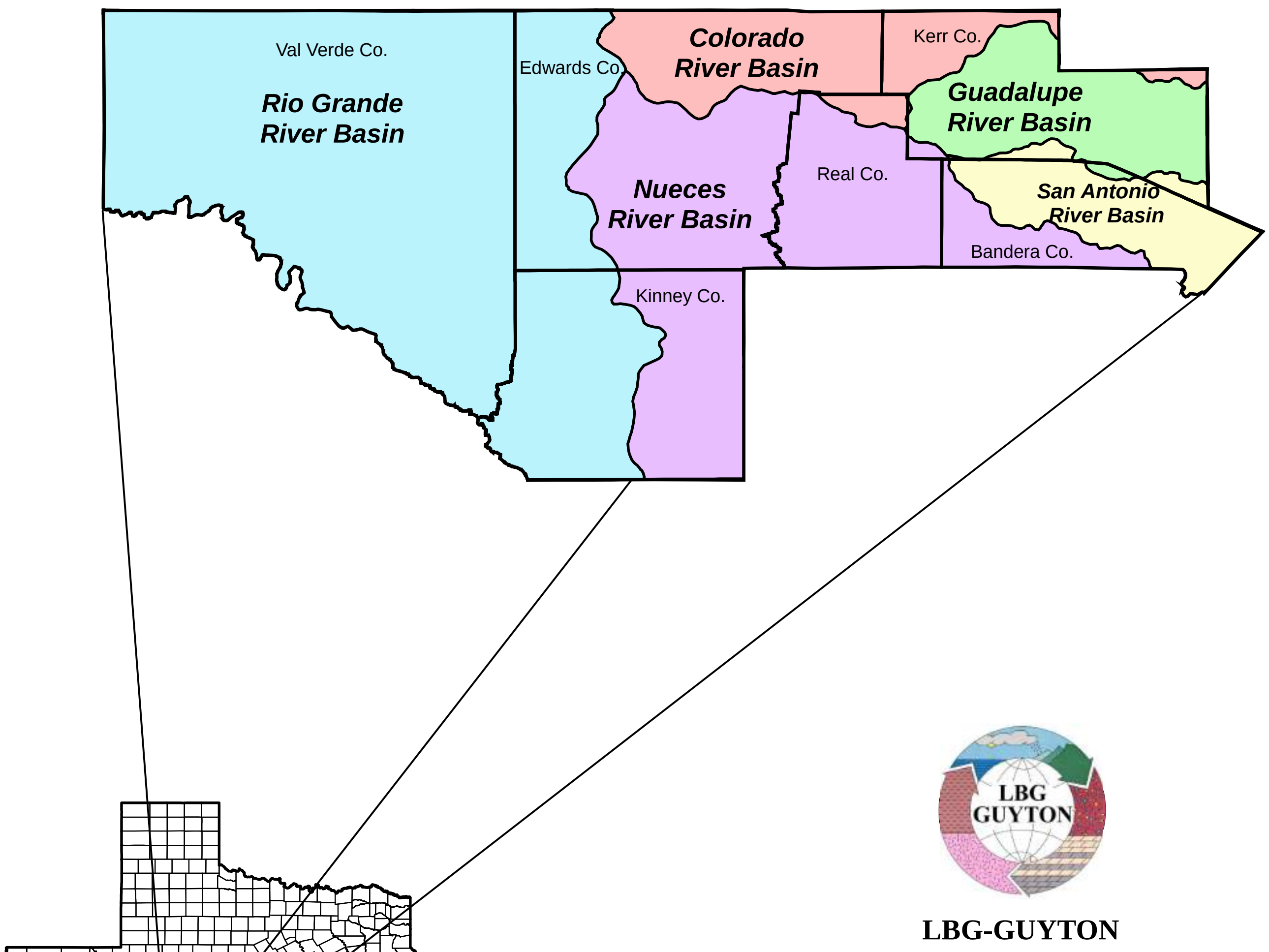
January 5, 2006

Prepared by

Plateau Water Planning Group

Prepared for

Texas Water Development Board



LBG-GUYTON ASSOCIATES

Freese and Nichols

EXECUTIVE SUMMARY

PLATEAU REGION

Located along the southern boundary of the Edwards Plateau Province, the Plateau Water Planning Region (originally designated as Region J) stretches from the Central Texas Hill Country westward to the Rio Grande and consists of Bandera, Edwards, Kerr, Kinney, Real and Val Verde Counties. The regional economy is based primarily on tourism, hunting, ranching, agribusiness, government and military activities. The beauty of the Hill Country, the solitude of the forested canyons and plateau grasslands, and the gateway to Mexico all support a major tourist and recreational trade. The natural resources of the Region include both terrestrial and aquatic habitats that boast some of the best scenic drives, beautiful vistas, river rafting, and hunting and fishing in Texas. Natural resources also include the great diversity of plant and animal wildlife that inhabit these environments.

In January of 2001, the first round of regional water planning was concluded with the adoption of the *Plateau Regional Water Plan*. It is understood that this plan is not a static plan but rather is intended to be revised as conditions change. For this reason, the current plan put forth in this document is not a new plan, but rather an evolutionary modification of the initial plan. Only those parts of the original plan that require updating, and there are many, have been revised.

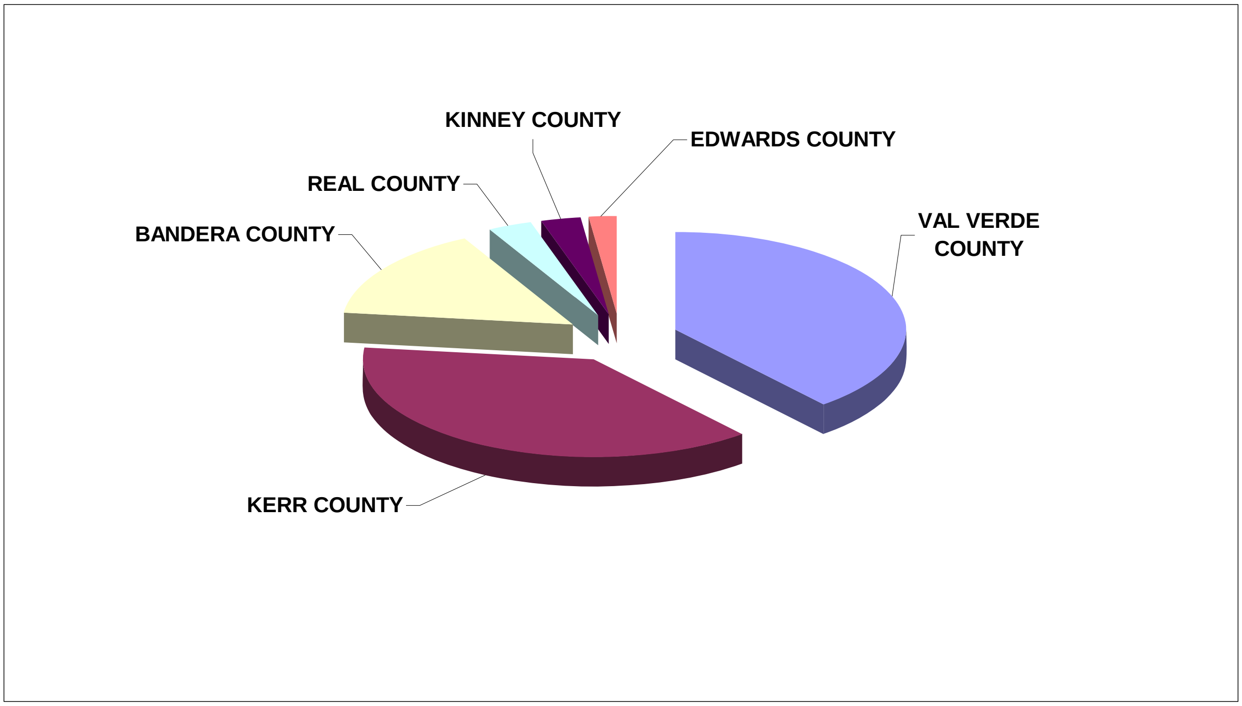
The purpose of the *2006 Plateau Region Water Plan* is to provide a document that water planners and water users can reference for long- and short-term water management recommendations. Equally important, this plan serves as an educational tool to enlighten all citizens as to the importance of properly managing and conserving the delicate water resources of this pristine region.

POPULATION AND WATER DEMAND

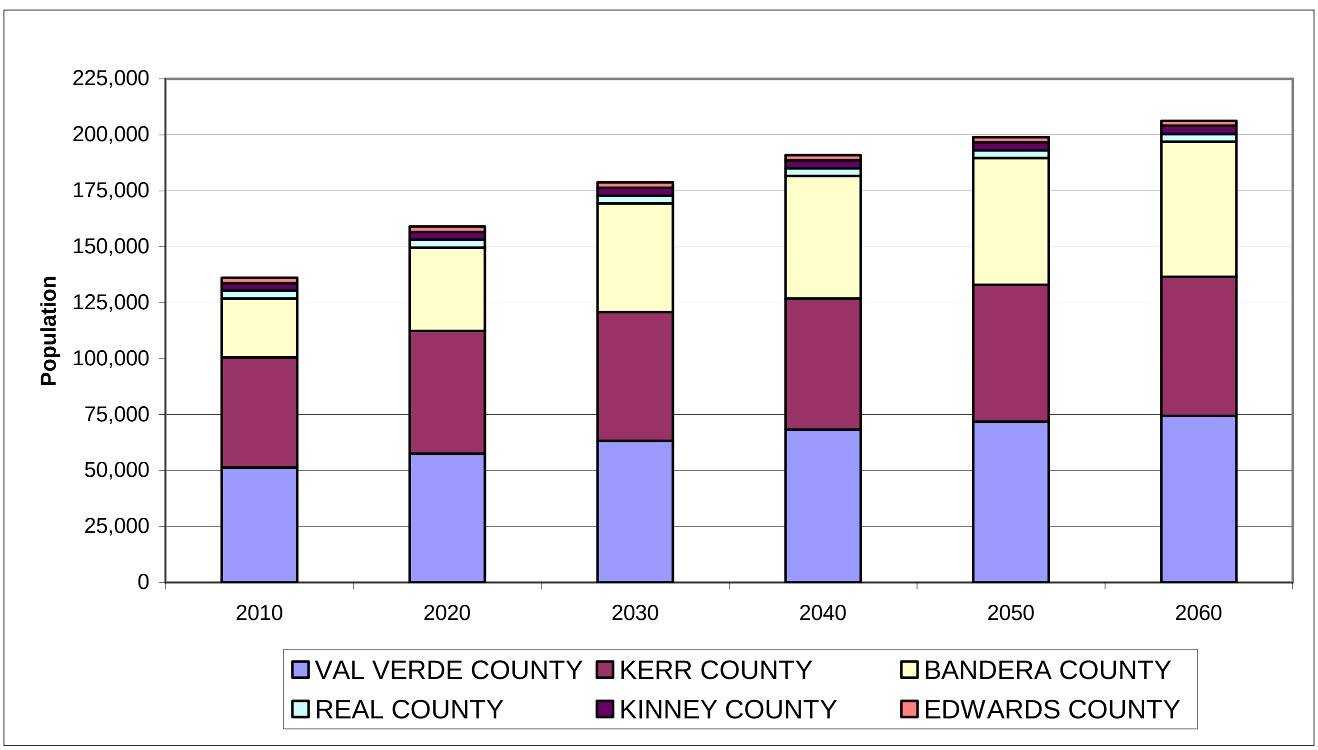
The U.S. Census Bureau performed a census count in 2000, which provides the base year for future population projections. Although the Plateau Water Planning Group (PWPG) accepts the 2000 census count, members express concern that the census does not recognize the significant seasonal population increase that occurs in these counties as the area draws large numbers of hunters and recreational visitors, as well as absentee land owners who maintain vacation, retirement, and hunting cabins. Therefore, an emphasis is made in this planning document, especially for the rural counties, to recognize a need for more water than is justified simply from the population-derived water-demand estimates.

The Plateau Region covers 9,252 square miles and contains a year-2000 population of 114,742. The mostly rural nature of this Region is reflected in its population density of 12.4 people per square mile, which is significantly less than the State average of 72 people per square mile. Approximately fifty percent of the total population of the area is located in the two largest cities, Del Rio and Kerrville. In the year 2000, Del Rio, including the population of Laughlin Air Force Base, had 36,092 residents and Kerrville had 20,425. The year-2000 population of other major communities in the Region were: Bandera (957); Rocksprings (1,285); Brackettville and Fort Clark Springs (3,182); Camp Wood (822); and Leakey (387). These population estimates do not include a significant transient (tourist, hunting, recreation, etc.) population that has a resulting significant impact on overall water supply demand in the Region.

Total population of the six counties is expected to increase by 79 percent from the 2000 census count of 114,742 to 205,910 by 2060. The greatest percentage increase in population is projected to occur in Bandera County, which is expected to grow from a current population of 17,645 to 60,346 by the year 2060, an increase of 342 percent. This growth is primarily influenced by the rapid expansion in the San Antonio metroplex. However, future escalation of fuel cost and cost of living could slow this growth rate. Population in the rural counties of Edwards, Kinney and Real is expected to remain relatively constant over the 50-year planning period, however the transient population will likely increase.

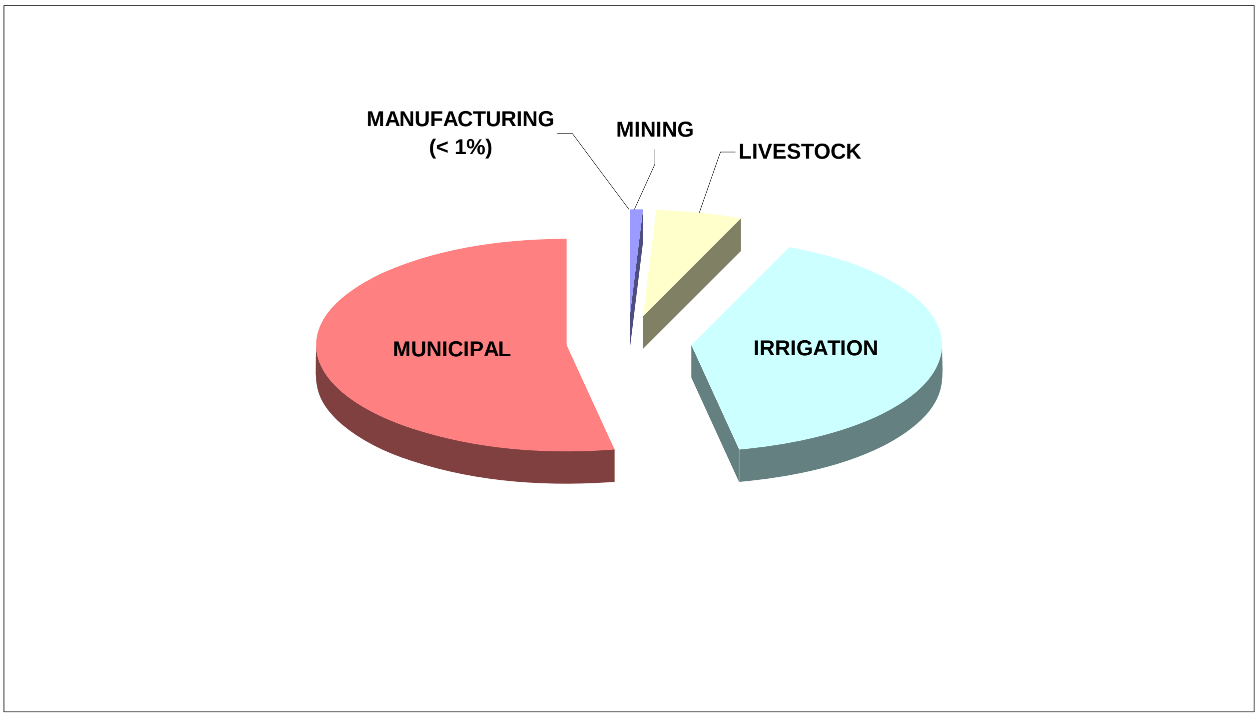


YEAR-2000 POPULATION

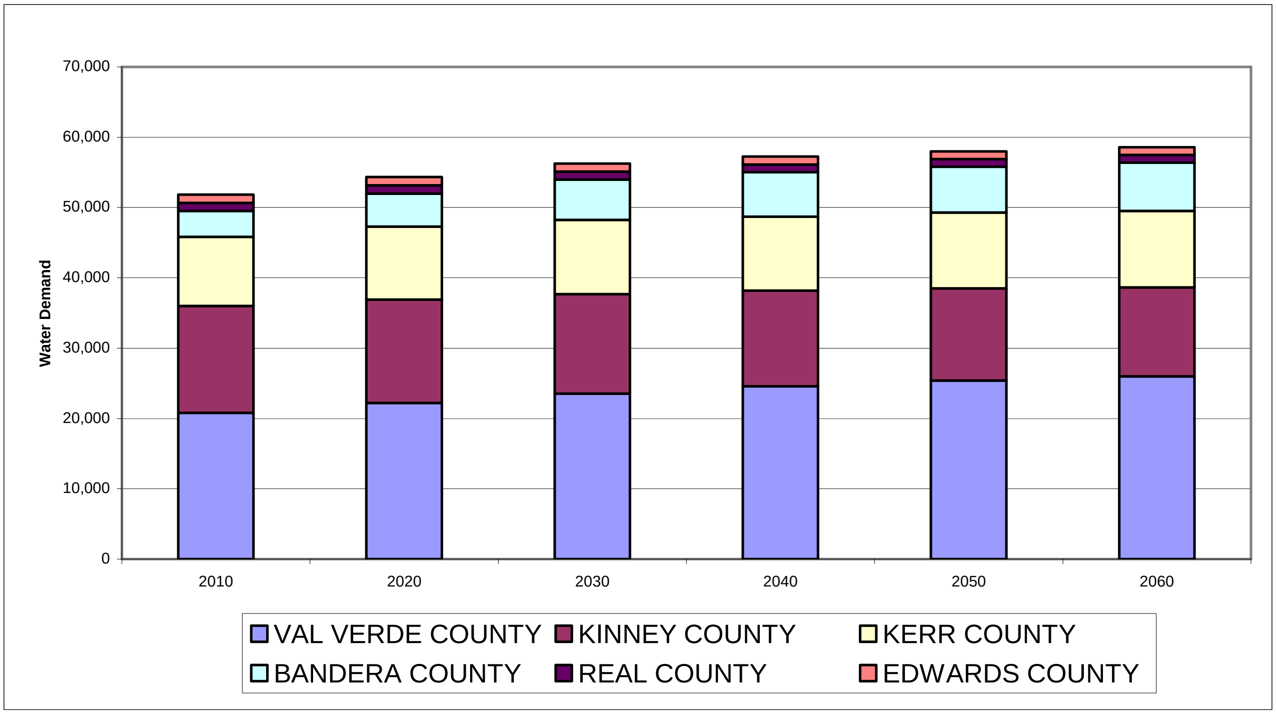


REGIONAL POPULATION PROJECTION

Total estimated water consumptive use in the Plateau Region in the year 2000 was 49,662 acre-feet. The largest category of demand was municipal (26,285 acre-feet), followed by irrigation (20,236 acre-feet), livestock (2,752 acre-feet), mining (364 acre-feet), and manufacturing (25 acre-feet). Municipal and irrigation combined represent 94 percent of all water used in the Region. The forecasted demand for total water needed in the Region will increase by 18 percent or a total of 58,559 acre-feet per year by the year 2060.



YEAR-2000 WATER DEMAND BY WATER USE CATEGORY



PROJECTED WATER DEMAND BY COUNTY

The largest center of municipal demand is Del Rio in Val Verde County, where 15,253 acre-feet of water was used in 2000 to support all areas of residential, commercial and military consumption. Fifty-eight percent of municipal water was used in Val Verde County, and 25 percent in Kerr County. The use of water for manufacturing purposes only occurs in Kerr County.

The City of Del Rio is the only entity in the Plateau Region that is designated as a wholesale water provider. In addition to its own use, the City provides water to Laughlin Air Force Base and subdivisions outside of the City. The Upper Guadalupe River Authority (UGRA) anticipates becoming a wholesale water provider in coming years with the intent to provide conjunctive water-supply sources to meet the needs of Kerr County citizens that will not be served by the City of Kerrville.

Municipal water demand in the Plateau Region is projected to increase from a current level of 26,285 acre-feet to 39,632 acre-feet by the year 2060. Because municipal water demand is directly related to population, Val Verde County has the highest demand in the Region. Bandera County, with the greatest projected percentage population increase, will likewise see the greatest percentage water demand increase over the 50-year period, 297 percent.

Most irrigation that occurs in the Plateau Region is for the watering of pastures and hay fields. Because of the typically rocky and uneven terrain throughout much of the Region, irrigation of commercial row crops is minimal. Kinney County has the highest irrigation water use (70 percent) and is the only county in which irrigation use is greater than municipal use. On a regional basis, water used for irrigation is projected to decline slightly over the 50-year planning horizon, from the current 20,236 acre-feet to 15,837 acre-feet by 2060. However, as any irrigator can attest, climate, water availability, and the market play key roles in how much water is actually applied on a year-by-year basis.

Environmental and recreational water use in the Plateau Region is recognized as being an important consideration as it relates to the natural community in which the residents of this Region share and appreciate. In addition, for rural counties, tourism activities centered around the natural resources offer perhaps the best hope for modest economic growth to areas that have seen a long decline in traditional economic activities such as agriculture.

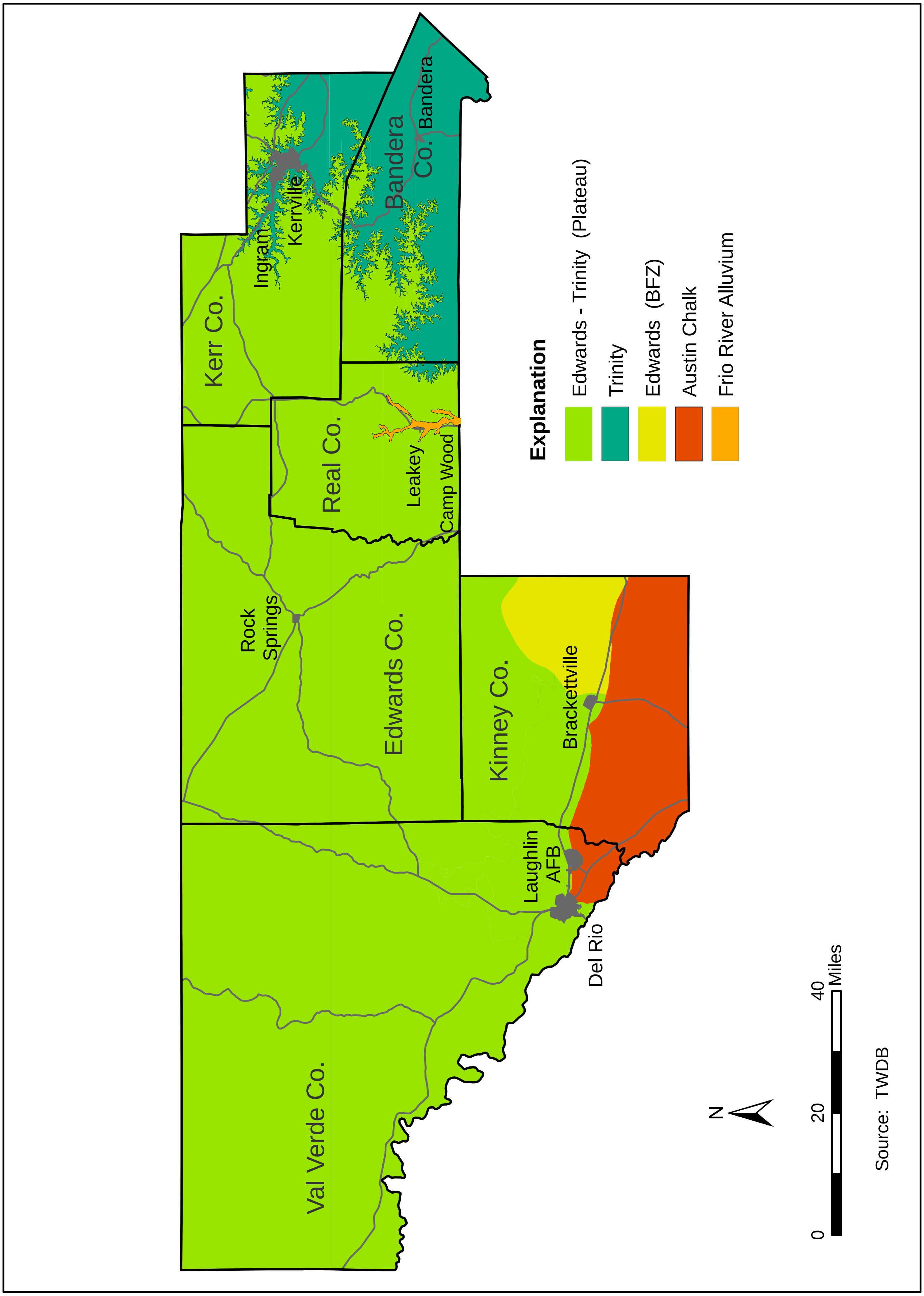
WATER SUPPLY RESOURCES

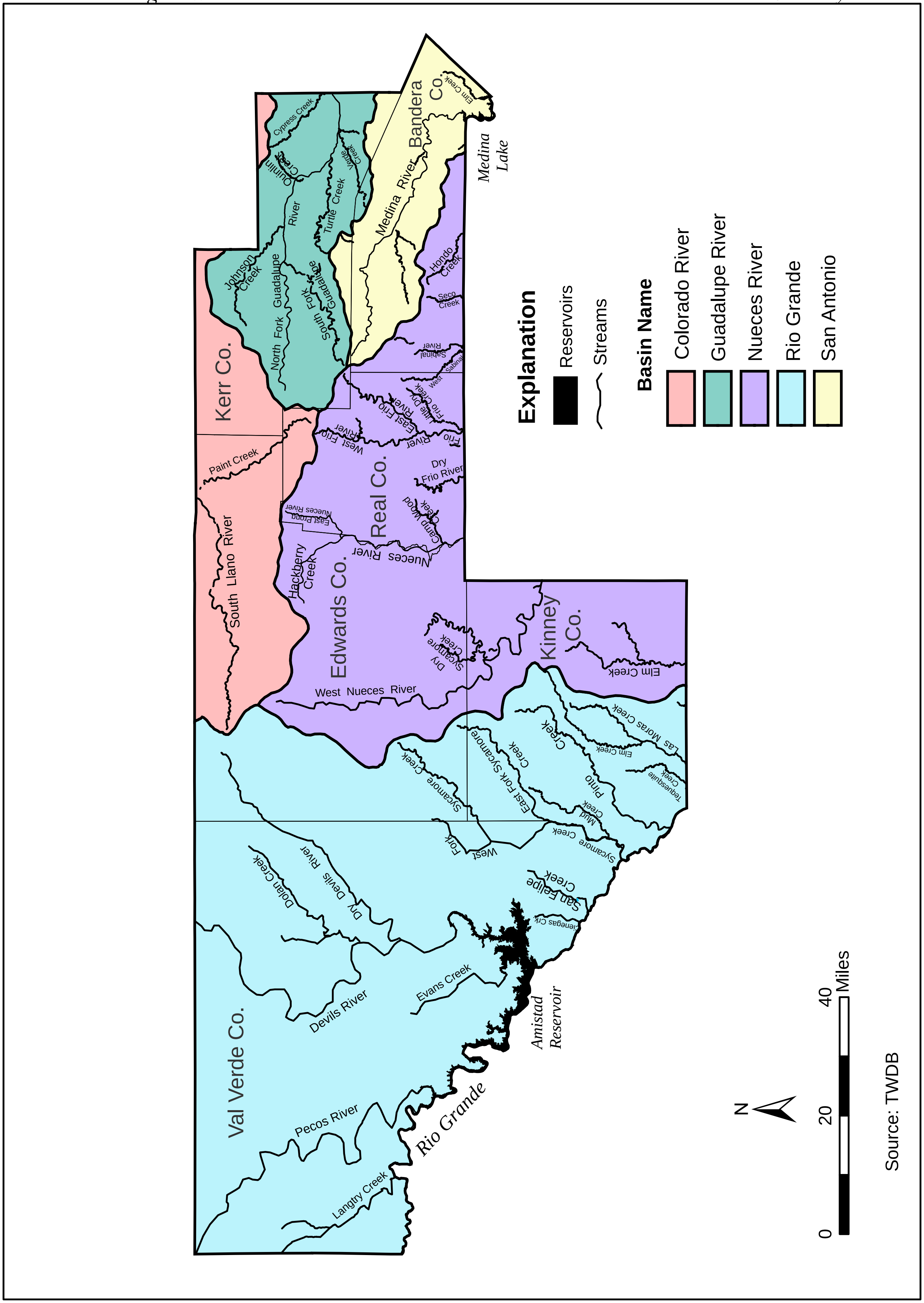
Water supply sources in the Plateau Region include groundwater from five aquifers and surface water within five river basins. Reuse of existing supplies is also considered a water supply source. Water supply availability under drought-of-record conditions is considered in the planning process to insure that water demands can be met under the worst of circumstances. In the consideration of available water supply sources, this plan fully recognizes and protects existing water rights, water contracts, and option agreements.

Within the Plateau Region, the TWDB recognizes three major aquifers [the Trinity, the Edwards-Trinity (Plateau), and the Edwards (Balcones Fault Zone)]. For this plan, the Austin Chalk aquifer in Kinney County and the Frio River Alluvium aquifer in Real County are also identified as groundwater sources. Groundwater conservation districts in Bandera, Kerr, Kinney, Real and Edwards Counties provide for local management control of the groundwater resources in their respective districts. Over much of the Region, water levels generally fluctuate with seasonal precipitation and are highly susceptible to declines during drought conditions. Discharge from the aquifers occurs naturally through springs and seeps, and artificially by pumping from wells. Some discharge also occurs through leakage from one unit to another and through natural down-gradient flow out of the Region.

Base flow to the many rivers and streams that flow through the Plateau Region is principally generated from the numerous springs that issue from rock formations that form the major aquifers. It is thus recognized that sustaining flow in these important rivers and streams is highly dependent on maintaining an appropriate water level in the aquifer systems that feed the supporting springs. With the sustainability of local water supplies and the economic welfare of the Region in mind, the PWPG thus defines groundwater availability as <u>a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions</u>. The PWPG also acknowledges that groundwater conservation districts have regulatory authority over permitted withdrawals. Where available, TWDB groundwater availability models (GAMs) were used to assist in the availability analysis process.

The counties that comprise the Plateau Region contain the headwaters of the Guadalupe, San Antonio, Medina, Sabinal, Frio, Nueces, and West Nueces Rivers; and tributaries to the Colorado River and Rio Grande such as the Pecos, Devils, and South Llano Rivers. Flow in these rivers and streams is critical to the Plateau Region in that it provides municipal drinking water, supplies irrigation and livestock needs, maintains environmental habitats, and supports a thriving ecological and recreational tourist economy. Water users downstream of the Plateau Region (Regions K, L, and M) likewise have a stake in maintaining and protecting river flows.


GROUNDWATER SOURCES
Explanation
Edwards - Trinity (Plateau)
Trinity
Edwards (BFZ)
Austin Chalk
Frio River Alluvium
Kerr Co.
Bandera Co.
Real Co.
Edwards Co.
Kinney Co.
Val Verde Co.
Bandera
Kerrville
Ingram
Leakey
Camp Wood
Rock Springs
Brackettville
Laughlin AFB
Del Rio
N
0
20
40
Miles
Source: TWDB



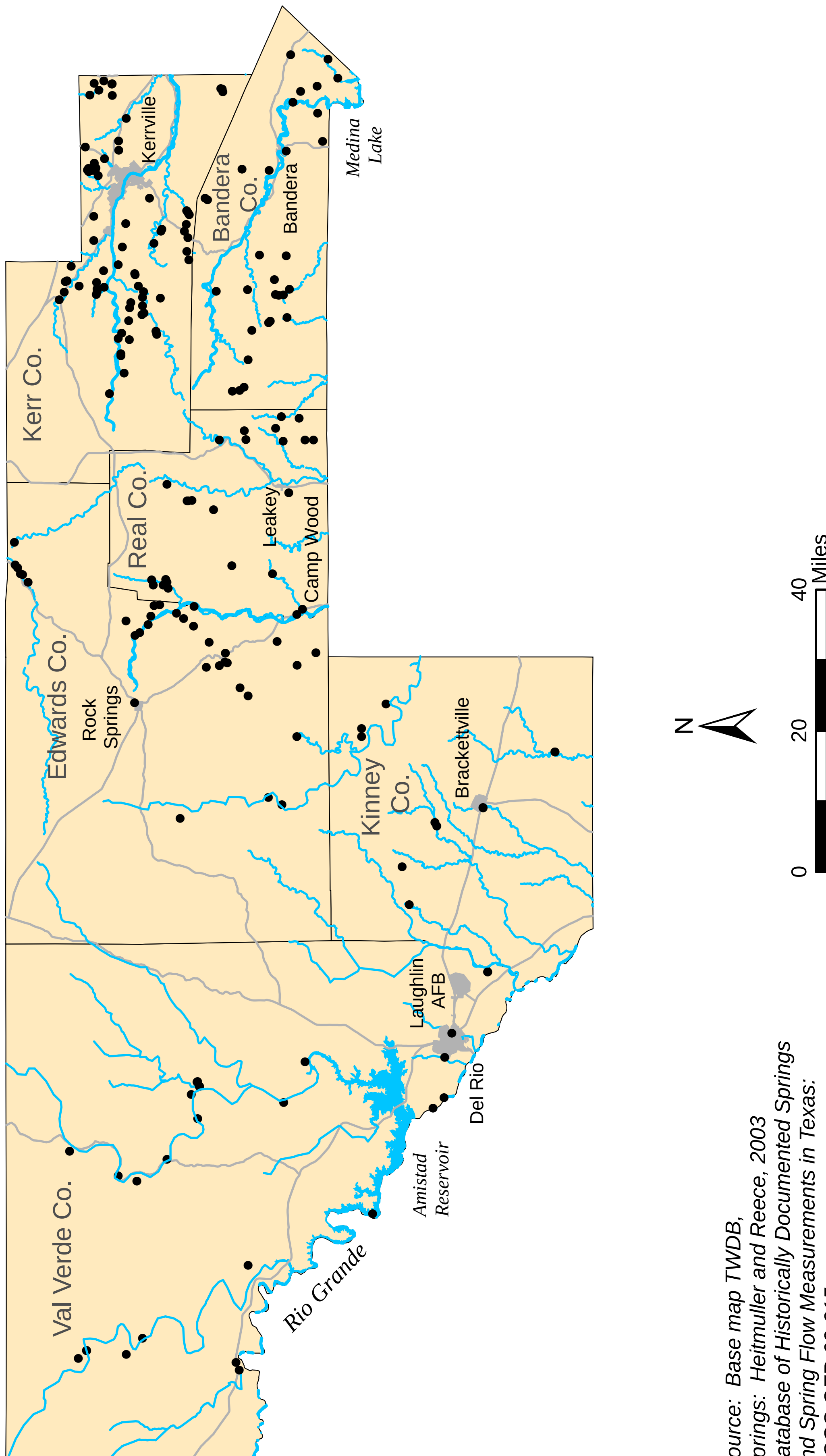
SURFACE WATER SOURCES

Although rather limited during severe drought conditions, surface-water supplies in the Region are important. The Cities of Kerrville and Del Rio currently use surface water from the Guadalupe River and from San Felipe Springs, respectively. Camp Wood in Real County is supplied from Old Faithful Spring located on a tributary to the Nueces River. For surface-water supplies, drought-of-record conditions relate to the quantity of water available to meet existing permits from the Rio Grande, Nueces, Colorado, Guadalupe, and San Antonio Rivers and their tributaries as estimated by Run 3 of the TCEQ Water Availability Models (WAMs).

Water recycling, or reuse, is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation or industrial processes. The City of Kerrville and the Town of Camp Wood have active water reuse programs.

The PWPG recognizes the important ecological water supply function that all springs perform in the Region. Springs create and maintain base flow to rivers, contribute to the esthetic and recreational value of land, and are significant sources of water for wild game and aquatic species. Water issuing from springs forms wetlands that attract migratory birds and other fowl that inhabit the Region throughout the year. The spring wetlands host numerous terrestrial and aquatic species, some of which are recognized as threatened and endangered.

The PWPG has identified three “Major Springs” (that are important for their municipal water supply contribution. The fourth largest spring system in Texas, San Felipe Springs, discharges to San Felipe Creek northeast of Del Rio and provides municipal drinking water for the City, as well as irrigation use downstream. Las Moras Springs in Kinney County is of historical significance for its importance as a supply source on early travel routes and military fortifications. Today, Las Moras Springs supports the Fort Clark Springs community and is hydrologically associated with the same aquifer system that serves Fort Clark Springs MUD and the City of Brackettville. The third major spring is Old Faithful in Real County, which is the drinking-water supply for the Town of Camp Wood. Although only three springs are identified as “Major Springs”, the PWPG recognizes that all springs in the Region are important and are deserving of natural resource protection.



Source: Base map TWDB,
Springs: Heitmuller and Reece, 2003
Database of Historically Documented Springs
and Spring Flow Measurements in Texas:
USGS OFR 02-315

LOCATION OF DOCUMENTED SPRINGS

WATER MANAGEMENT STRATEGIES

A purpose of this plan is to identify municipalities and water-use categories that may, in times of severe drought, be unable to meet expected water-supply needs based on today's ability to access, treat, and distribute the supply. Recommended alternatives, or strategies, to meet anticipated drought-induced shortages are presented for consideration. It should be acknowledged that the PWPG has no authority to mandate that any recommended strategies be implemented, and that it is the individual entity's initiative to act on needed changes.

The table below lists the cities and water-use categories by county that are determined to have potential future shortages during drought-of-record conditions based on no new infrastructure development. These entities and water-use categories are expected to have sufficient water supplies to meet drought-of-record conditions if one or a combination of recommended strategies is implemented. Potential municipal water shortages are only anticipated for the City of Kerrville, Kerrville South WSC, and the Town of Camp Wood. Irrigation shortages in Bandera and Kerr Counties are the result of the lack of available water in specific rivers to meet permitted irrigation water rights. Total capital cost to implement the recommended strategies is $14.4 million.

WATER SUPPLY SHORTAGES DURING DROUGHT-OF-RECORD CONDITIONS (Acre-Feet/Year)

WATER USER GROUP	S2010	S2020	S2030	S2040	S2050	S2060
BANDERA COUNTY						
Irrigation	-114	-114	-114	-114	-114	-114
KERR COUNTY						
Kerrville	-1322	-1706	-1878	-1897	-2112	-2222
Kerrville South WSC		-17	-28	-4		
Irrigation	-457	-397	-342	-288	-235	-184
REAL COUNTY						
Camp Wood	-172	-172	-166	-160	-163	-167

Under drought-of-record conditions, available supplies from the Guadalupe River are nonexistent for the City of Kerrville. The City, along with the UGRA, hopes to obtain additional water rights or modify existing water rights to supplies in Canyon Reservoir. The City is also considering the following strategies to meet potential shortages:

- Purchase of raw water from UGRA
- Development of additional groundwater supplies from a new remote well field
- Increase of water treatment capacity and expansion of the current ASR system by adding two additional wells.

The Town of Camp Wood is considering the drilling of water wells to supplement its current supply from Old Faithful Spring.

Although a supply deficit for the Kerr County Other category is not forecasted, the PWPG is concerned that future population growth in the unincorporated areas of the County could result in supply problems. A special strategy, which incorporates UGRA's intent to be a conjunctive use wholesale water provider, is included in this plan to meet this potential need.

Suggested short- and long-term solutions to meet irrigation shortages in Bandera and Kerr Counties include implementation of agricultural best management practices (BMPs), which entail improved irrigation use management techniques and modern water delivery systems. However, in most cases, irrigators will likely simply cease irrigation operation for the duration of the water-supply shortage.

Water conservation management strategies recommended for Kerrville and Camp Wood include water audits and loss audits to reduce distribution losses, and public education to bring awareness of wasteful practices. Brush management, rainfall harvesting, and conservative landscape irrigation are recognized as constructive conservation practices on a regional scale.

A goal of this plan is to provide for the health, safety, and welfare of the human community, with as little detrimental effect to the environment as possible. Recreation activities involve human interaction with the outdoor environment and are often directly dependent on water resources. It is recognized that the maintenance of the regional environmental community's water supply needs serves to enhance the lives of citizens of the Plateau Region as well as the tens of thousands of annual visitors to this Region.

The implementation of water management strategies recommended in Chapter 4 of this regional plan is not expected to have any impact on native water quality. In particular, primary and secondary safe drinking water standards, which are the key parameters of water quality identified by the PWPG as important to the use of the water resource, are not compromised by the implementation of the strategies.

Only one recommended strategy involves moving water from a rural location for use in an urban area. The development of a remote well field by the City of Kerrville could potentially result in the lowering of groundwater levels, which could impact shallow livestock wells in the vicinity of the well field. No well field location has been identified at this early stage of consideration. If implemented, the recommendation that the Headwaters Groundwater Conservation District establish management guidelines for the Edwards-Trinity (Plateau) aquifer in western Kerr County could minimize the impact of additional pumping in the area.

WATER QUALITY

Water quality plays an important role in determining the suitability of water supplies to meet current and future water needs. Primary and secondary safe drinking water standards are the key parameters of water quality identified by the PWPG as important to the use of water resource and are used for comparisons of water quality data. The reservoirs within the Plateau Region - Amistad Reservoir and Medina Lake - are some of the clearest (most transparent) water bodies in the State of Texas. Amistad Reservoir is the third clearest water body in Texas and Medina Lake is the fifth clearest.

Groundwater resources in the Plateau Region are generally potable, although between five and ten percent of the groundwater is brackish. Groundwater quality problems are generally related to naturally high concentrations of total dissolved solids (TDS) or to the occurrence of elevated concentrations of individual dissolved constituents. High concentrations of TDS are primarily the result of the lack of sufficient recharge and restricted circulation. Together, these retard the flushing action of fresh water moving through the aquifers.

Water quality is generally good throughout the Plateau Region; however, a few specific water quality issues are of concern.

- Increase in urban runoff generally comes with an increase in impervious cover in populated areas. Urbanization also causes increased pollutant loads, including sediment, chemicals from motor vehicles, pesticides/herbicides/fertilizers from gardens and lawns, viruses/bacteria/ nutrients from human and animal wastes including septic systems, heavy metals from a variety of sources, and higher temperatures of the runoff.
- Increasing population has also manifested itself in the fragmentation of larger properties. With the advent of fragmentation comes the proliferation of new wells being drilled to serve individual properties. Each new well thus becomes another potential conduit for surface contamination to reach the underlying aquifer system.
- Vehicular traffic in streambeds disrupts streamflow, damages plants and animals living in these areas, damages channels and erodes banks, and decreases water quality by increasing the turbidity of the water in these rivers and streams.
- The constituent of most concern is nitrate, which was found above the primary maximum contaminant level in a number of water-sample analyses from the Edwards (BFZ) aquifer and the Austin Chalk aquifer in Kinney County. Historically, the primary contribution to poor groundwater quality occurs in wells that do not have adequately cemented casing.
- Poorer groundwater quality in the Region is generally from two sources, evaporite beds in the Glen Rose limestone and from surface contamination, both of which can be prevented by proper well construction. Also of concern are above normal levels of radioactivity that have been detected in sand sequences of the Glen Rose and Hensell formations.

WATER CONSERVATION AND DROUGHT CONTINGENCY

Water conservation and drought contingency planning are two of the most important components of water supply management. Recognizing their potential contribution, setting realistic goals, and aggressively enforcing their implementation may significantly extend the time when new supplies and associated infrastructure are needed. Water conservation are those practices, techniques, programs, and technologies that will protect water resources, reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling or reuse of water so that a water supply is made available for future or alternative uses.

Although residents of the Plateau Region are generally accustomed to highly variable climatic conditions, the relatively low rainfall and the accompanying high levels of evaporation underscore the necessity of developing plans that respond to potential disruptions in the supply of groundwater and surface water caused by drought conditions.

Drought contingency plans provide a structured response that is intended to minimize the damaging effects caused by water shortage conditions. A common feature of drought contingency plans is a structure that allows increasingly stringent drought response measures to be implemented in successive stages as water supply or water demand conditions intensify. This measured or gradual approach allows for timely and appropriate action as a water shortage develops. The onset and termination of each implementation stage should be defined by specific "triggering" criteria. Triggering criteria are intended to ensure that timely action is taken in response to a developing situation and that the response is appropriate to the level of severity of the situation.

PROTECTION OF WATER, AGRICULTURAL AND NATURAL RESOURCES

The long-term protection of the Plateau Region's water resources, agricultural resources, and natural resources is an important component of this 2006 update of the *Plateau Region Water Plan*. Long-term water resources protection occurs in the conservative methodology of estimating water supply availability, evaluation of water management strategies for potential threats to water resources, the recommendation of water conservation strategies, and regional recommendations pertaining to water conservation and drought management practices. When enacted, the conservation practices will diminish water demand, the drought management practices will extend supplies over stress periods, and land management practices (land stewardship) will potentially increase aquifer recharge and stream base flow conditions.

Agricultural resources are protected in this plan by providing irrigation strategy recommendations that address irrigation conservation best management practices. These strategies include appropriate application scheduling, use monitoring, and use of low-pressure delivery systems. If implemented, these practices will result in reduced water application per acre irrigated. Also, non-agricultural strategies include an analysis of potential impact to agricultural interests.

The protection of natural resources as intended in this plan is closely linked with the protection of water resources as discussed above. The methodology adopted to assess groundwater source availability estimates is based on not significantly impacting spring flows that contribute to base flows in area rivers. Thus, the intention to protect surface flows is directly related to those natural resources that are dependent on surface water sources for their existence.

Environmental impacts were evaluated in the consideration of strategies to meet water-supply deficits. Of prime consideration was whether a strategy potentially could diminish the quantity of water currently existing in the natural environment and if a strategy could impact water quality to a level that would be detrimental to animals and plants that naturally inhabit the area under consideration. Although no specific ecologically unique river and stream segments are recommended in this plan, the PWPG is very explicit in acknowledging the importance of all springs and stream segments for their significance as wildlife habitat.

RECOMMENDATIONS

Water-supply resources intended to meet the future needs of all water-use categories in the Plateau Region are recognized to be limited in comparison to resources available in many other parts of the State. A conscientious effort to maintain an awareness of existing conditions and anticipate future water needs is recognized by the PWPG as being the foundation of continued regional water planning. In support of this belief, the PWPG is providing specific recommendations in this plan that address:

- Legislative Water Code modifications
- State funding and assistance opportunities
- Planning and information management modifications
- Needed studies and data

The PWPG encourages the continued public process of developing region-based water plans. Copies of the *2006 Plateau Region Water Plan* are accessible in county courthouses, public libraries, and from the Texas Water Development Board web site: http://www.twdb.state.tx.us/.

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CHAPTER 1

PLATEAU REGION DESCRIPTION

1.1 INTRODUCTION

Located along the southern boundary of the Edwards Plateau Province, the six-county Plateau Water Planning Region stretches from the eastern Texas Hill Country westward to the Rio Grande. Apache and Comanche Indians populated the region in its early history. Under land grants issued by Mexico and later by the Republic of Texas, German immigrants colonized the area. These first immigrants and those to follow settled small towns along many of the spring-fed streams that crossed the area and from these way stations spread out to establish farms and ranches throughout the region. Even today, the area retains much of its original cowboy frontier and German heritage. Chapter 1 that follows is a broad introduction to this Region and the water supply challenges it faces. The Region's economic health and quality of life concerns, including the aquatic environment and recreational opportunities, are dependent on a sustainable water supply that is equitably managed.

In January of 2001, the first round of regional water planning was concluded with the adoption of the *2001 Plateau Regional Water Plan.* It is understood that this plan is not a static plan but rather is intended to be revised as conditions change. For this reason, the current plan put forth in this document is not a new plan, but rather an evolutionary modification of the initial plan. Only those parts of the original plan that required updating, and there were many, have been revised.

The purpose of the regional water plan is to provide a document that water planners and users can reference for long- and short-term water management recommendations. Equally important, this plan serves as an educational tool to enlighten all citizens as to the importance of properly managing and conserving the delicate water resources of this pristine region. Chapter 1 presents a broad overview of the Region and of many of the key issues that must be addressed as part of any attempt to develop a comprehensive water management plan that is acceptable to those who reside here.

1.1.1 Planning Process

The *2006 Plateau Region Water Plan* follows an identical format as the plans prepared by the other 15 water planning regions in the State as mandated by the Texas Legislature and overseen by the Texas Water Development Board. The plan provides an evaluation of current and future water demands for all water-use categories, and evaluates water supplies available during drought-of-record conditions to meet those demands. Where future water demands exceed available supplies, alternative strategies are considered to meet the potential water shortages. Because our understanding of current and future water demand and supply sources are constantly changing, it is intended for this plan to be revised every five years or sooner if deemed necessary. There are no known conflicts between this plan and plans prepared for other regions.

Water supply availability under drought-of-record conditions is considered in the planning process to insure that water demands can be met under the worst of circumstances. For surface water supplies, drought-of-record conditions relate to the quantity of water available to meet existing permits from the Rio Grande, Nueces, Colorado, Guadalupe, and San Antonio Rivers and their tributaries as estimated by Run 3 of the TCEQ Water Availability Models (WAM). This plan has no impact on navigation on these surface-water courses.

The availability of groundwater during drought-of-record conditions is based on an annual quantity of water that can be withdrawn from each aquifer that results in an acceptable level of water-level decline over the 50-year planning period. Where available, a TWDB groundwater availability models were used to assist in this process. Chapter 3 contains a detailed analysis of water supply availability in the Region.

Since the completion of the 2001 Plan, a number of advances in water planning have been made available. The year-2000 census provided for more accurate estimates of current population and municipal/rural water demand. Groundwater and surface water availability models (GAMs and WAMs) have been developed as resource tools for use in evaluating water-supply source availability. These computer simulation models were used in the current planning process and provided a more realistic analysis of possible water supply source conditions. Results from the use of these models are reported in Chapter 3.

Also new to this planning period was the availability, through Texas Parks & Wildlife Department, of environmental data on the more prominent watercourses in the Region. This data was useful in the assessment and consideration of environmental flow needs, springs, and ecologically significant stream segments. The plan also acknowledges the City of Kerrville's 2004 comprehensive Water Management Plan, which documents the City's conjunctive-use policy for both surface water and groundwater.

This plan fully recognizes and protects existing water rights, water contracts, and option agreements. The Plateau Water Planning Group (PWPG) strongly encouraged all entities to participate in the planning process so that their specific concerns could be recognized and addressed.

The PWPG also encouraged the participation of groundwater conservation districts and recognized their management plans and rules. District management plans were specifically respected when establishing groundwater availability estimates.

Water quality is recognized as an important component in this 50-year water plan. Water supplies can be diminished or made more costly to prepare for distribution if water quality is compromised. To insure that this plan fully considers water quality, the federal Clean Water Act and the state Clean Rivers Program were reviewed and considered when developing water-supply availability estimates (Chapter 3), water deficit strategies (Chapter 4), water quality impacts (Chapter 5), and recommendations (Chapter 8).

In the year 2000, the U.S. Census Bureau performed a census count, which provides the base year for future population projections in the Region. Although the PWPG accepts the 2000 census count, members express concern that the census does not recognize the significant seasonal population increase that occurs in these counties as the area draws large numbers of hunters and recreational visitors, as well as absentee land owners who maintain vacation, retirement, and hunting homes and cabins. Therefore, an emphasis is being made in this planning document, especially in the rural counties, to recognize a need for more water than is justified simply from the population-derived water demand quantities.

1.1.2 Definitions

The following definitions are included in Chapter 1 to provide the reader with a reference source for selected technical terms found in this report.

Acre-feet – A quantity of water equal to 325,851 gallons – or the volume of water required to cover one acre of land to a depth of one foot.

Alluvial – A geologic unit composed of sediment deposited by a stream or river.

Aquifer - One or more formations that contain sufficient saturated permeable material to conduct groundwater and to yield economically significant quantities of water to wells and springs.

Drought-of-Record - A drought period with the greatest hydrologic/ agricultural/public water-supply impact recorded in a region.

Evaporation - The process by which water passes from the liquid state to the vapor state.

Evapotranspiration - The loss of water from a land area through transpiration by plants and evaporation from the soil.

Firm Yield - That amount of water that the reservoir could have produced annually if it had been in place during the worst drought of record. In performing this simulation, naturalized streamflows will be modified as appropriate to account for the full exercise of upstream senior water rights is assumed as well as the passage of sufficient water to satisfy all downstream senior water rights valued at their full authorized amounts and conditions as well as the passage of flows needed to meet all applicable permit conditions relating to instream and freshwater inflow requirements.

Formation - The basic geologic unit in the classification of rocks, consisting of a body of rock generally characterized by some degree of compositional homogeneity and by a prevailingly but not necessarily tabular shape over its areal extent.

Hydraulic interconnection - The degree to which groundwater is able to move between different water-bearing rocks or between basins.

Intermittent stream - A stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality. Compare with "perennial stream."

Perennial stream - A stream or reach of a stream that flows continuously throughout the year.

Recharge - The addition of water into an underground reservoir or aquifer by natural or artificial means.

Reuse - The process of recapturing water following its initial use and making it available for additional uses. The process generally requires a level of treatment appropriate for its next intended use.

Riparian - Situated on the bank of a body of water, especially of a watercourse such as a river.

Sustainability - An amount of water that can be produced over a planning period to meet specified demands that results in an acceptable level of impact to the source.

Topography - The general configuration of a land surface, including its relief and the position of its natural and man-made features, and as expressed by the contour lines of a map.

Water demand - The total volume of water required to meet the needs of a water-use category. This quantity may exceed actual usage.

Water supply availability – The volume of water capable of being withdrawn or

diverted from specific sources of supply that results in an acceptable impact on the water source and its primary users.

1.2 REGIONAL GEOGRAPHIC SETTING

1.2.1 Plateau Region

The Plateau Region encompasses six counties in the west-central part of the State, stretching from the headwaters of the Guadalupe and San Antonio Rivers in the Central Texas Hill Country westward to Del Rio and the Rio Grande international border (Figure 1-1). With a total area of 9,252 square miles (mi^2), the Plateau Region represents 3.5 percent of the total area of the State of Texas and includes the counties of Bandera (792mi^2), Edwards (2,120mi^2), Kerr (1,106mi^2), Kinney (1,364mi^2), Real (700mi^2), and Val Verde (3,171mi^2).

1.2.2 Physiography

The Plateau Region lies primarily along the southern edge of the Edwards Plateau and is bounded on the east by the Central Texas Hill Country and on the west by the Rio Grande international border. The Balcones escarpment generally forms the southern boundary of the Plateau Region. The escarpment is a steep topographic feature that traces the path of a major fault system that formed more than 10 million years ago. The escarpment separates the more resistant rocks of the Edwards Plateau to the north from softer and more easily erodible rocks to the south. Erosion by streams has cut steep canyons back into the thick limestone beds of the Edwards Plateau.

The Region is characterized by its rolling prairies and the large number of spring-fed perennially flowing streams. The uplands are fairly level, but the landscape of the stream valleys is very hilly with steep canyons that provide rapid drainage. Upland soils are dark alkaline clays and clay loams; the river valley soils are gravelly and light colored. Some cultivation takes place in the deep, dark-gray or brown loams and clays of the river bottoms and to a greater extent over the broad flat farming belt of western Kinney County. The major soil-management concerns are brush control, low fertility and excess lime.

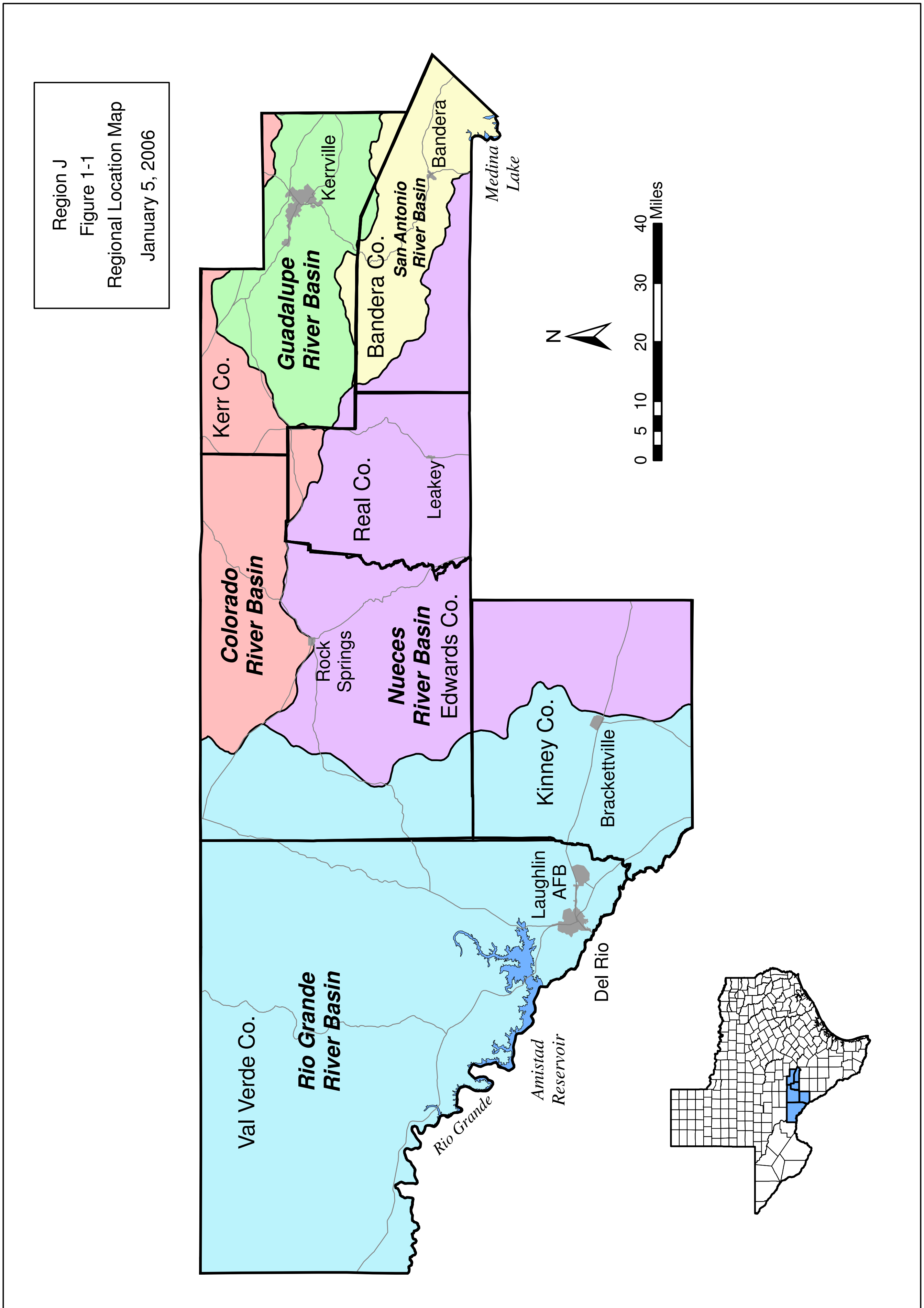

FIGURE 1-1. LOCATION OF THE PLATEAU REGION

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1.2.3 Population and Regional Economy

The total year-2000 population in the Plateau Region was 114,742 (Figure 1-2). The population density for the Region is 12.4 people per square mile, which is much less than the state average of 72 people per square mile. Current and projected future population of the Region is discussed in detail in Chapter 2.

Approximately fifty percent of the total population of the Region is located in the two largest cities, Del Rio and Kerrville. In the year 2000, Del Rio, including the population of Laughlin Air Force Base, had 36,092 residents and Kerrville had 20,425. The year-2000 population of other major communities in the Region are: Bandera (957); Rocksprings (1,285); Brackettville and Fort Clark Springs (3,182); Camp Wood (822); and Leakey (387). These population estimates do not include a significant transient (tourist, hunting, recreation, etc.) population that has a resulting significant impact on overall water supply demand for the Region.

The regional economy is based primarily on tourism, hunting, ranching agribusiness and government. The beauty of the Hill Country, the solitude of the forested canyons and plateau grasslands, and the gateway to Mexico all support a major tourist trade. Agribusiness is predominantly associated with the raising of sheep, goats, beef cattle and exotic game throughout the Region. Apple orchards in Bandera County, oil and gas production and mohair production in Edwards and Real Counties, medical services and manufacturing in Kerr County, irrigated cotton, hay and wheat in Kinney County, and a military base and trade with Mexico in Val Verde County all contribute largely to the Region's overall economy.

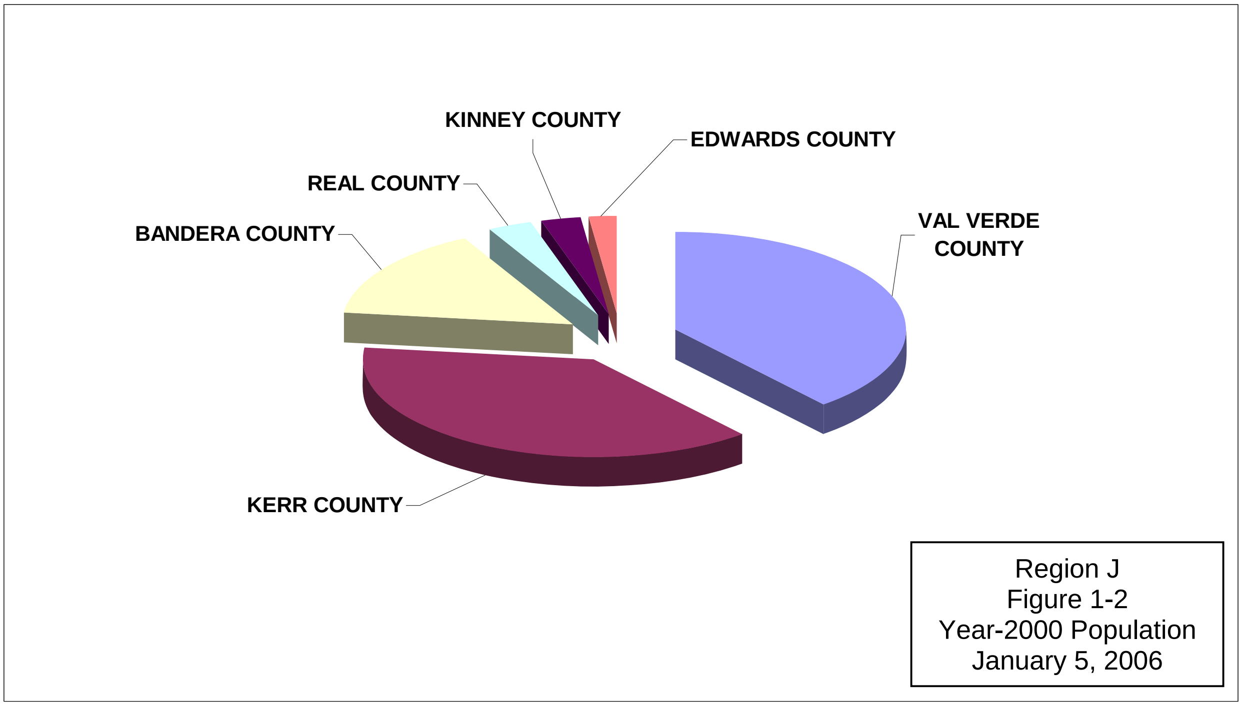

FIGURE 1- 2. YEAR-2000 POPULATION

1.2.4 Land Use

Land use in the six-county Region is divided into seven categories (Figure 1-3):

- Urban (or developed)
- Agricultural (cultivated)
- Range
- Forest
- Water
- Wetlands
- Barren

Urban lands are the location of cities and towns, that make up less than one percent of the Region's total land area. Agricultural lands are identified as areas that support the cultivation of crops. These lands, which potentially involve extensive irrigation, also occupy less than one percent of the Region. Together, urban and agricultural lands comprise the two most significant areas of water consumption in the Plateau Region.

Rangeland is defined as all areas that are either associated with or are suitable for livestock production. Although this is the largest category of land use in areal extent in the Region, rangeland accounts for one of the smallest sources of water demand. Forestland is limited to areas where topography and climate support the growth of native trees. Areas designated as either water or wetlands are associated with the rivers and their tributaries. Barren lands are defined as undeveloped areas with little potential for use as agricultural land, rangeland or forestland.

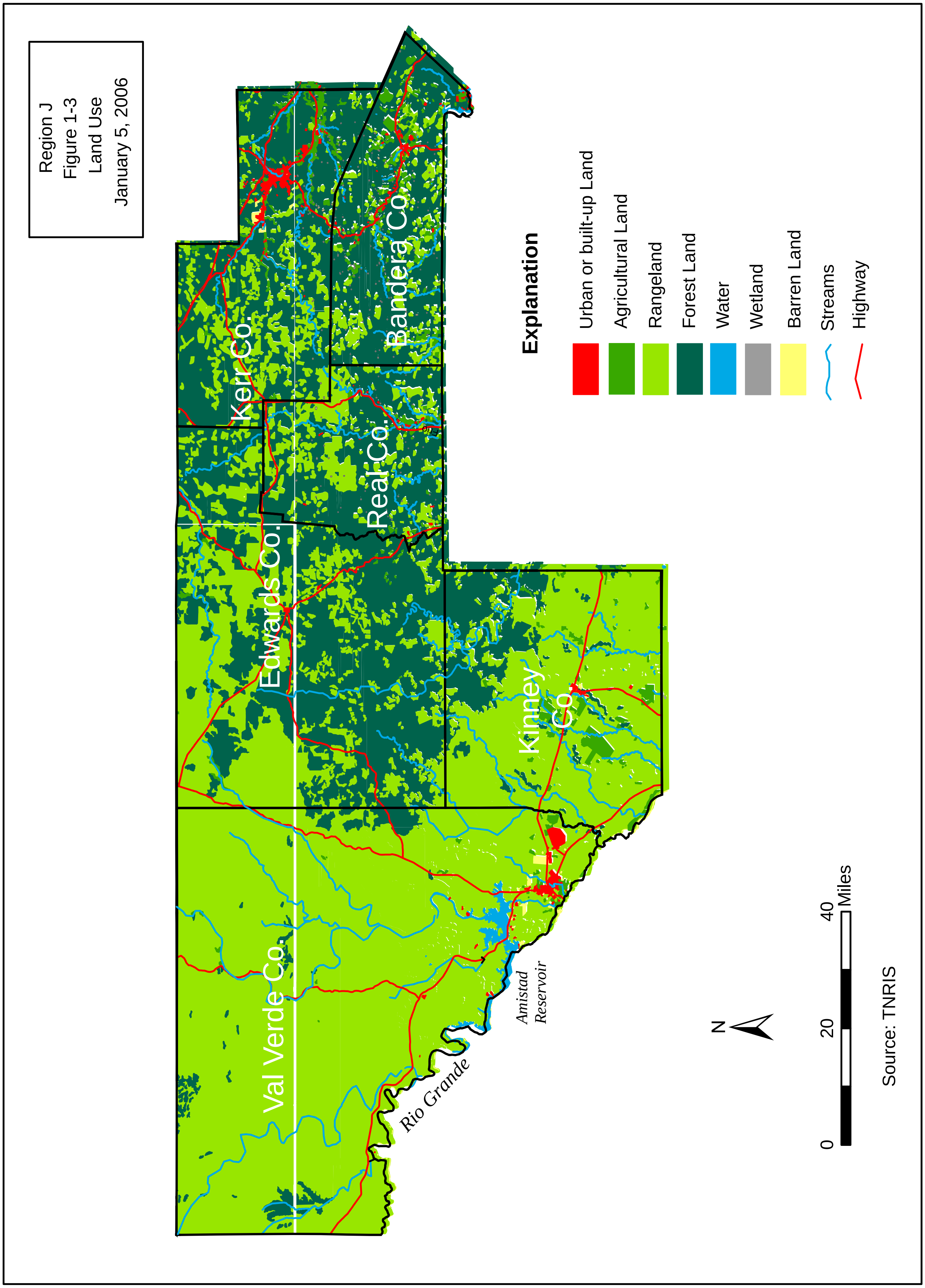

FIGURE 1-3. LAND USE

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1.2.5 Climate

The climate of the Plateau Region is semi-arid to arid as precipitation decreases westward across the Region. The average for the Edwards Plateau is 25 inches. Figure 1-4 illustrates the variability with respect to the six counties of the Region. Precipitation decreases from approximately 32 inches in the easternmost reaches of Bandera and Real Counties to less than 20 inches in western Val Verde County. Net lake evaporation (Figure 1-5) increases from 38 inches in Bandera and Real Counties to about 60 inches in western Val Verde County. Net lake evaporation is the difference between total evaporation from a lake and total precipitation. Figure 1-6 illustrates average monthly rainfall for selected stations.

Long periods of below-normal rainfall may have severe impacts on groundwater recharge, spring flow, and stream flow. The effects of low rainfall over long periods of time are most readily reflected in the form of decreased spring flow and stream flow. Under these conditions, the lack of rainfall leads to reduced recharge to aquifers and to lower water levels in wells. As water levels fall in aquifers in drought-stricken areas, the volume of water discharging from San Felipe Springs, for example, may decrease to levels that are insufficient to supply the full needs of the City of Del Rio with enough drinking water to meet all municipal, industrial and manufacturing demands for water. Landowners who are dependent on spring-fed stream flow may also find insufficient volumes of surface water needed to support irrigation or other farming and ranching activities. The direct linkage between precipitation and water levels in aquifers of the Plateau Region is indicated by hydrograph records of wells that show rapid increases in water levels as a response to local rainstorms.

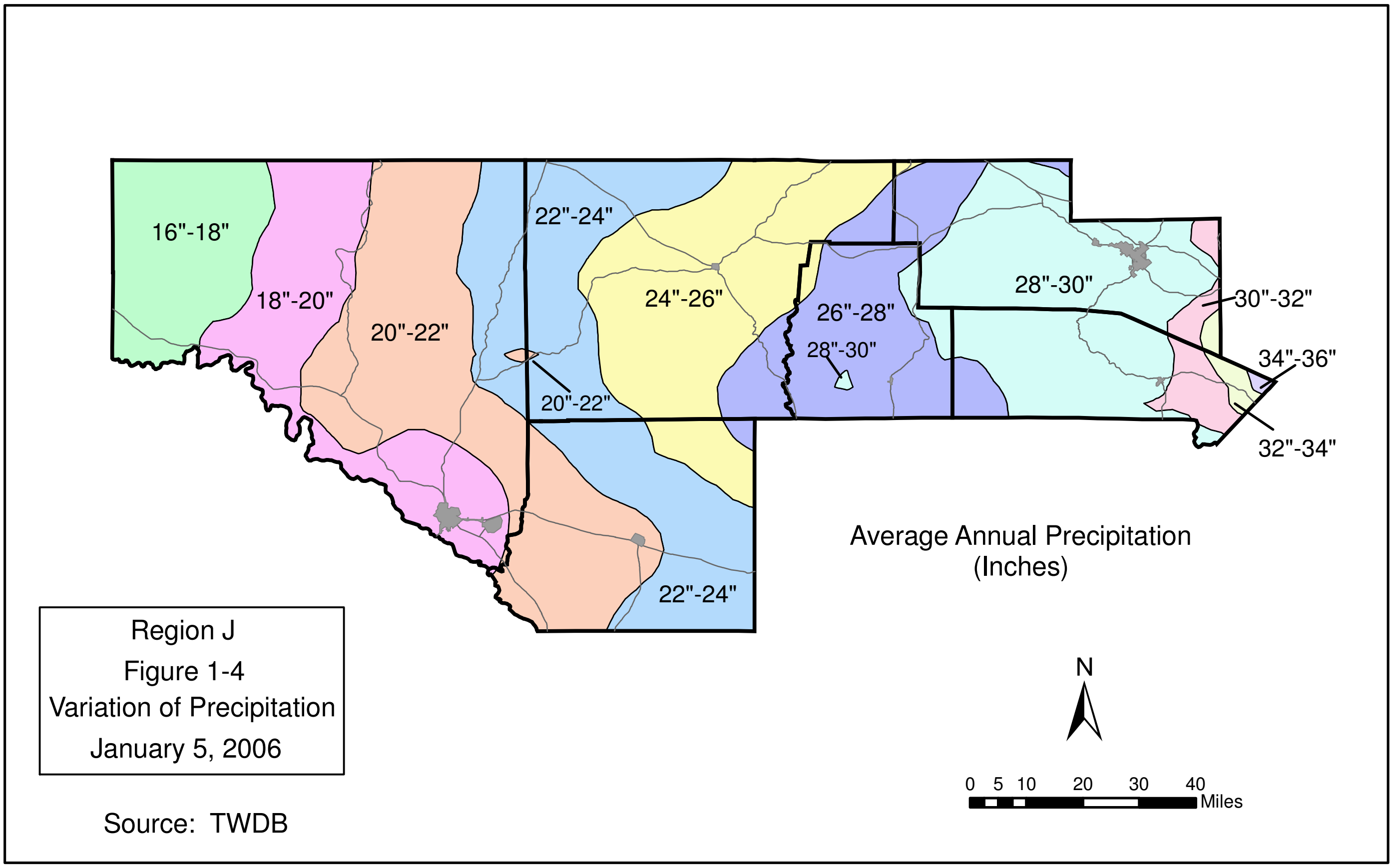

FIGURE 1-4. VARIATION OF PRECIPITATION, 1961-1990

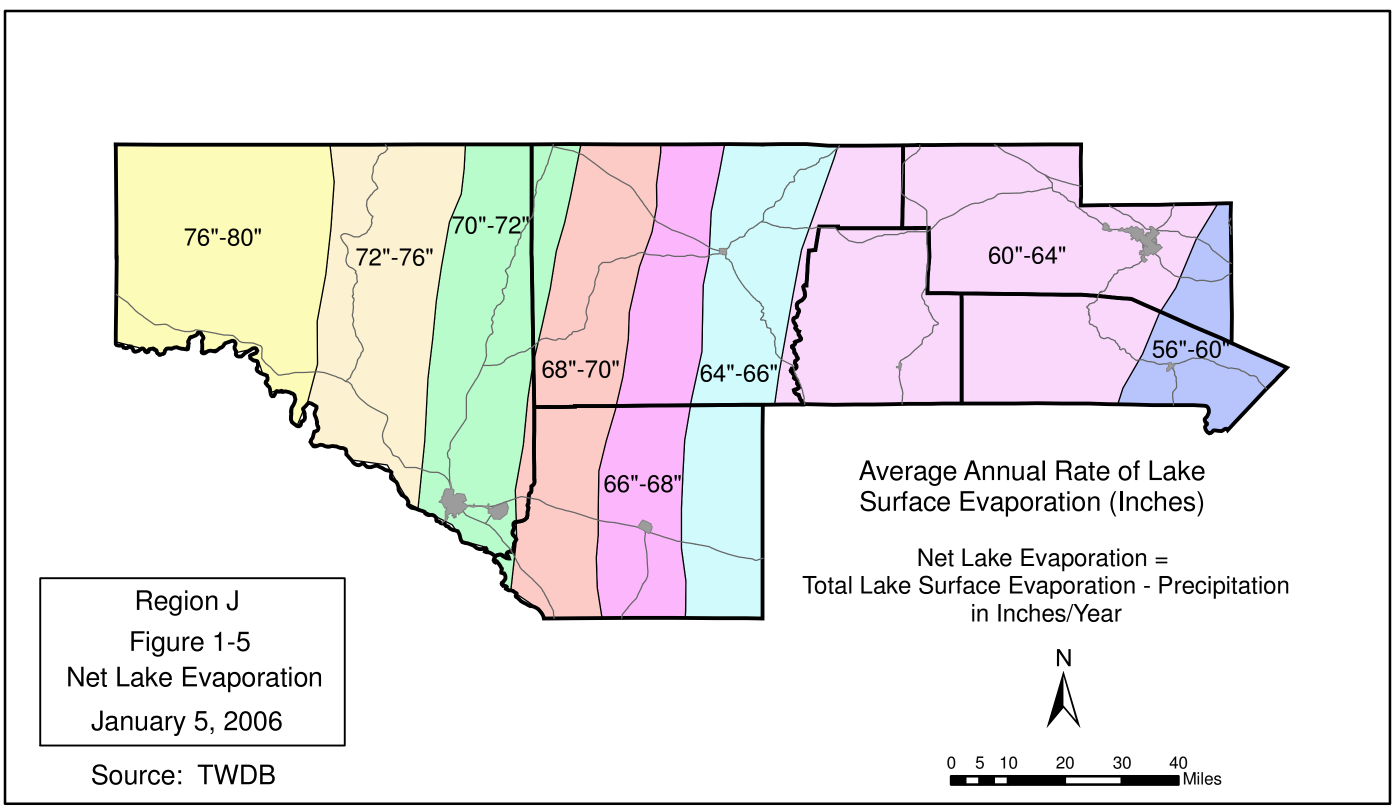

FIGURE 1-5. NET LAKE SURFACE EVAPORATION, 1940-1978

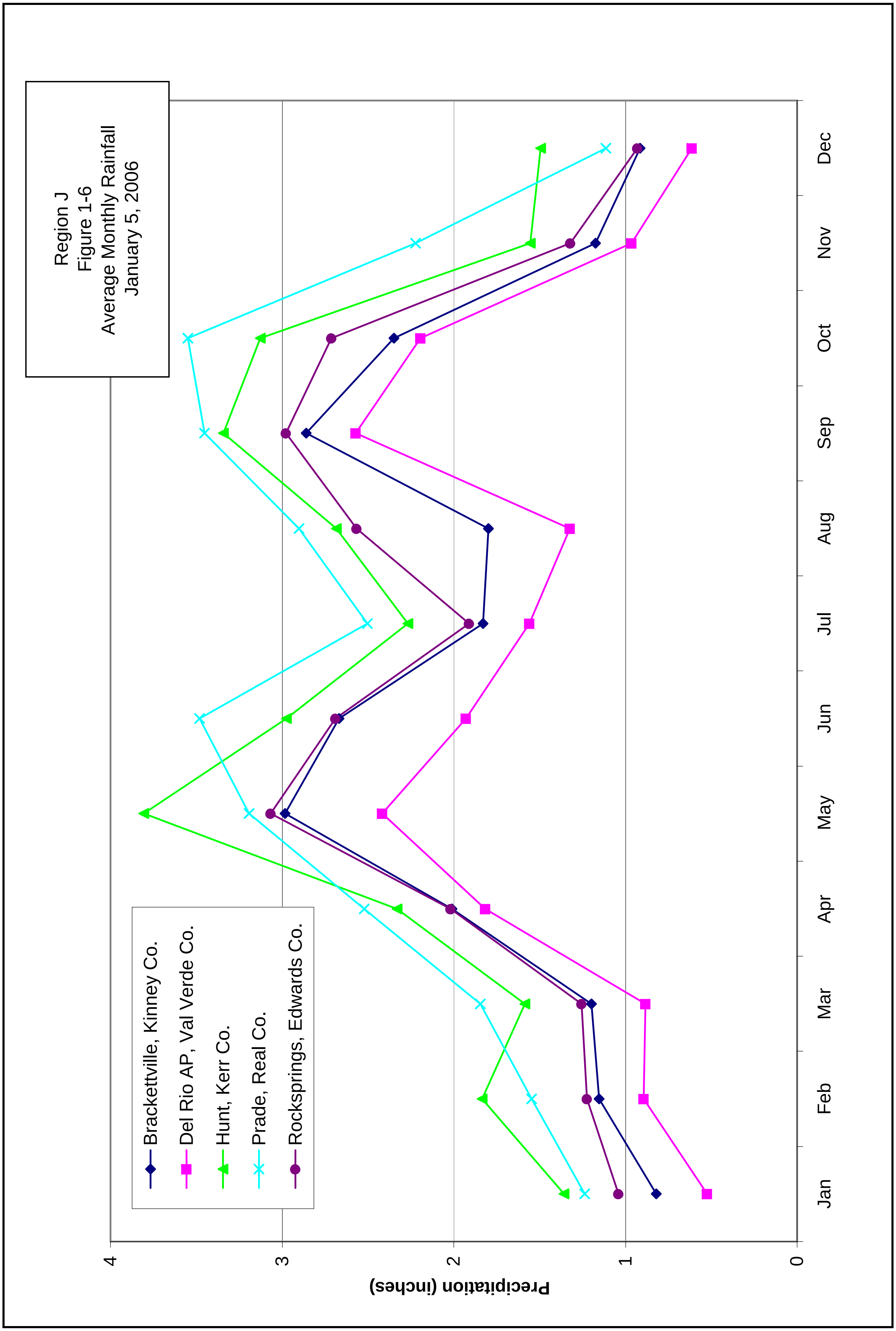

FIGURE 1-6. AVERAGE MONTHLY RAINFALL FOR SELECTED STATIONS

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1.2.6 Drought

Drought conditions are assumed in the planning process to insure that adequate infrastructure and planning is in place under severe water shortage conditions. Drought is generally defined as a period of abnormally dry weather of sufficient length to cause a serious hydrologic imbalance, which may be observed in any of the following conditions:

- Lower precipitation in key watersheds
- Extended periods of high temperature
- Higher levels of evapotranspiration
- Reduced runoff
- Stressed plants and grasses
- Reduced stream flow and spring flow
- Lower reservoir and groundwater levels
- Increased regional water demand

Drought can also be defined in the following operational definitions:

Meteorologic drought is a shortfall of precipitation, usually over a period of months or years, compared with the expected supply.

Agricultural drought is defined as that condition when rainfall and soil moisture are insufficient to support the healthy growth of crops and to prevent extreme crop stress. It may also be defined as a deficiency in the amount of precipitation required for the support of livestock and other farming or ranching operations.

Hydrologic drought is a long-term condition of abnormally dry weather that ultimately leads to the depletion of surface-water and groundwater supplies; the drying up of lakes and reservoirs; and the reduction or cessation of spring flow or stream flow. The tables developed in this report are based on the concept of hydrologic drought.

Although agricultural drought and hydrologic drought are consequences of meteorological drought, the occurrence of meteorological drought does not guarantee that either one or both of the others will develop.

1.2.7 Native Vegetation and Ecology

A biotic province is a considerable and continuous geographic area that is characterized by the occurrence of one or more ecologic associations that differ, at least in proportional area covered, from the associations of adjacent provinces. In general, biotic provinces are characterized by peculiarities of vegetation type, ecological climax, flora, fauna, climate, physiography and soil. Most of the Plateau Region has been classified as belonging to the "Balconian" Biotic Province, but small portions of Val Verde and Kinney Counties also lie within the "Tamaulipan" and "Chihuahuan" Biotic Provinces (Figure 1-7).

In the 1800s, the area was predominantly savannas of tall native grasses with occasional stands of Live Oak and Spanish Oak. Largely because of the suppression of prairie fires in the last century, most of the area has become blanketed by Ashe Juniper (commonly referred to as "cedar"), which once was primarily found within steep canyon lands. Another infestation of tree species found in the area is that of Mesquite. Infestation of trees can reduce the quantity and quality of water from watersheds, as well as reduce the diversity of plant species beneath the trees' canopies.

Cypress trees line the banks of many of the rivers. Other species of trees that are generally found are Post Oak, Elm, Hackberry, Cottonwood, Sycamore and Willow. Native grass species include Little and Big Bluestem, Indian Grass, Sideoat Grama and Texas Winter Grass. Some of the introduced species of grass include Coastal Bermuda, Plains Lovegrass, Klein Grass and King Ranch Bluestem. In the western portion of the Region, a varying growth of prickly pear, other cactus species, sage and other brushy species predominate.

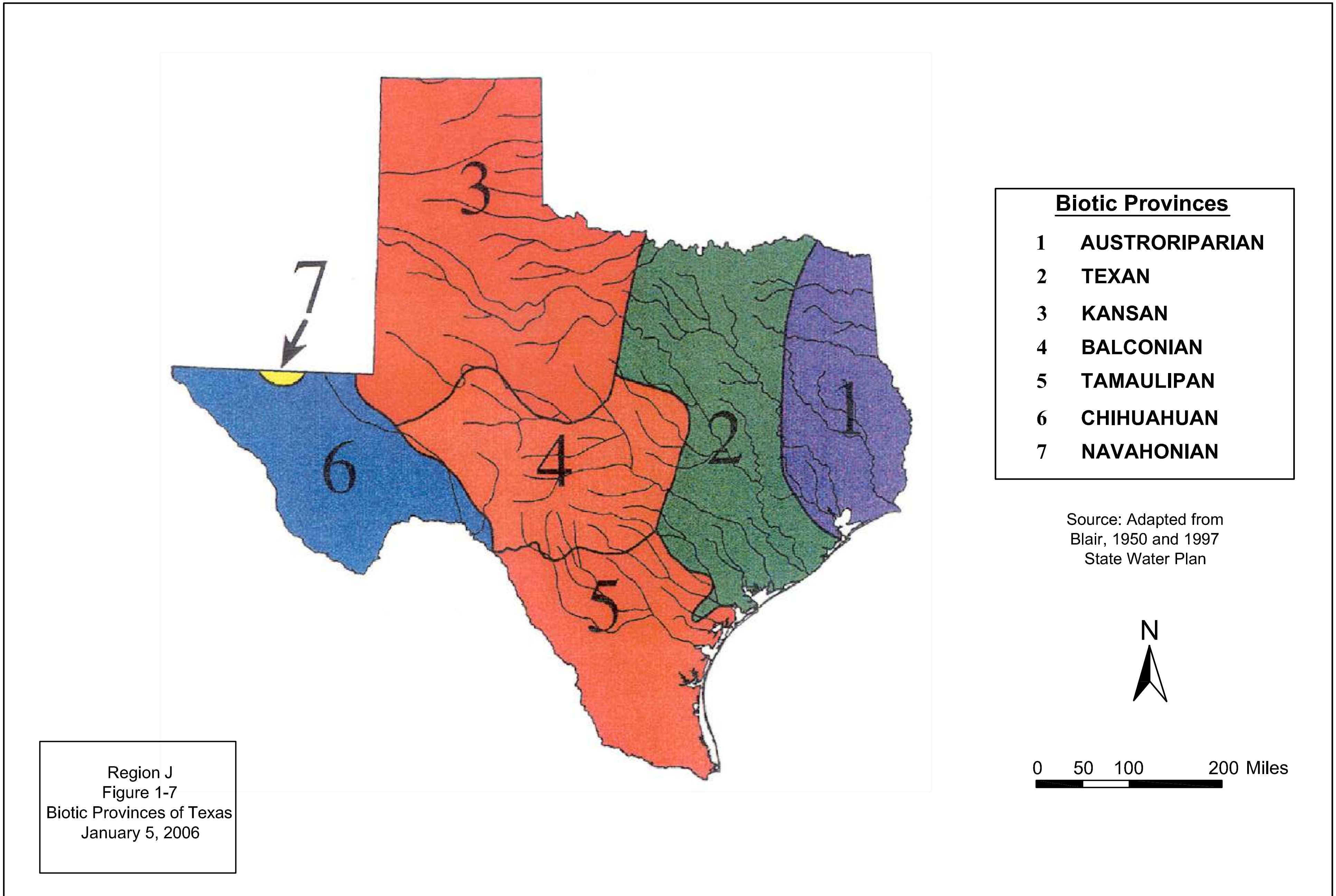

FIGURE 1-7. BIOTIC PROVINCES OF TEXAS

1.2.8 Agricultural and Natural Resources

The agricultural resources include beef cattle, sheep, goat, and exotic game animals. Apple and pecan orchards, along with hay, are grown in the eastern part of the Region. Kinney County, with its extensive irrigated lands in the western half of the county, account for twice the amount of water used for irrigation as the rest of the Region combined.

The natural resources of the Region include both terrestrial and aquatic habitats that boast some of the best scenic drives and vistas, river rafting, and hunting and fishing in Texas. Natural resources also include the great diversity of plant and animal wildlife that inhabit these environments. Texas Parks and Wildlife Department's Natural Diversity Database is a comprehensive source of information on rare, threatened, and endangered plants and animals.

Understandably, both local residents and tourists make use of these resources in their enjoyment of numerous public parks, dude ranches, resorts, recreational vehicle parks, and camping facilities. The following protected sites located within the Plateau Region depend upon adequate water to supply both environmental and recreational needs:

- Lost Maples State Natural area
- Hill Country State Natural Area
- Devils River State Natural Area
- Seminole Canyon State Historic Park
- Dolan Falls Ranch Preserve (Nature Conservancy)
- Devils Sinkhole State Natural Area
- Kickapoo Cavern State Park
- Kerrville-Schreiner Park
- Heart of the Hills Fisheries Science Center
- Amistad Natural Recreational Area

Both agricultural and natural resources water-supply needs are directly influenced by the quantity and quality of water available primarily in rivers and tributaries that flow through the Region and to a lesser extent on impounded lakes, ponds and tanks. With the exception of the Rio Grande, much of the drainage basins for the headwater of local rivers lie within Plateau Region counties. Springflow emanating from shallow groundwater sources creates the base flow of these streams. As such, these headwater areas are particularly susceptible to drought conditions as the water table naturally drops and springflow diminishes.

Agricultural activities in the Region that rely on surface water are designed to accommodate the intermittent nature of the supply. In most cases, this means that agricultural water supply needs will be supplemented by groundwater sources, or that irrigation activities will cease until river supplies are replenished. Both plant and animal species endemic to this Region have developed a tolerance for the intermittent nature of surface water availability; however, significantly long drought conditions can have a sever effect on these species. Riparian water needs for birding habitat is particularly critical. Of recognized importance to the water planning process is the concern of the effect that future development of water supplies might have on the diversity of species in the Region. Water-supply deficit strategies developed in Chapter 4 of this plan include an evaluation of each strategy's effect on agricultural and environmental concerns.

1.3 REGIONAL WATER DEMAND

1.3.1 Major Demand Categories

Total estimated year-2000 water consumptive use in the Plateau Region is 49,662 acre-feet. The largest category of demand is municipal (26,285 acre-feet), followed by irrigation (20,236 acre-feet), livestock (2,752 acre-feet), mining (364 acre-feet), and manufacturing (25 acre-feet). Municipal and irrigation combined represent 94 percent of all water use in the Region (Figure 1-8). Current and projected water demand for all water-use types are discussed in detail in Chapter 2.

1.3.2 Municipal

Municipal demand consists of both residential and commercial water uses. Commercial water consumption includes business establishments, public offices, and institutions, but does not include industrial water use. Residential and commercial uses are categorized together because they are similar types of uses, i.e.: they both use water primarily for drinking, cleaning, sanitation, air conditioning, and landscape watering.

The largest center of municipal demand is Del Rio in Val Verde County, where 15,253 acre-feet of water was used in 2000 to support all areas of residential, commercial, public and military consumption. Fifty-eight percent of municipal water is used in Val Verde County, and 25 percent is used in Kerr County.

1.3.3 Wholesale Water Provider

The City of Del Rio is the only entity in the Plateau Region that is designated as a wholesale water provider. In addition to its own use, the city provides water to Laughlin Air Force Base and subdivisions outside of the city. The city also provides water and wastewater services to two colonias, Cienegas Terrace and Val Verde Park Estates.

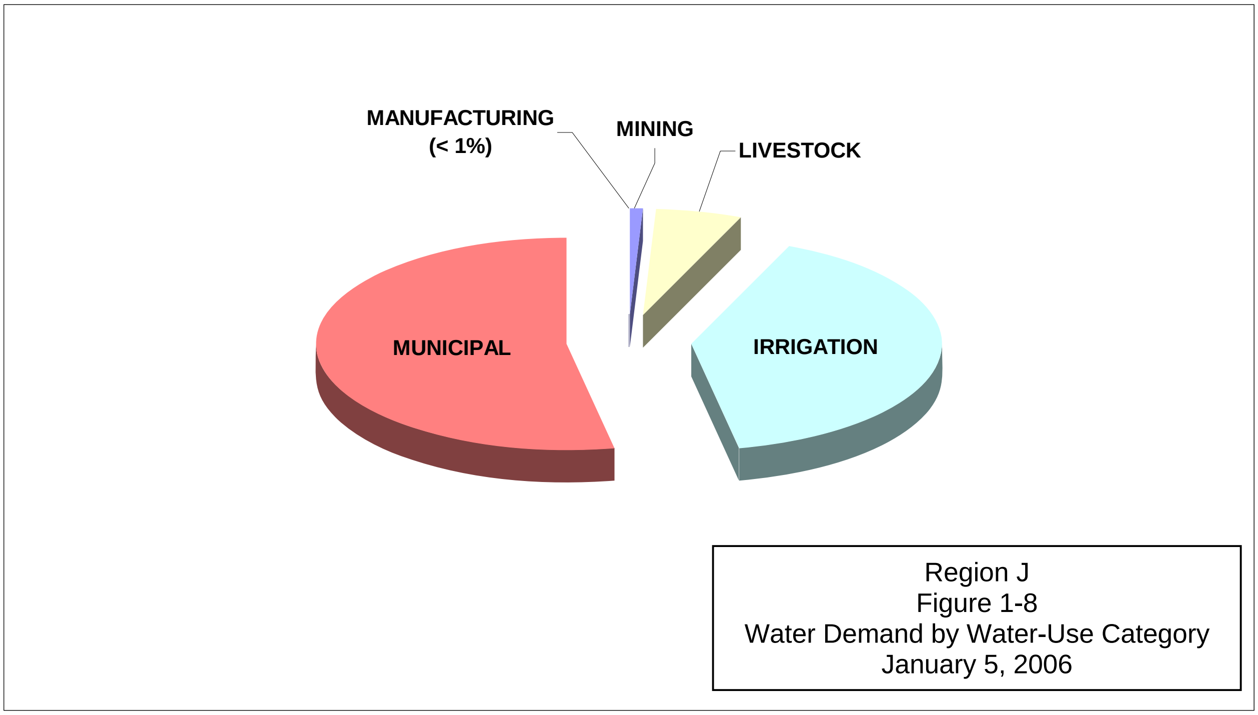

FIGURE 1- 8. YEAR-2000 WATER DEMAND BY WATER-USE CATEGORY

1.3.4 Agriculture and Ranching

This category of demand consists of all water used by the agricultural industry to support the cultivation of crops and the watering of livestock and wildlife. Where groundwater is the source of irrigation water, the TWDB defines irrigation use as "on farm demand." Where surface water is the source of irrigation water, the TWDB defines irrigation use as both "on farm" demand and "diversion loss." Diversion loss, also referred to as conveyance loss, is the amount of water lost during the delivery of surface water from the point of diversion on the river or stream to the point of use on the farm. Surface water is typically conveyed by an open canal system, which exposes the water supply to possible loss from seepage, breaks, evaporation, and uptake by riparian vegetation.

In the year-2000, irrigation represented the second greatest water use in the Region (20,236 acre-feet) with Kinney County accounting for 70 percent. Livestock use in the Region amounted to (2,752 acre-feet).

1.3.5 Manufacturing, Industrial and Mining

Manufacturing and industrial (M&I) demand consists of all water used in the production of goods for domestic and foreign markets. Some processes require direct consumption of water as part of the manufacturing process. Others require very little water consumption, but may require large volumes of water for cooling or cleaning purposes. In some manner or another, water is passed through the manufacturing facility and used either as a component of the product or as a transporter of waste heat and materials. Within the Plateau Region, M&I is only accounted for in Kerr County.

This mining demand consists of all water used in the production and processing of nonfuel (e.g., sulfur, clay, gypsum, lime, salt, stone and aggregate) and fuel (e.g., oil, gas, and coal) natural resources by the mining industry. In all instances, water is required in the mining of minerals either for processing, leaching to extract certain ores, controlling dust at the plant site, or for reclamation. This also includes the production of crude petroleum and natural gas. Most of the water used in the mining industry in the Plateau Region is related to the extraction of gravel and road-base material, with Kerr and Val Verde Counties recording the greatest use.

1.3.6 Environmental and Recreational Water Needs

Environmental and recreational water use in the Plateau Region is recognized as being an important consideration as it relates to the natural community in which the residents of this Region share and appreciate. In addition, for rural counties, tourism activities based on natural resources offer perhaps the best hope for modest economic growth to areas that have seen a long decline in traditional economic activities such as agriculture.

A goal of this plan is to provide for the health, safety, and welfare of the human community, with as little detrimental effect to the environment as possible. To accomplish this goal, the evaluation of strategies to meet future water needs (Chapter 4) includes a distinct consideration of the impact that each implemented strategy might have on the environment.

Recreation activities involve human interaction with the outdoor environment and are often directly dependent on water resources. It is recognized that the maintenance of the regional environmental community's water supply needs serves to enhance the lives of citizens of the Plateau Region as well as the tens of thousands of annual visitors to this Region. Environmental and recreational water needs are further discussed throughout the plan and especially in Chapters 2, 3, 4 and 8.

1.4 WATER SUPPLY SOURCES

Water supply sources in the Plateau Region include groundwater primarily from five aquifers and surface water from five river basins. Reuse of existing supplies is also considered a water supply source. A more detailed description of these sources and estimates of their supply availability is provided in Chapter 3.

1.4.1 Groundwater

Within the Plateau Region, the TWDB recognizes three major aquifers [the Trinity, the Edwards-Trinity (Plateau), and the Edwards (Balcones Fault Zone)] (Figure 1-9). For this plan, the Austin Chalk aquifer in Kinney County and the Frio River Alluvium aquifer in Real County have also been identified as groundwater sources. Groundwater conservation districts in Bandera, Kerr, Kinney, Real and Edwards Counties provide for local management control of their groundwater resources.

1.4.1.1 Trinity Aquifer

The Trinity aquifer occurs in its entirety in a band from the Red River in North Texas to the Hill Country of south central Texas and provides water in all or parts of 55 counties. Trinity Group formations also occur as far west as the Panhandle and Trans-Pecos regions where they are included as part of the Edwards-Trinity (High Plains) and Edwards-Trinity (Plateau) aquifers. The Trinity aquifer is composed of marine sediments (primarily limestone) deposited during the Cretaceous Period. The Trinity Group in the Plateau Region includes the Glen Rose and underlying Travis Peak formations. The Glen Rose consists of up to approximately 1,000 feet of limestone with interbedded shale, marl and occasional anhydrite (gypsum). The Travis Peak contains sands, clays and limestones and is subdivided into water-bearing members of the Hensell, Cow Creek, Sligo and Hosston.

1.4.1.2 Edwards-Trinity (Plateau) Aquifer

Rock formations of the Edwards-Trinity (Plateau) aquifer form the Edwards Plateau east of the Pecos River, and in its entirety provide water to all or parts of 38 counties. The aquifer extends from the Hill Country of Central Texas to the Trans-Pecos region of West Texas. The aquifer consists of saturated sediments of lower Cretaceous age Trinity Group formations and overlying limestones and dolomites of the Edwards Group. The Glen Rose limestone is the primary unit in the Trinity in the southern part of the Plateau. Springs issuing from the aquifer form the headwaters of several eastward and southerly flowing rivers. Some of the largest springs of the area are located in Val Verde County, such as San Felipe Springs near Del Rio.

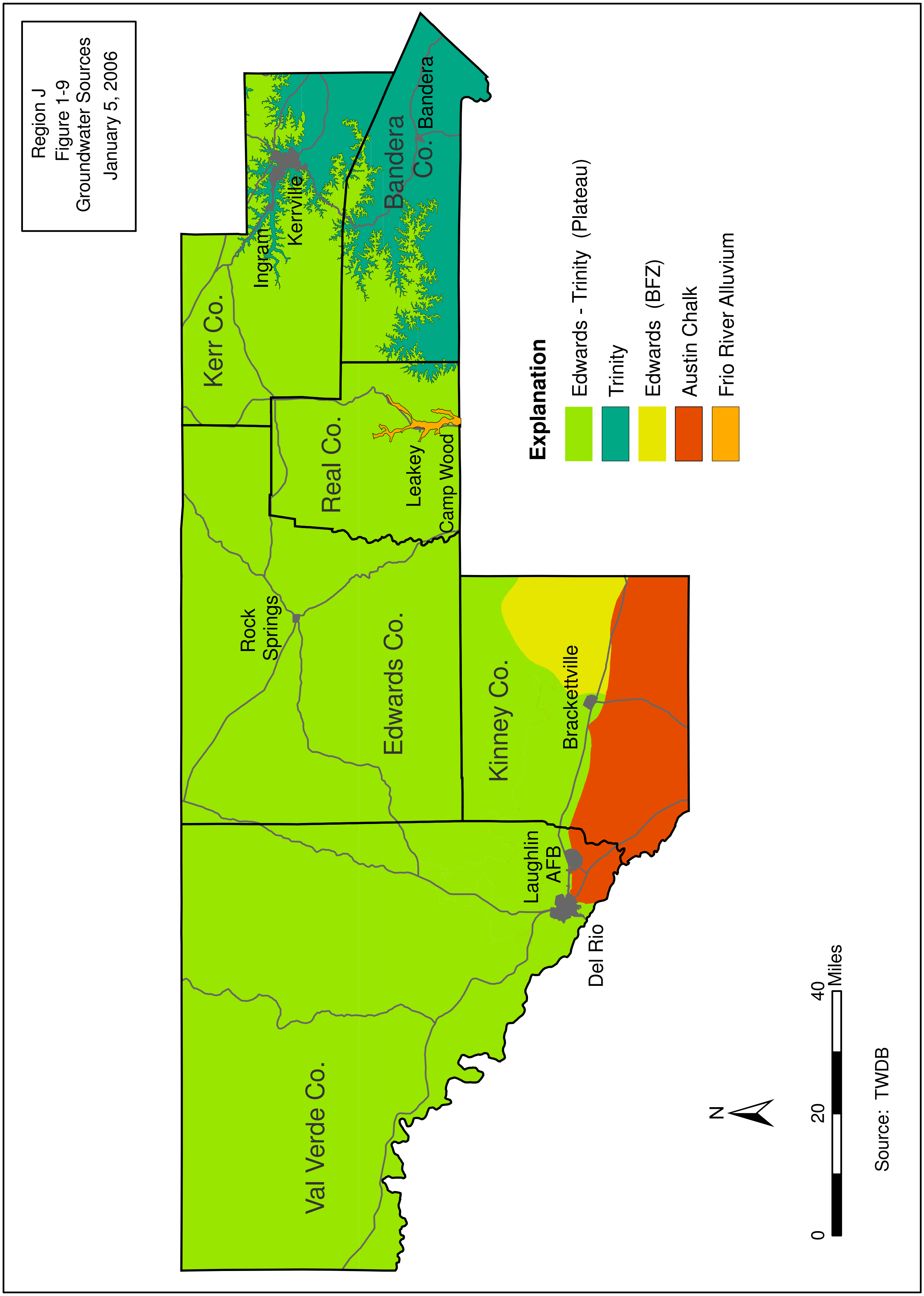

FIGURE 1-9. GROUNDWATER SOURCES

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1.4.1.3 Edwards (BFZ) Aquifer

The Edwards (Balcones Fault Zone)(BFZ) aquifer in its entirety covers approximately 4,350 mi^2 in parts of 11 counties. It forms a narrow belt extending from a groundwater divide in Kinney County through the San Antonio area northeastward to the Leon River in Bell County. In the Plateau Region, the westernmost end of the Edwards (BFZ) aquifer occurs in Kinney County. Within the Region, water in the aquifer generally moves from the recharge zone toward natural discharge points such as Las Moras Springs near Brackettville or south-easterly toward San Antonio.

1.4.1.4 Austin Chalk Aquifer

The Austin Chalk aquifer occurs in the southern half of Kinney County and in the southernmost extent of Val Verde County. Most Austin Chalk wells discharge only enough water for domestic or livestock use; however, primarily in the area along Las Moras Creek, a few wells are large enough to support irrigation.

1.4.1.5 Frio River Alluvium Aquifer

The Frio River Alluvium in central Real County extends over an area of approximately 1,120 acres and contains approximately 2,800 acre-ft of recoverable water. The alluvium is mostly composed of gravels and sands eroded from surrounding limestone hills and deposited along the Frio River. Water supplies for the City of Leakey and other rural domestic homes are derived from this small aquifer.

1.4.1.6 Other Aquifers

Located along many of the streams and rivers throughout most of the Region are shallow alluvial floodplain deposits. Wells completed in these deposits supply small to moderate quantities of water mostly for domestic and livestock purposes. The alluvium is in direct hydraulic connection with the rivers and streams that meander through them.

Also within the Region, the State has identified other minor aquifers only in Kerr County. These are the downdip extensions of the Ellenburger-San Saba and the Hickory. According to TWDB records none of their inventoried wells penetrate either aquifer.

1.4.2 Surface Water

The Plateau Region is unique within all planning regions in that it straddles several different river basins rather than generally following a single river basin or a large part of a single river basin (Figure 1-10). From west to east, these basins include the Rio Grande, Nueces, Colorado, Guadalupe, and San Antonio. The headwaters of three of these rivers (Nueces, Guadalupe, and San Antonio) originate within this Region.

1.4.2.1 Rio Grande Basin

The Rio Grande, or Rio Bravo as it is known in Mexico, forms the border between the United States and Mexico. International treaties governing the ownership and distribution of water in the Rio Grande are discussed in Chapter 3. The 3.4 million acre-foot International Amistad Reservoir is located on the Rio Grande in Val Verde County. Within the Plateau Region, the Pecos and Devils Rivers in Val Verde County are the primary tributaries to the Rio Grande. Numerous springs, including San Felipe, Goodenough, and Las Moras Springs issue from the Edwards aquifer and flow into tributaries of the Rio Grande. The Rio Grande does not provide water for municipal use in the Plateau Region and only provides limited amounts for irrigation use, primarily from San Felipe Creek.

1.4.2.2 Nueces River Basin

The main stem of the Nueces River forms a portion of the border between Edwards and Real Counties. Tributaries of the Nueces River located in the Plateau Region include the Sabinal River and Hondo Creek in Bandera County, the West Nueces River in Edwards and Kinney Counties, and the Frio, East Frio, Dry Frio Rivers in Real County and other significant tributaries.

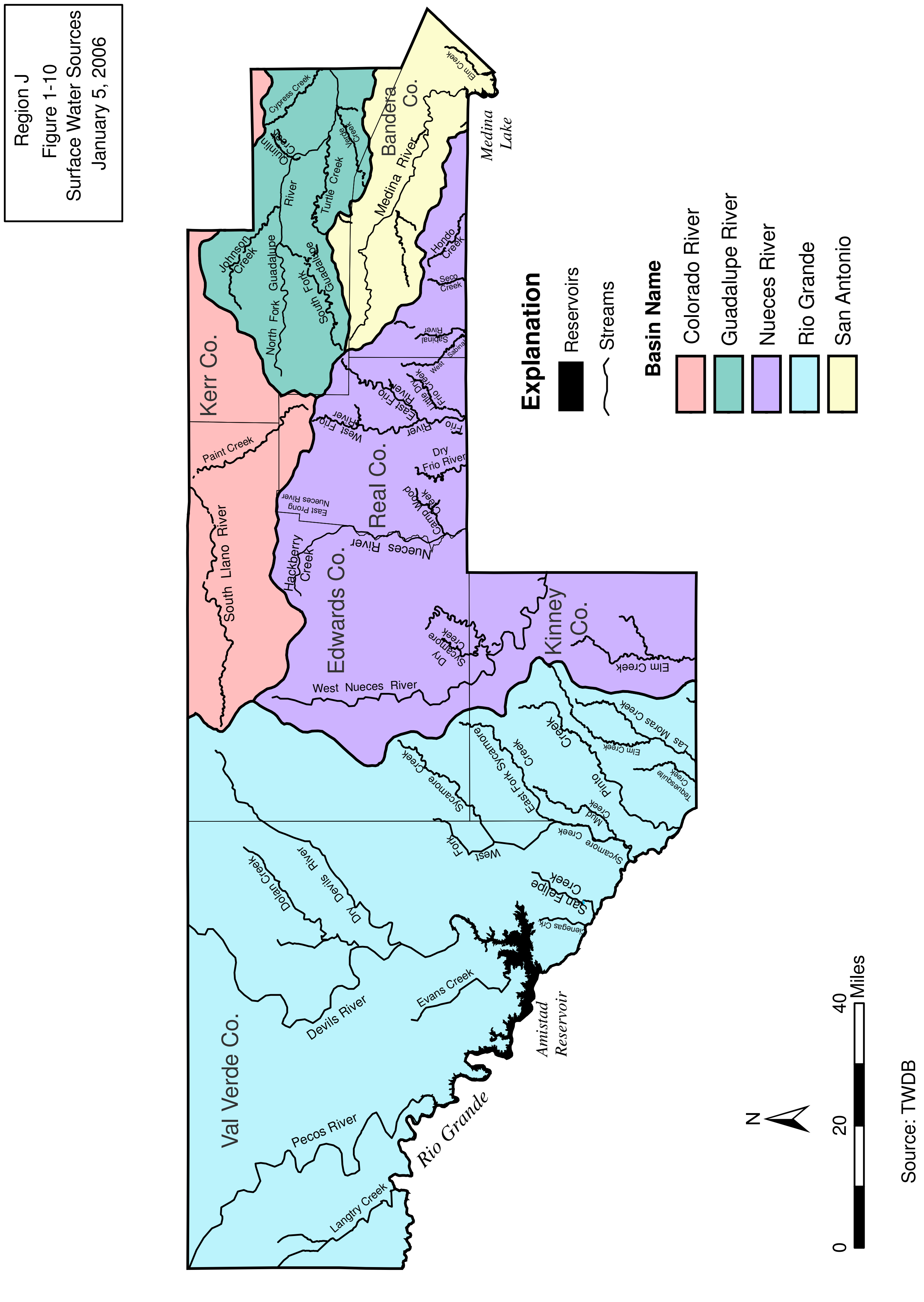

FIGURE 1-10. SURFACE WATER SOURCES

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1.4.2.3 Colorado River Basin

The City of Rocksprings in Edwards County straddles the drainage divide between the Nueces River Basin and the Colorado River Basin. The portion of Edwards County north of Rocksprings, small northern portions of Real County and the northwestern part of Kerr County drain to the Llano River watershed in the Colorado River Basin.

1.4.2.4 Guadalupe River Basin

The majority of Kerr County lies in the Guadalupe River Basin. The Guadalupe is not only an important water supply source for Kerrville and other communities in Kerr County, but is also a major tourist attraction for the region. Although Kerrville and the Upper Guadalupe River Authority own water rights, much of the flow of the Guadalupe is permitted for downstream use.

1.4.2.5 San Antonio River Basin

Most of Bandera County is split between the Nueces and San Antonio River Basins. The Medina River flows through Bandera County and drains to the San Antonio River. Medina Lake straddles the boundary between Bandera, Medina and Bexar Counties. This reservoir has a volume of 254,843 acre-feet and serves as a major irrigation source for land downstream in Medina County. Bandera County has contracted for 5,000 acre-feet and Bexar Metropolitan Water District has contracted for 6,000 acre-feet. The Bexar-Medina-Atascosa Counties Water Control and Improvement District #1 has a permit to sell 20,000 acre-feet of water diverted from Medina Lake.

1.4.3 Springs and Wildlife Habitat

Springs have played an important role in the development of the Plateau Region. They were important sources of water for Native American Indians, as indicated by the artifacts and petroglyphs found in the vicinity of many of the springs. These springs were also principal sources of water for early settlers and ranchers. Although springs are often recognized by a given name, in reality, most springs are a complex of numerous openings through which groundwater flows to the surface. Additional discussion pertaining to springs and their function in the relationship between groundwater and surface water is contained in Chapter 3.

The PWPG has identified three "Major Springs" (that are important for their municipal water supply (Figure 1-11). The fourth largest spring in Texas, San Felipe Springs, discharges to San Felipe Creek northeast of Del Rio and provides municipal drinking water for Del Rio, as well as irrigation use downstream. Las Moras Springs in Kinney County is of historical significance for its importance as a supply source on early travel routes and military fortifications. Today, Las Moras Springs supports the Fort Clark community and is hydrologically associated with the same aquifer system that serves Fort Clark MUD and the City of Brackettville. The third major spring is Old Faithful in Real County, which is the drinking-water supply for the Community of Camp Wood. Although only three springs are identified as "Major Springs", the PWPG recognizes that all springs in the Region are important and are deserving of natural resource protection.

The PWPG also recognizes the important ecological water supply function that all springs perform in the Region. Springs create and maintain base flow to rivers, contribute to the esthetic and recreational value of land, and are significant sources of water for wild game and aquatic species. Water issuing from springs forms wetlands that attract migratory birds and other fowl that inhabit the Region throughout the year. The spring wetlands host numerous terrestrial and aquatic species, some of which are recognized as threatened and endangered.

Two supplemental study reports were prepared for the PWPG that address springs. The first report (Ashworth and Stein, 2005) considers the location and geohydrology of springs in Kinney and Val Verde Counties, and the second report (Ashworth, 2005) relates springflow in western Kerr County to base flow in the three branches of the upper Guadalupe River. (See reference list in Chapter 3)

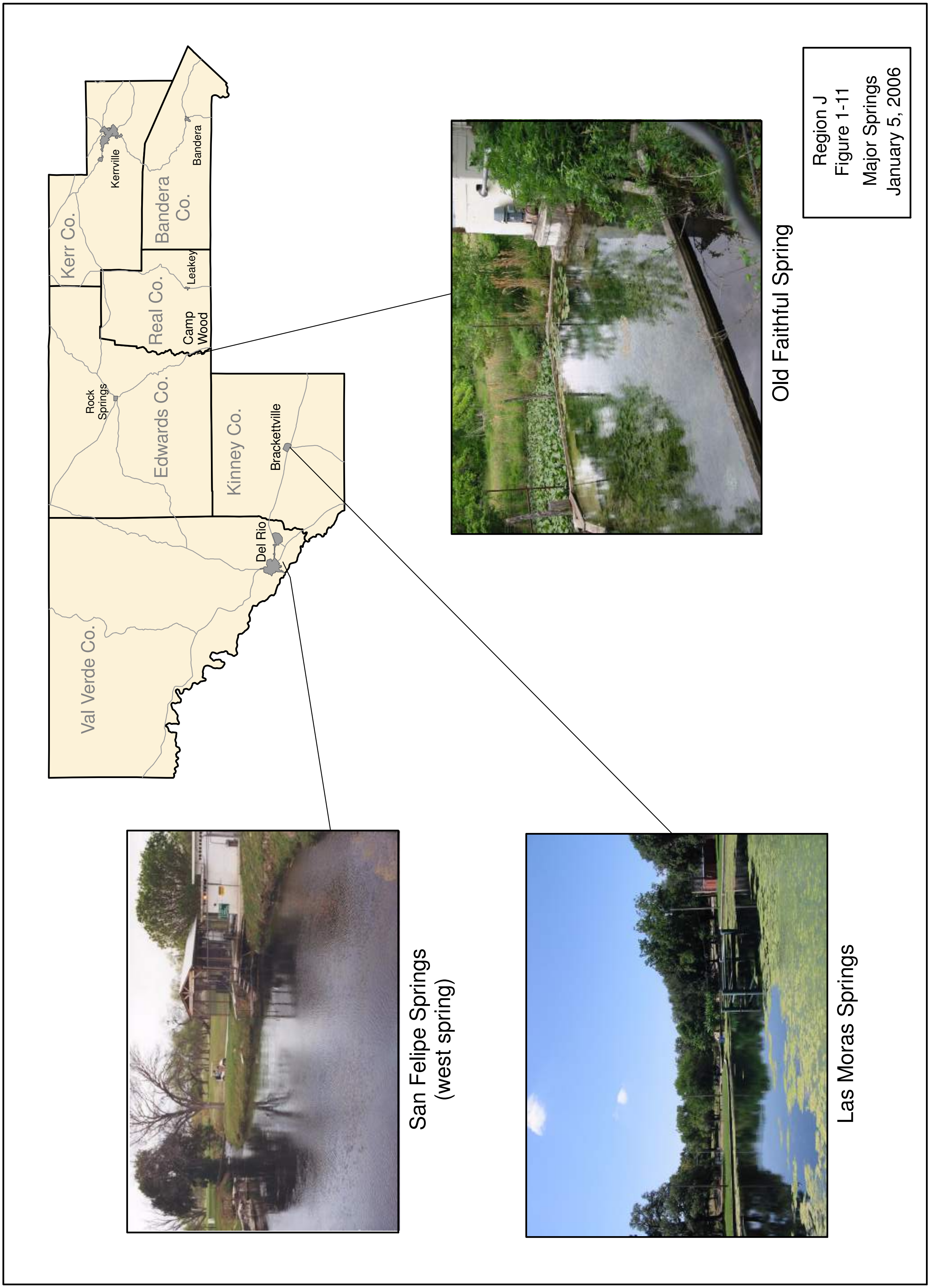

FIGURE 1-11. MAJOR SPRINGS

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1.4.4 Reuse

Water recycling, or reuse, is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation or industrial processes. The Cities of Kerrville and Camp Wood have active water reuse programs that are described in Chapter 3.

1.4.5 Water Quality Issues

Water quality is generally good throughout the Plateau Region; however, a few specific water quality issues should be mentioned. A more detailed discussion on these issues can be found in Chapter 5.

Increasing population impacts water quality in many ways, one of which is the increase in urban runoff that comes with the increase in impervious cover in populated areas. Impervious cover concentrates runoff into storm sewers and drains, which then discharges into streams, increasing the flow, which also increases the erosional power of the water. In addition, urbanization also causes increased pollutant loads, including sediment, oil/grease/toxic chemicals from motor vehicles, pesticides/herbicides/fertilizers from gardens and lawns, viruses/bacteria/ nutrients from human and animal wastes including septic systems, heavy metals from a variety of sources, and higher temperatures of the runoff.

Increasing population has also manifested itself in the fragmentation of larger properties. With the advent of fragmentation comes the proliferation of new wells being drilled to serve the individual properties. Each new well thus becomes another potential conduit for surface contamination to reach the underlying aquifer system.

Of concerns to the PWPG is the impact that vehicular traffic is having on streambeds. Vehicular traffic in streambeds disrupts streamflow, damages plants and animals living in these areas, damages channels and erodes banks, and decreases water quality by increasing the turbidity of the water in these rivers and streams. This traffic disturbs the environment both in the streambed and out of it.

From a regional perspective, groundwater quality is relatively good. However, the constituent of most concern is nitrate, which is found above the primary maximum contaminant level in a number of water-sample analyses from the Edwards (BFZ) aquifer and the Austin Chalk aquifer in Kinney County.

Historically, the primary contribution to poor groundwater quality occurs in wells that do not have adequately cemented casing. Improperly completed wells allow poorer quality water to migrate into zones containing good quality water. Poorer groundwater quality in the Region is generally from two different sources, evaporite beds in the Glen Rose formation and from surface contamination, both of which can be prevented by proper well construction. Also of concern are above normal levels of radioactivity that have been detected in sand sequences of the Glen Rose and Hensell formations in some areas.

1.5 WATER MANAGEMENT PLANNING

1.5.1 State Water Plan

The Texas Water Development Board (TWDB) adopted *Water for Texas - 2002* on January 2002 as the official water plan for Texas. The Texas Water Code directs the TWDB to update this comprehensive water plan, which is used as a guide for the management of the State's water resources. This State Plan was the result of a consensus planning process that is directed by the TWDB and included efforts by the Texas Commission on Environmental Quality (TCEQ), the Texas Parks and Wildlife Department (TPWD), and the Texas Department of Agriculture (TDA). This plan is the direct result of local input from 16 regional water planning areas as authorized under Senate Bill 1 of the 77th Legislative Session. Key points mentioned in the State Plan for the Plateau Region include:

- No new reservoirs
- 12 water user groups with projected water needs by 2050
- Endangered and threatened species could limit future development options
- Historical groundwater data insufficient for planning purposes

1.5.2 Local Water Management Studies and Plans

The City of Kerrville's 2004 Comprehensive Water Management Plan is recognized. Additional local and regional water management plans and studies that have been developed to address current and long-term water supply issues were summarized in the initial *2001 Plateau Regional Water Plan*. The PWPG is unaware of any additional plans or studies completed since 2001.

- City of Kerrville Water Management Plan
- Trans-Texas Water Program - West Central Study Area;
- Springhills Water Management District - Regional Water Supply Study;
- Val Verde County - Regional Waterworks and Wastewater Systems Study;
- Kerr County - Regional Water and Wastewater Planning Study;
- Kerr County - Regional Water Plan, Phase I for UGRA; and
- UGRA/Kerrville - Aquifer Storage and Recovery Feasibility Investigation

The Plateau Region often experiences periods of limited rainfall, especially compared with more humid areas in the eastern part of the state. Although residents of the region are generally accustomed to these conditions, the low rainfall and accompanying high evaporation underscore the necessity of developing plans to manage resources responsibly and to respond to potential disruptions in the supply of groundwater and surface water caused by drought conditions. The following entities have developed drought contingency plans:

- City of Del Rio;
- City of Brackettville;
- City of Kerrville;
- Fort Clark Municipal Utility District;
- Headwaters Groundwater Conservation District;
- City of Bandera; and
- Real-Edwards Conservation and Reclamation District.

1.5.3 Groundwater Conservation Districts

The Texas Legislature has established a process for local management of groundwater resources through groundwater conservation districts. Groundwater conservation districts are charged to manage groundwater by providing for the conservation, preservation, protection, recharging and prevention of waste of groundwater within their jurisdictions. An elected or appointed board governs these districts and establishes rules, programs and activities specifically designed to address local problems and opportunities. Texas Water Code §36.0015 states, in part, "Groundwater Conservation Districts created as provided by this chapter are the state's preferred method of groundwater management." Four districts are currently in operation within the planning region (Figure 1-12), their management goals are discussed in further detail in Chapter 6.

- Bandera County River Authority and Groundwater District
- Headwaters Groundwater Conservation District
- Real-Edwards Conservation and Reclamation District
- Kinney County Groundwater Conservation District

1.5.4 Water-Supply Source Vulnerability/Security

Following the events of September 11th, Congress passed the Bio-Terrorism Preparedness and Response Act. Drinking water utilities serving more than 3,300 people were required and have completed vulnerability preparedness assessments and response plans for their water, wastewater, and stormwater facilities. The U.S. Environmental Protection Agency (EPA) funded the development of three voluntary guidance documents, which provide practical advice on improving security in new and existing facilities of all sizes. The documents include:

- Interim Voluntary Security Guidance for Water Utilities
  www.awwa.org
- *Interim Voluntary Security Guidance for Wastewater/Stormwater Utilities*
  www.wef.org
- *Interim Voluntary Guidelines for Designing an Online Contaminant Monitoring System*
  www.asce.org

1.6 COLONIAS

Colonias represent a special, and growing, subset of municipal demand in the Region, and a challenge to water suppliers. Most colonias are subdivisions in unincorporated areas located along the United States/Mexico international border and typically consist of small land parcels sold to low-income people. These subdivisions often lack basic services such as potable water, sewage disposal and treatment, paved roads, and proper drainage. Public health problems are often associated with these colonias.

The Economically Distressed Area Program (EDAP) was created by the Texas Legislature in 1989 and is administered by the TWDB. The intent of the program is to provide local governments with financial assistance for bringing water and wastewater services to the colonias. An economically distressed area is defined as one in which water supply or wastewater systems are not adequate to meet minimal state standards, financial resources are inadequate to provide services to meet those needs, and there was an established residential subdivision on June 1, 1989. Affected counties are counties adjacent to the Texas/Mexico border, or that have per capita income 25 percent below the state average and unemployment rates 25 percent above the state average for the most recent three consecutive years for which statistics are available. Additional information pertaining to eligibility and requirements for this program are available on the TWDB web site: http://www.twdb.state.tx.us/assistance/financial/fin_infrastructure/edapfund.asp.

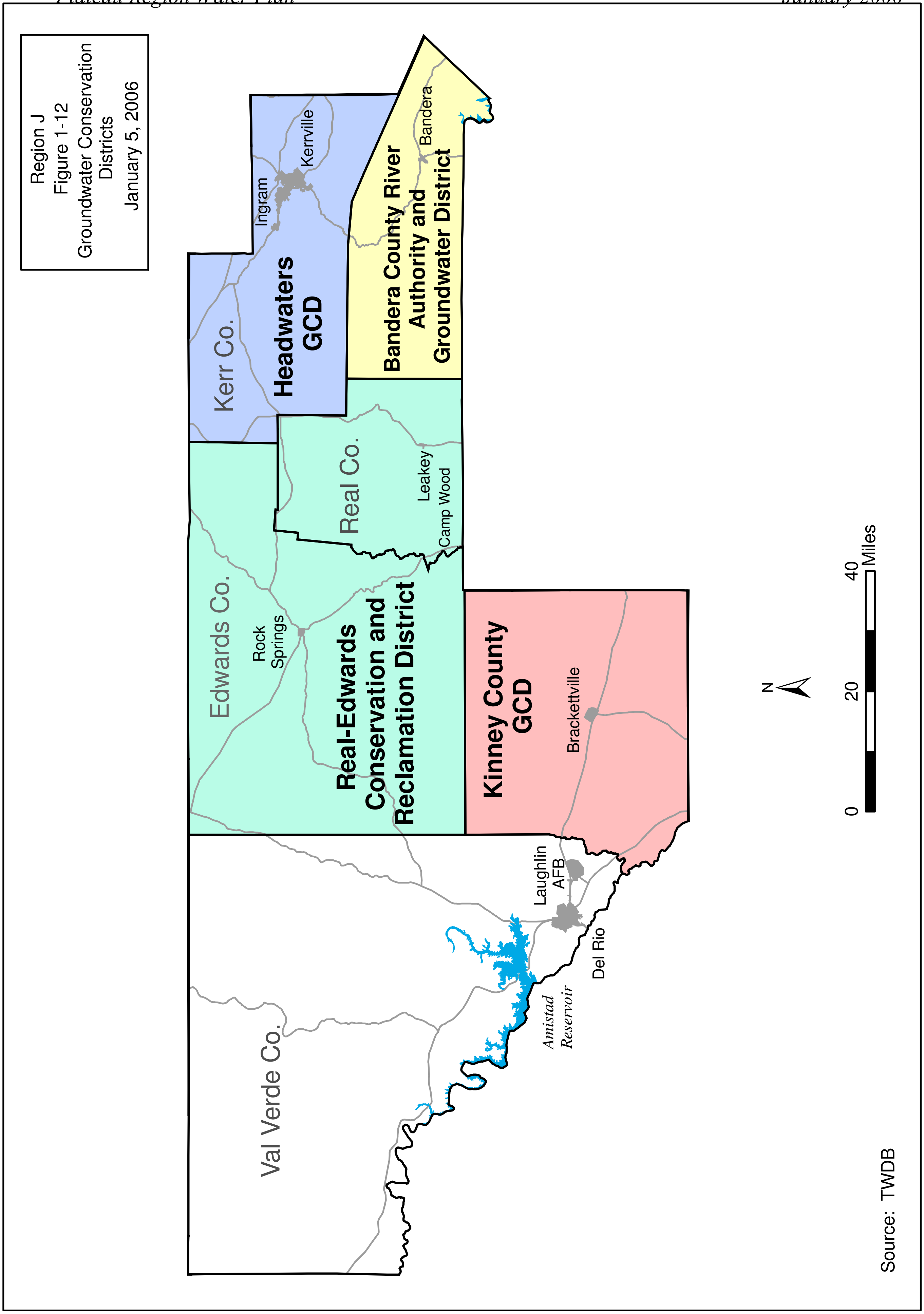

FIGURE 1-12. GROUNDWATER CONSERVATION DISTRICTS

LBG-GUYTON ASSOCIATES

EDAP projects in the Plateau Region are located in Kinney and Val Verde Counties. Data pertaining to all EDAP projects in the State can be accessed through the TWDB web site: http://www.twdb.state.tx.us/publications/reports/Colonias/status.pdf. The following three projects have been completed as of February 2005:

City of Spofford – Kinney County
New water service for 66 colonia residents
$400,000
Completed 9-22-1998

City of Del Rio (Cienegas Terrace) – Val Verde County
Water and wastewater service for 1,412 colonia residents
$3,510,000
Completed 10-16-1996

City of Del Rio (Val Verde Park Estates) – Val Verde County
Water and wastewater service for an estimated 2,747 colonia residents
$11,480,000
Completed 8-21-2002

1.7 STATE AND FEDERAL AGENCIES

1.7.1 Texas Water Development Board (TWDB)

The TWDB is the state agency charged with statewide water planning and administration of low-cost financial programs for the planning, design and construction of water supply, wastewater treatment, flood control and agricultural water conservation projects. The TWDB, especially the Water Resources Planning Division, is at the center of the legislatively mandated regional water planning effort. The agency has been given the responsibility of directing the process in order to ensure consistency and to guarantee that all regions of the state submit plans in a timely manner.

1.7.2 Texas Commission on Environmental Quality (TCEQ)

The TCEQ strives to protect the state's natural resources, consistent with a policy of sustainable economic development. TCEQ's goal is clean air, clean water, and the safe management of waste, with an emphasis on pollution prevention. The TCEQ is the major state agency with regulatory authority over state waters in Texas and administers water rights of the Lower Rio Grande through the office of the Watermaster. The TCEQ is also responsible for ensuring that all public drinking water systems are in compliance with the

strict requirements of the State of Texas. TCEQ is involved with the TWDB in developing a state consensus water plan. Prior to permit approval, TCEQ is required to determine if projects are consistent with regional water plans.

1.7.3 Texas Parks and Wildlife Department (TPWD)

The TPWD provides outdoor recreational opportunities by managing and protecting wildlife and wildlife habitat and acquiring and managing parklands and historic areas. The agency currently has 10 internal divisions: Wildlife, Coastal Fisheries, Inland Fisheries, Law Enforcement, State Parks, Infrastructure, Resource Protection, Communications, Administrative Resources, and Human Resources. Three senior division directors provide special counsel to the Executive Director in the areas of water policy, land policy and administrative matters. The Department has automatic status as a recognized party in any water right contested hearing case.

TPWD is involved with the TWDB in developing a state consensus water plan. Specifically, the agency looks to see that statewide environmental water needs are included. A TPWD staff person is a non-voting member of the Plateau Water Planning Group and provides essential environmental expertise to the planning process.

1.7.4 Texas Department of Agriculture (TDA)

The TDA was established by the Texas Legislature in 1907. The TDA has marketing and regulatory responsibilities and administers more than 50 separate laws. The current duties of the Department include: (1) promoting agricultural products locally, national, and internationally (2) assisting in the development of the agribusiness in Texas; (3) regulating the sale, use and disposal of pesticides and herbicides; (4) controlling destructive plant pests and diseases; and (5) ensuring the accuracy of all weighing or measuring devices used in commercial transactions. The Department also collects and reports statistics on all activities related to the agricultural industry in Texas. A TDA staff person is a non-voting member of the Plateau Water Planning Group and provides essential agricultural expertise to the planning process.

1.7.5 Texas State Soil and Water Conservation Board (TSSWCB)

The TSSWCB is charged with the overall responsibility for administering and coordinating the state's soil and water conservation program with the state's soil and water conservation districts. The agency is responsible for planning, implementing, and managing programs and practices for abating agricultural and sivicultural nonpoint source pollution.

Currently, the agricultural/sivicultural nonpoint source management program includes: problem assessment, management program development and implementation, monitoring, education, and coordination.

1.7.6 International Boundary and Water Commission (IBWC)

The IBWC administers the international waters of the Rio Grande according to the two treaties between Mexico and the U.S., which govern these waters; the treaties are discussed in Chapter 3. The IBWC is continuing discussions with Mexico on the issue of "water debt" under the 1944 treaty. As of the publication of this Plan, Mexico has made up its Rio Grande "water debt". IBWC staff has provided groundwater data that has been used in the assessment of groundwater resources in the Del Rio area for this planning purpose.

1.7.7 United States Geological Survey (USGS)

The USGS serves the Nation by providing reliable scientific information to (1) describe and understand the Earth; (2) minimize loss of life and property from natural disasters; (3) manage water, biological, energy, and mineral resources; and (4) enhance and protect quality of life.

The USGS's Water Resources Division has played a major role in the understanding of the groundwater resources of Texas. Scientists with the USGS have conducted regional studies of water availability and water quality. Many of these studies have been conducted in conjunction with the TWDB. These studies have provided much of the data for more recent investigations conducted by graduate students and faculty members of the geology departments of many Texas universities.

1.7.8 United States Environmental Protection Agency (EPA)

The mission of the EPA is to protect human health and the environment. Programs of the EPA are designed (1) to promote national efforts to reduce environmental risk, based on the best available scientific information; (2) ensure that federal laws protecting human health and the environment are enforced fairly and effectively; (3) guarantee that all parts of society have access to accurate information sufficient to manage human health and environmental risks; and (4) guarantee that environmental protection contributes to making communities and ecosystems diverse, sustainable, and economically productive.

1.7.9 United States Fish and Wildlife Department (USFWS)

The USFWS enforces federal wildlife laws, manages migratory bird populations, restores nationally significant fisheries, conserves and restores vital wildlife habitat, protects and recovers endangered species, and helps other governments with conservation efforts. It also administers a federal aid program that distributes money for fish and wildlife restoration, hunter education, and related projects across the country. The USFWS has provided comments that are pertinent to wildlife water needs to draft planning documents.

CHAPTER 2

POPULATION AND WATER DEMAND

2.1 INTRODUCTION

Planning for the wise use of the existing water resources in the Plateau Region requires a reasonable estimation of current and future water needs for all water-use categories. The Texas Water Development Board (TWDB) Regional Planning Guidelines specify in Section 357.5 (d) that in developing regional water plans, the Regional Water Planning Groups shall use for population and water-demand projections one of the following:

- *State population and water demand projections contained in the state water plan or adopted by the Board (TWDB) after consultation with the Texas Commission on Environmental Quality, Texas Department of Agriculture, Texas Parks and Wildlife Department, and regional water planning groups in preparation for revision of the state water plan; or*
- *Population or water demand projection revisions that have been adopted by the Board* (TWDB), *after coordination with Texas Commission on Environmental Quality, Texas Department of Agriculture, Texas Parks and Wildlife Department, and regional water planning groups when the requesting regional water planning group demonstrates that the population and water demand projections developed pursuant to paragraph (1) of this subsection no longer represent a reasonable projection of anticipated conditions based on changed conditions and availability of new information.*

Regional population and water demand data was initially provided to the planning groups at the beginning of the planning period. This information incorporated data from the State Data Center and from the U.S. Census Bureau's 2000 census count. In accordance with the second criteria above, the Plateau Water Planning Group (PWPG) requested and was given approval to revise specific population and water demand data for use in the regional plan. Thus, the population and water demand projections shown in this chapter are derived from a combination of TWDB data and approved revisions.

2.2 POPULATION ANDWATER DEMAND PROJECTION REVISIONS

The PWPG provided draft population and water demand summary tables to municipalities, water providers, county judges, and non-municipal water use representatives, and solicited all entities within the Region to submit desired changes to the projections. Revision requests, along with required back-up documentation, were prepared and submitted to the TWDB. Of primary concern was the original projection of a declining population in Kerrville and Kerr County after the year 2030. Following review by the TWDB, the PWPG was granted formal approval to use the revised population and water-demand projection estimates in the regional planning process. The net result of the approved revisions allows for a modest population increase beyond the year 2030 for Kerrville and rural Kerr County.

Requested revisions in draft water-demand projections fell into two categories, municipal and irrigation. Revised municipal projections for the City of Kerrville and Bandera County rural were based on documented changes to per-capita water use and reallocation of population. Projected water demand for irrigation use was also revised downward in Bandera County and upward in Real and Val Verde Counties to better reflect average historical trends.

2.3 POPULATION

2.3.1 Population Projection Methodology

Starting with the 2000 census year count, TWDB staff used a cohort-component procedure to calculate population projections. Separate cohorts (age, sex, race, and ethnic groups) and components of cohort change (fertility rates, survival rates, and migration rates) are used to estimate county populations. The projected county population is then allocated to each city containing 500 or more people on the basis of each city's historic share of the county population. In some cases, the water user group (WUG) is a utility. In these cases, the population reported for the utility represents the population served by that utility. The rural “county other” population is calculated as the difference between the total projected population of cities and major utilities, and the total projected county population. Population is thus projected from the 2000 base year by decade to the year 2060.

The PWPG expresses concern that the population projections do not recognize the impact to the municipal and rural population and its related water demand that occurs as the result of seasonal vacationers, hunters, and absentee land-owner homes, especially in the rural counties. The PWPG recommends that for future regional water plans, that a region be allowed to adjust the total regional population rather than having to adjust individual county populations to achieve a non-changeable total population.

2.3.2 Current and Projected Population

In the year 2000, the U.S. Census Bureau performed a census count, which provides the base year for future population projections in the Region. Although the PWPG accepts the 2000 census count, members expressed concern that the census does not recognize the significant seasonal population increase that occurs in these counties as the area draws large numbers of hunters and recreational visitors, as well as absentee land owners who maintain vacation, retirement, and hunting cabins. Laughlin Air Force Base in Val Verde County is also anticipating an increase in military population in the near future. Therefore, an emphasis is being made in this planning document, especially for the rural counties, to recognize a need for more water than is justified simply from the population-derived water demand quantities.

The approved projections may also underestimate population and subsequent water demand in Kerr County by more than just undercounting hunters, absentee landowners and tourists. The cohort-component model used to project population growth does not adequately account for expected business and market factors that can influence population growth. Several Kerr County organizations are actively pursuing market development and business growth in order to maintain a consistent double-digit growth rate not reflected in the long-term population forecast. Similar underestimations may also occur elsewhere in the Region.

Current and projected population by decade for communities, water utilities, and county rural areas in the Plateau Region is listed in Table 2-1. The year-2000 population for the entire Region is 114,742 of which 77 percent reside in Kerr and Val Verde Counties (Figure 2-1). Del Rio, with a population of 33,867, is the largest community in the Region. The regional population is projected to increase by 79 percent to 205,910 by the year 2060, which is an increase of 91,168 citizens (Figure 2-2).

The greatest percentage increase in population is projected to occur in Bandera County, which is expected to grow from a current population of 17,645 to 60,346 by the year 2060, an increase of 342 percent. This rapid growth is primarily influenced by the rapid expansion in the San Antonio metroplex. However, future escalation of fuel cost and cost of living could slow this growth rate. Population in the rural counties of Edwards, Kinney and Real is expected to remain relatively constant over the 50-year planning period, however the transient population is expected to increase.

TABLE 2- 1. PLATEAU REGION POPULATION PROJECTION

COUNTY	WATER USER GROUP	2000	2010	2020	2030	2040	2050	2060
BANDERA	Bandera	957	1,056	1,179	1,307	1,411	1,499	1,586
	County-Other	16,688	25,317	36,086	47,270	53,418	55,143	58,760
	BANDERA TOTAL	**17,645**	**26,373**	**37,265**	**48,577**	**54,829**	**56,642**	**60,346**
EDWARDS	Rocksprings	1,285	1,380	1,439	1,405	1,362	1,346	1,290
	County-Other	877	942	982	959	929	918	880
	EDWARDS TOTAL	**2,162**	**2,322**	**2,421**	**2,364**	**2,291**	**2,264**	**2,170**
KERR	Kerrville	20,425	23,044	25,681	26,934	27,544	28,926	29,545
	Ingram	1,740	1,963	2,188	2,295	2,219	2,081	1,963
	Kerrville South WC	3,300	3,723	4,149	4,352	4,208	3,946	3,723
	County-Other	18,188	20,520	22,868	23,984	24,691	26,251	27,021
	KERR TOTAL	**43,653**	**49,250**	**54,886**	**57,565**	**58,662**	**61,204**	**62,252**
KINNEY	Brackettville	1,876	1,893	1,914	1,933	1,952	1,965	1,968
	Fort Clark Springs	1,306	1,364	1,433	1,499	1,563	1,609	1,619
	County-Other	197	146	115	97	86	79	75
	KINNEY TOTAL	**3,379**	**3,403**	**3,462**	**3,529**	**3,601**	**3,653**	**3,662**
REAL	Camp Wood	822	826	839	821	807	828	845
	County-Other	2,225	2,237	2,272	2,221	2,186	2,242	2,287
	REAL TOTAL	**3,047**	**3,063**	**3,111**	**3,042**	**2,993**	**3,070**	**3,132**
VAL VERDE	Del Rio	33,867	37,024	40,050	42,869	45,270	47,024	48,289
	Laughlin AFB	2,225	2,225	2,225	2,225	2,225	2,225	2,225
	County-Other	8,764	12,063	15,225	18,171	20,680	22,512	23,834
	VAL VERDE TOTAL	**44,856**	**51,312**	**57,500**	**63,265**	**68,175**	**71,761**	**74,348**
	REGION TOTAL	**114,742**	**135,723**	**158,645**	**178,342**	**190,551**	**198,594**	**205,910**

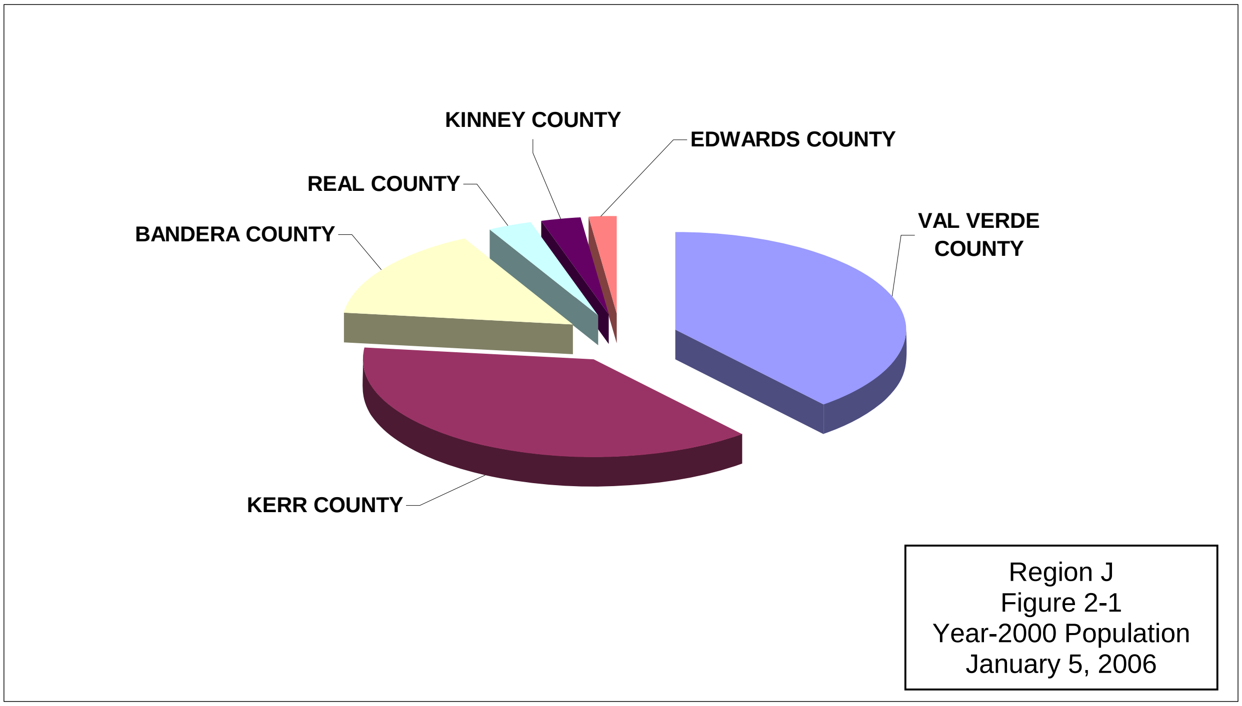

FIGURE 2- 1. YEAR-2000 POPULATION

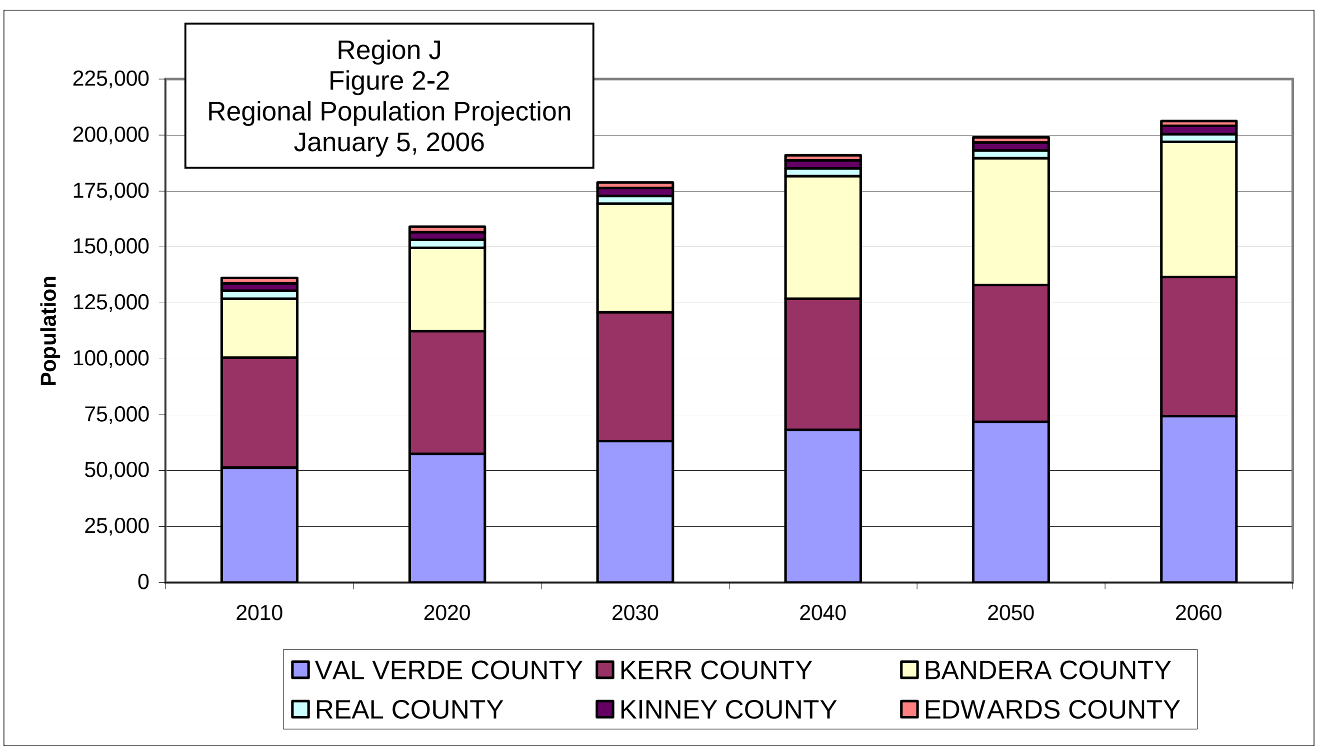

FIGURE 2- 2. REGIONAL POPULATION PROJECTION

2.4 WATER DEMAND

A major component of water planning is the establishment of accurate water demand estimates for all water-use categories. Water demands in this Plan represent annual drought-of-record conditions and not a peak demand condition within a single year. Categories of water use include (1) municipal and rural domestic, (2) manufacturing, (3) irrigation, (4) steam electric, (5) livestock, and (6) mining. Of these categories, there is no recognized water use in the Plateau Region for the "steam electric" category. Table 2-2 lists the current and future projected regional water demands by county and water-use category. Water demand is further distributed by river basin in Appendix 2A. The municipal category includes cities, retail public utilities, and county rural use. The percent distribution of water demand in the Region by the five water-use categories is shown in Figure 2-3. Water demand is reported in "acre-feet"; one acre-foot is equivalent to a quantity of water one foot deep occupying one acre, or 325, 851 gallons. Other water use categories that are not quantified in this plan but are addressed (Section 2.5) include environmental and recreational needs.

Figures 2-4 and 2-5 show current water demand and projected water demand by county in acre-feet per year. From the year 2000 to 2060 the total water demand in the Region is projected to increase from 49,662 acre-feet to 58,559 acre-feet. Water demand methodologies and trends for each of the five water-use categories are provided in the following subsections.

The potential role of conservation is an important factor in projecting future water supply requirements. Water demands listed in the 2001 Regional Water Plan included demand adjustments based on expected conservation practices. In this plan, conservation is only included in the municipal projections as a measure of expected savings based on requirements of the State plumbing code. All other conservation practices are discussed in terms of water supply strategies in Chapter 4 and as a component of drought management plans in Chapter 6.

The following sections present an overview of water supply needs for each of the five designated water-use categories and includes methods and assumptions used in the State's consensus water planning process. This information has been taken from the 2002 State Water Plan (Water For Texas - 2002) and Exhibit B - Guidelines for Regional Water Plan Development. The 2002 State Water Plan can be found on the Texas Water Development Board's web page, http://www.twdb.state.tx.us.

As stated previously in Section 2.3.2, the PWPG is concerned that the population and subsequent water demand projections throughout the Region may be understated due to the large number of temporary residents in the Region including hunters, tourists and absentee landowners. In addition to these factors, water demand may be understated in Kerr County (as well as elsewhere in the Region) because the cohort-component model does not reflect market and business factors that are expected to increase water demand in the county, especially in the municipal and manufacturing use category.

TABLE 2- 2. PLATEAU REGION WATER DEMAND PROJECTIONS (Acre-Feet/Year)

COUNTY	WATER USER GROUP	2000	2010	2020	2030	2040	2050	2060
BANDERA	Bandera	240	259	284	312	332	351	371
	County-Other	1,813	2,609	3,638	4,659	5,206	5,374	5,726
	Manufacturing	0	0	0	0	0	0	0
	Irrigation	464	464	464	464	464	464	464
	Mining	23	24	24	24	24	24	24
	Livestock	315	315	315	315	315	315	315
	BANDERA TOTAL	**2,855**	**3,671**	**4,725**	**5,774**	**6,341**	**6,528**	**6,900**
EDWARDS	Rocksprings	260	272	279	268	256	250	240
	County-Other	165	173	177	169	163	158	152
	Manufacturing	0	0	0	0	0	0	0
	Irrigation	160	153	147	141	135	129	123
	Mining	6	5	5	5	5	5	5
	Livestock	562	562	562	562	562	562	562
	EDWARDS TOTAL	**1,153**	**1,165**	**1,170**	**1,145**	**1,121**	**1,104**	**1,082**
KERR	Ingram	203	220	238	242	229	212	200
	Kerrville	3,958	4,362	4,746	4,918	4,937	5,152	5,262
	Kerrville South WC	370	405	437	448	424	393	371
	County-Other	2,139	2,322	2,510	2,551	2,572	2,705	2,784
	Manufacturing	25	30	33	36	39	41	44
	Irrigation	1,880	1,821	1,761	1,706	1,652	1,599	1,548
	Mining	173	167	165	164	163	162	161
	Livestock	487	487	487	487	487	487	487
	KERR TOTAL	**9,235**	**9,814**	**10,377**	**10,552**	**10,503**	**10,751**	**10,857**
KINNEY	Brackettville	584	583	583	582	582	581	582
	Fort Clark Springs	604	626	653	678	704	723	727
	County-Other	91	67	52	44	39	35	34
	Manufacturing	0	0	0	0	0	0	0
	Irrigation	14,112	13,507	12,928	12,373	11,843	11,337	10,853
	Mining	0	0	0	0	0	0	0
	Livestock	445	445	445	445	445	445	445
	KINNEY TOTAL	**15,836**	**15,228**	**14,661**	**14,122**	**13,613**	**13,121**	**12,641**
REAL	Camp Wood	174	172	172	166	160	163	167
	County-Other	431	428	427	411	396	405	413
	Manufacturing	0	0	0	0	0	0	0
	Irrigation	408	392	377	361	346	330	314
	Mining	6	5	5	5	5	5	5
	Livestock	176	176	176	176	176	176	176
	REAL TOTAL	**1,195**	**1,173**	**1,157**	**1,119**	**1,083**	**1,079**	**1,075**
VAL VERDE	Del Rio	11,988	12,898	13,817	14,646	15,314	15,855	16,281
	Laughlin AFB	1,311	1,303	1,296	1,289	1,281	1,276	1,276
	County-Other	1,954	2,621	3,274	3,888	4,378	4,766	5,046
	Manufacturing	0	0	0	0	0	0	0
	Irrigation	3,212	3,086	2,968	2,852	2,743	2,636	2,535
	Mining	156	118	111	107	104	101	99
	Livestock	767	767	767	767	767	767	767
	VAL VERDE TOTAL	**19,388**	**20,793**	**22,233**	**23,549**	**24,587**	**25,401**	**26,004**
	REGION TOTAL	**49,662**	**51,844**	**54,323**	**56,261**	**57,248**	**57,984**	**58,559**

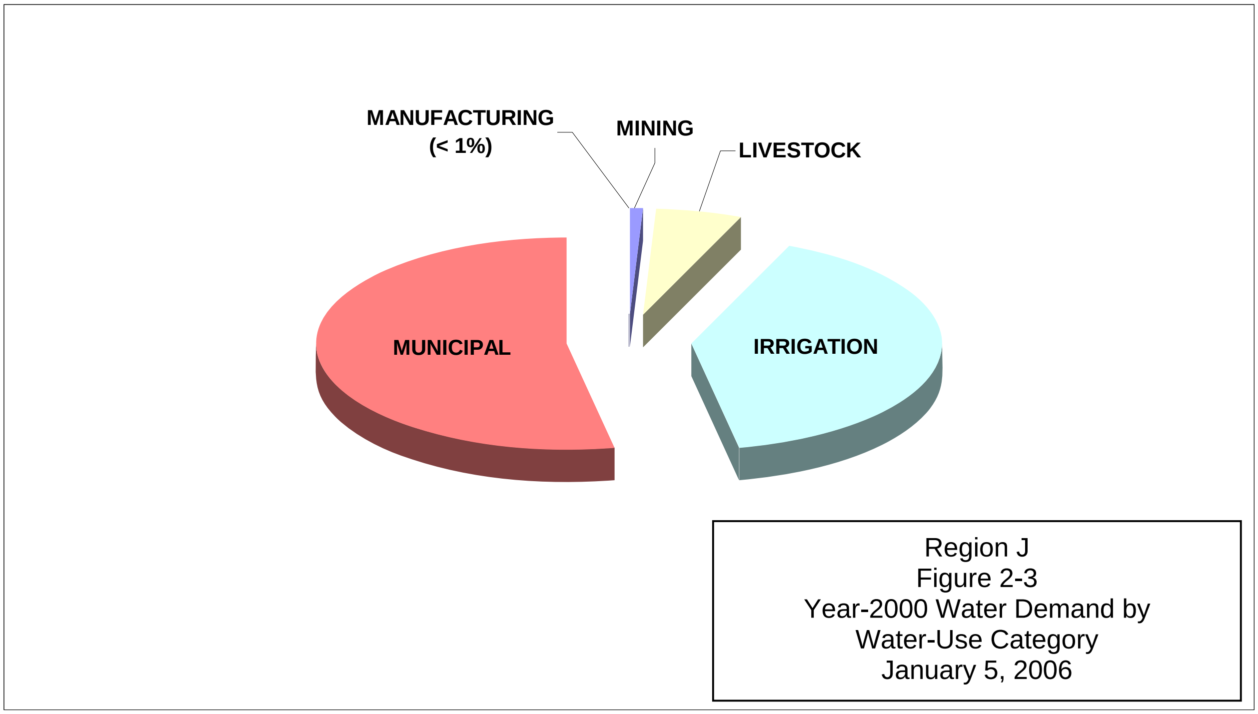

FIGURE 2- 3. YEAR-2000 WATER DEMAND BY WATER-USE CATEGORY

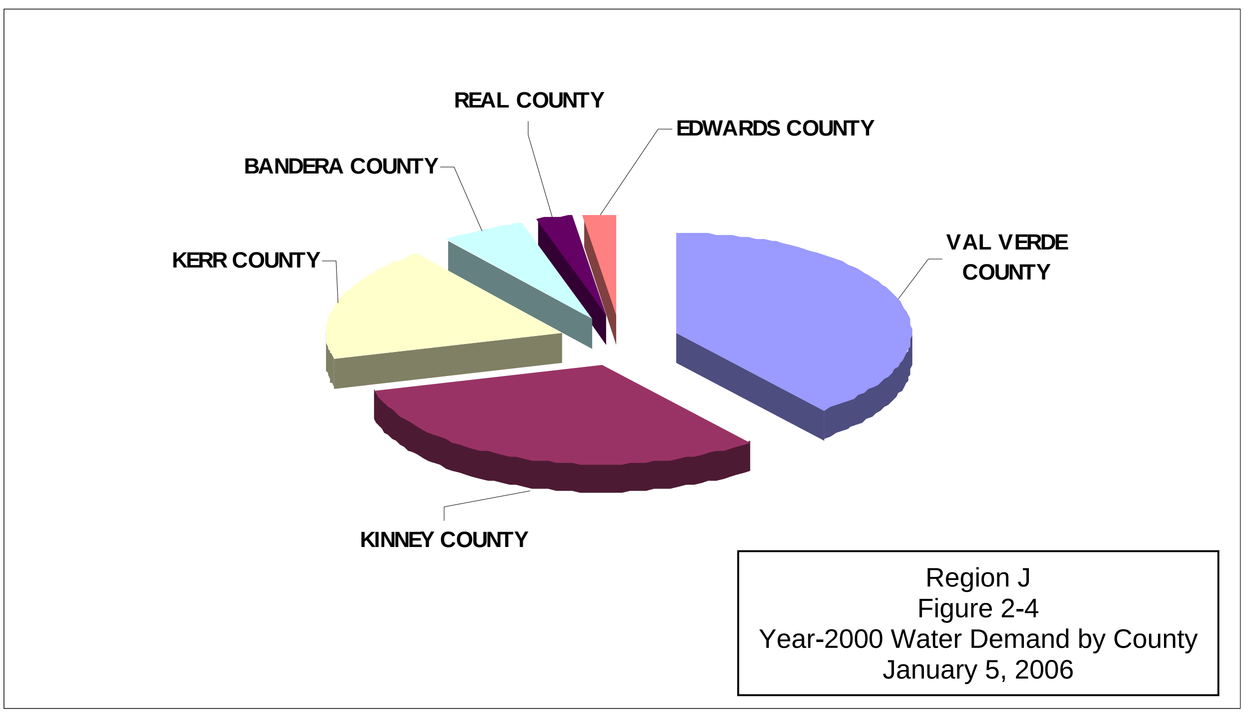

FIGURE 2- 4. YEAR-2000 WATER DEMAND BY COUNTY

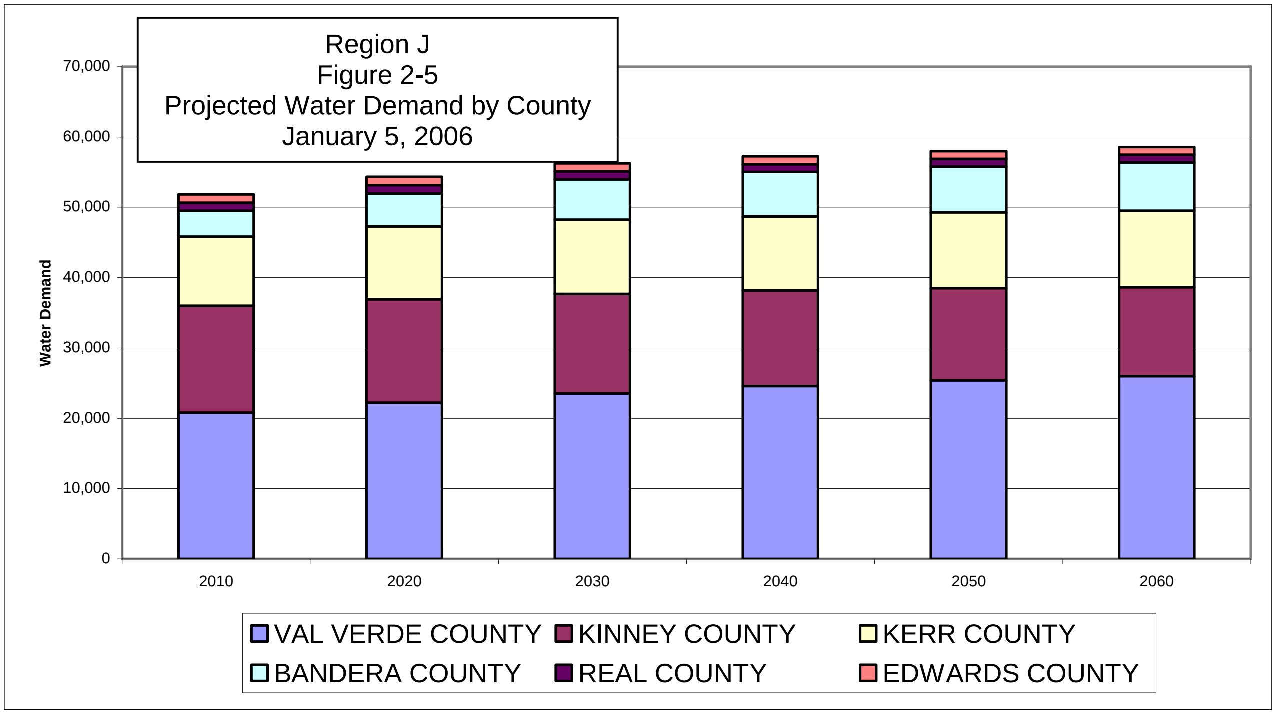

FIGURE 2- 5. PROJECTED WATER DEMAND BY COUNTY

2.4.1 Municipal

The quantity of water used for municipal and rural domestic purposes is heavily dependent on population growth, climatic conditions, and water-conservation measures. For planning purposes, municipal water use comprises both residential and commercial. Commercial water use includes business establishments, public offices, and institutions. Residential and commercial uses are categorized together because they are similar types of uses: i.e., they both use water primarily for drinking, cleaning, sanitation, air conditioning, and landscape watering. Also included in this category is water supplied to golf courses from municipal supply sources. Water use within a city that is not included in the quantification of municipal demand is that used in manufacturing and industrial processes.

Projected municipal water demand is based on the year-2000 per-capita water use, which is calculated with year-2000 population counts divided into reported water use for the same year. Per-capita water use in communities with significant non-residential water demands, such as commercial customers will appear abnormally high. The year-2000 per-capita water use is reduced slightly over time to simulate expected conservation savings due to State-mandated plumbing code implementation. The conservation adjusted per-capita water use is then applied to each of the decade population estimates to produce the projected water demand for each entity.

Municipal (and larger water utility) water demand in the Plateau Region is projected to increase from a current level of 26,285 acre-feet to 39,632 acre-feet by the year 2060. Because municipal water demand is directly related to population, Val Verde County has the highest demand in the Region. Water demand in Val Verde County may increase even beyond the current projection if the Laughlin Air Force Base expansion occurs as expected. Bandera County, with the greatest projected percentage population increase, will likewise see the greatest percentage water demand increase over the 50-year period, 297 percent.

Municipal Water Demand Projection (in acre-feet/year)

County	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bandera	2,053	2,868	3,922	4,971	5,538	5,725	6,097
Edwards	425	445	456	437	419	408	392
Kerr	6,670	7,309	7,931	8,159	8,162	8,462	8,617
Kinney	1,279	1,276	1,288	1,304	1,325	1,339	1,343
Real	605	600	599	577	556	568	580
Val Verde	15,253	16,822	18,387	19,823	20,973	21,897	22,603
Total	**26,285**	**29,320**	**32,583**	**35,271**	**36,973**	**38,399**	**39,632**

Wholesale Water Provider

A wholesale water provider is any person or entity that has contracts to sell more than 1,000 acre-feet of water wholesale in any one year during the five years immediately preceding the adoption of the last regional Water Plan. The City of Del Rio is the only entity in the Plateau Region to meet this criterion. In addition to its own use, the city provides water to Laughlin Air Force Base and subdivisions outside of the city. The city also provides water and wastewater services to two colonias, Cienegas Terrace and Val Verde Park Estates.

The Upper Guadalupe River Authority (UGRA) anticipates becoming a wholesale water provider in coming years with the intent to provide conjunctive water-supply sources to meet the needs of Kerr County citizens that will not be served by the City of Kerrville.

Del Rio Wholesale Demand Projection (in acre-feet/year)

County	Basin	Water User Group	2000	2010	2020	2030	2040	2050	2060
Val Verde	Rio Grande	City of Del Rio	11,988	12,898	13,817	14,646	15,314	15,855	16,281
		Laughlin AFB	1,245	1,238	1,231	1,225	1,217	1,212	1,212
		County Other	528	708	884	1,050	1,182	1,287	1,362

2.4.2 Manufacturing

Manufacturing and industrial water use is quantified separately from municipal use even though the demand centers may be located within a city limits. Future manufacturing and industrial water use is largely dependent on technological changes in the production process, on improvements in water-efficient technology, and on the economic climate of the marketplace. Technological changes in production affect how water is used in the production process, while improvements in water-efficient technology affect how much water is used in the production process. As older production facilities and accompanying production processes are modernized or retooled, the new production processes are anticipated to be more resource efficient. In the Plateau Region, the use of water for manufacturing purposes is only recognized in Kerr County.

Manufacturing Water Demand Projection
(in acre-feet/year)

County	2000	2010	2020	2030	2040	2050	2060
Bandera	0	0	0	0	0	0	0
Edwards	0	0	0	0	0	0	0
Kerr	25	30	33	36	39	41	44
Kinney	0	0	0	0	0	0	0
Real	0	0	0	0	0	0	0
Val Verde	0	0	0	0	0	0	0
Total	**25**	**30**	**33**	**36**	**39**	**41**	**44**

2.4.3 Irrigation

A comprehensive irrigation survey was performed for the TWDB in 2000 that provided up-to-date crop and irrigation data. The acreage planted for each crop under irrigation, along with the water application rate for each crop, was estimated by the Natural Resource Conservation Service (NRCS) and computed to give total irrigation use for each county. Irrigation water demand includes estimates of surface water lost in the process of transportation to the field. In lieu of the above process, irrigation districts could provide more accurate estimates based on actual measured diversions or pumping withdrawals. Future irrigation use is then projected from this 2000 base year at a rate established for the same county irrigation projection in the previous regional water plan.

Statewide, irrigation water demands are expected to decline over time. More efficient canal delivery systems have improved water-use efficiencies of surface water irrigation. More efficient on-farm irrigation systems have also improved the efficiency of groundwater irrigation. Other factors that have contributed to decreased irrigation demands are declining groundwater supplies and the voluntary transfer of water rights historically used for irrigation to municipal uses.

Kinney County has the highest irrigation water use in the region (70 percent) and is the only county in which irrigation use is greater than municipal use. Elsewhere in the Region, most irrigation that occurs is for the watering of pastures and hay fields. Because of the typically rocky and uneven terrain throughout much of the Region, irrigation of commercial row crops is minimal. On a regional basis, water used for irrigation is projected to decline slightly over the 50-year planning horizon, from the current 20,236 acre-feet to 15,837 acre-feet by 2060. However, as any irrigator can attest, climate, water availability, and the market play key roles in how much water is actually applied on a year-by-year basis.

The PWPG is concerned about the accuracy of the irrigation surveys and believes that there is significantly more irrigation water use than is documented. For example, numerous small irrigated exotic and wildlife feed plots are likely not identified. Also, groundwater used to irrigate golf courses, if not provided by municipalities, may not be accounted for in the irrigation survey estimates. These withdrawals may have a significant impact on local supplies.

Irrigation Water Demand Projection (in acre-feet/year)

County	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Bandera	464	464	464	464	464	464	464
Edwards	160	153	147	141	135	129	123
Kerr	1,880	1,821	1,761	1,706	1,652	1,599	1,548
Kinney	14,112	13,507	12,928	12,373	11,843	11,337	10,853
Real	408	392	377	361	346	330	314
Val Verde	3,212	3,086	2,968	2,852	2,743	2,636	2,535
Total	**20,236**	**19,423**	**18,645**	**17,897**	**17,183**	**16,495**	**15,837**

2.4.4 Livestock

Texas is the nation's leading livestock producer, accounting for approximately 11 percent of the total United States production. Although livestock production is an important component of the Texas economy, the industry consumes a relatively small amount of water.

Estimating livestock water consumption is a straightforward procedure that consists of estimating water consumption for a livestock unit and the total number of livestock. Texas A&M University Cooperative Extension Service provides information on water-use rates, estimated in gallons per day per head, for each type of livestock: cattle, poultry, sheep and lambs, hogs and pigs, horses, and goats. The Texas Agricultural Statistics service provides current and historical numbers of livestock by livestock type and county. Water-use rates are then multiplied by the number of livestock for each livestock type for each county.

For water-supply planning purposes, livestock water use is held constant throughout the 50-year planning period. However, reality dictates that during prolonged drought periods, when poor range conditions exist and/or during unfriendly market conditions, livestock herds are generally reduced thus resulting in significantly less water demand. Val Verde County has the greatest livestock water use in the region.

In recent years, an expanding use of groundwater in the Region has been to fill and maintain artificial lakes that primarily are intended to add value to the property by providing a source of water for livestock and wildlife, thus increasing the aesthetic value. Although not quantified, the amount of water pumped from local aquifers for this purpose is likely significant and is not reflected in the-water demand estimates provided in this chapter.

Exotic game ranching has become commonplace throughout the state, and is quite evident in the Plateau Region counties. Bandera and Kerr Counties have the largest population of exotic game in the State (Texas A&M exotics on the Range). The total numbers of exotic game likely may equal or even exceed domestic livestock. Yet the livestock water demand projections reported in this plan may not fully reflect this water use.

High game fences that come with the exotic game industry often block the ability of both native and exotic game to access surface water, thus requiring more wells and groundwater use. Groundwater is also often used to irrigate small acreage feed plots for these animals. Future water plans will need to attempt to quantity this specific use and include it in the overall total projected water needs in the State.

Livestock Water Demand Projection (in acre-feet/year)

County	2000	2010	2020	2030	2040	2050	2060
Bandera	315	315	315	315	315	315	315
Edwards	562	562	562	562	562	562	562
Kerr	487	487	487	487	487	487	487
Kinney	445	445	445	445	445	445	445
Real	176	176	176	176	176	176	176
Val Verde	767	767	767	767	767	767	767
Total	**2,752**	**2,752**	**2,752**	**2,752**	**2,752**	**2,752**	**2,752**

2.4.5 Mining

Although the Texas mineral industry is foremost in the production of crude petroleum and natural gas in the United States, it also produces a wide variety of important nonfuel minerals. In all instances, water is required in the mining of these minerals either for processing, leaching to extract certain ores, controlling dust at the plant site, or for reclamation. For each category of mineral products, the requirements for mining water are determined as a function of production. Estimates of future production are calculated by analyzing both recent data, and state and national production trends. A water-use coefficient, computed from data collected by the TWDB's Water Use Survey, which reports the quantity of water used in the production of each increment of output, was applied to estimated mineral production levels. A rate of water consumption derived from U.S. Bureau of Mines data was then applied to the total water use for each mineral industry.

Much of the water used in the mining industry in the Plateau Region is related to its use in the extraction of gravel and road base materials, with Kerr and Val Verde Counties recording the greatest use. Although very little petroleum exploration occurs in this region, some of the counties are witnessing an increase in exploratory drilling.

Mining Water Demand Projection (in acre-feet/year)

County	2000	2010	2020	2030	2040	2050	2060
Bandera	23	24	24	24	24	24	24
Edwards	6	5	5	5	5	5	5
Kerr	173	167	165	164	163	162	161
Kinney	0	0	0	0	0	0	0
Real	6	5	5	5	5	5	5
Val Verde	156	118	111	107	104	101	99
Total	**364**	**319**	**310**	**305**	**301**	**297**	**294**

2.5 ENVIRONMENTAL AND RECRETIONAL WATER NEEDS

Environmental and recreational water use in the Plateau Region is not quantified but is recognized as being an important consideration as it relates to the natural community in which the residents of this region share and appreciate. In Chapter 1, environmental and recreational resources are identified and described. In this section, the water resources needed to maintain these functions is discussed. Water-supply sources that serve environmental needs are characterized in Chapter 3 and potential water-supply strategy consequences on the environment are analyzed in Chapter 4.

All living organisms require water. The amount and quality of water required to maintain a viable population, whether it be plant or animal, is highly variable. While some individuals are capable of migrating long distances in search of water (birds, larger mammals, etc.), others are stationary (plants, fishes, etc.) and must rely on existing supplies.

Natural and environmental resources are often overlooked when considering the consequences of prolonged drought conditions. As water supplies diminish during drought periods, the balance between both human and environmental water requirements becomes increasingly competitive. A goal of this plan is to provide for the health, safety, and welfare of the human community, with as little detrimental effect to the environment as possible. To accomplish this goal, the evaluation of strategies to meet future water needs includes a distinct consideration of the impact that each implemented strategy might have on the environment.

As discussed in Section 2.4.4 (Livestock), an expanding use of groundwater in the Region has been to fill and maintain artificial lakes. Although this use may exert stress on the local aquifer system, the resulting impoundments do provide aesthetic value to the property and a water source for wildlife.

Recreational activities that involve human interaction with the outdoors environment are often directly dependent on water resources such as fishing, swimming and boating; while a healthy environment enhances many others, such as hunting, hiking, and bird watching. Thus, it is recognized that the maintenance of the regional environmental community's water-supply needs serves to enhance the lives of citizens of the Plateau Region as well as the multitude of annul visitors to this region.

In Chapter 4, each water management strategy contains an environmental impact assessment. A review of these strategies reveals that while some strategies may contain variable levels of negative impact, other strategies may likely have a positive effect. Negative environmental impacts are generally associated with the lowering of aquifer water levels due to increased groundwater withdrawals and its potential to cause a reduction or cessation of spring flow. Also of concern is that lowered water levels could deplete supplies in shallow livestock wells, which are often the only available source of water for some wildlife. The positive environmental aspect of the strategies is that during severe drought conditions when normal wildlife water supplies may naturally diminish, new supply sources might be developed such that wildlife could benefit.

APPENDIX 2A

REGIONAL WATER DEMAND PROJECTIONS

BY COUNTY AND RIVER BASIN

APPENDIX 2A. WATER DEMAND PROJECTIONS BY COUNTY AND RIVER BASIN
(Acre-Feet*/Year)

County	Water User Group	Basin	2010	2020	2030	2040	2050	2060
Bandera	Bandera	San Antonio	259	284	312	332	351	371
	County Other	Guadalupe	1	2	2	3	3	3
		San Antonio	2,425	3,381	4,330	4,817	4,932	5,232
		Nueces	183	255	327	386	439	491
	Mining	San Antonio	24	24	24	24	24	24
	Irrigation	Guadalupe	0	0	0	0	0	0
		San Antonio	283	283	283	283	283	283
		Nueces	181	181	181	181	181	181
	Livestock	Guadalupe	6	6	6	6	6	6
		San Antonio	218	218	218	218	218	218
		Nueces	91	91	91	91	91	91
	Bandera County Total		**3,671**	**4,725**	**5,774**	**6,341**	**6,528**	**6,900**
Edwards	Rocksprings	Colorado	174	179	172	164	160	154
		Nueces	98	100	96	92	90	86
	County Other	Colorado	35	36	34	33	32	31
		Nueces	118	121	116	111	108	104
		Rio Grande	20	20	19	19	18	17
	Mining	Colorado	5	5	5	5	5	5
	Irrigation	Colorado	153	147	141	135	129	123
		Nueces	0	0	0	0	0	0
		Rio Grande	0	0	0	0	0	0
	Livestock	Colorado	175	175	175	175	175	175
		Nueces	230	230	230	230	230	230
		Rio Grande	157	157	157	157	157	157
	Edwards County Total		**1,165**	**1,170**	**1,145**	**1,121**	**1,104**	**1,082**

County	Water User Group	Basin	2010	2020	2030	2040	2050	2060
Kerr	Ingram	Guadalupe	220	238	242	229	212	200
	Kerrville	Guadalupe	4,362	4,746	4,918	4,937	5,152	5,262
	Kerrville South WSC	Guadalupe	405	437	448	424	393	371
	County Other	Colorado	58	62	63	60	56	52
		Guadalupe	2,246	2,429	2,469	2,494	2,632	2,716
		San Antonio	18	19	19	18	17	16
	Manufacturing	Guadalupe	30	33	36	39	41	44
	Mining	Colorado	13	12	12	12	12	12
		Guadalupe	154	153	152	151	150	149
	Irrigation	Guadalupe	1,821	1,761	1,706	1,652	1,599	1,548
	Livestock	Colorado	125	125	125	125	125	125
		Guadalupe	324	324	324	324	324	324
		San Antonio	34	34	34	34	34	34
		Nueces	4	4	4	4	4	4
	Kerr County Total		**9,814**	**10,377**	**10,552**	**10,503**	**10,751**	**10,857**
Kinney	Brackettville	Rio Grande	583	583	582	582	581	582
	Fort Clark Springs	Rio Grande	626	653	678	704	723	727
	County Other	Nueces	35	21	13	8	4	3
		Rio Grande	32	31	31	31	31	31
	Irrigation	Nueces	338	323	310	296	284	271
		Rio Grande	13,169	12,605	12,063	11,547	11,053	10,582
	Livestock	Nueces	187	187	187	187	187	187
		Rio Grande	258	258	258	258	258	258
	Kinney County Total		**15,228**	**14,661**	**14,122**	**13,613**	**13,121**	**12,641**
Real	Camp Wood	Nueces	172	172	166	160	163	167
	County Other	Colorado	11	11	11	10	11	11
		Nueces	417	416	400	386	394	402
	Mining	Colorado	5	5	5	5	5	5
	Irrigation	Nueces	392	377	361	346	330	314
	Livestock	Nueces	148	148	148	148	148	148
		Colorado	28	28	28	28	28	28
	Real County Total		**1,173**	**1,157**	**1,119**	**1,083**	**1,079**	**1,075**

County	Water User Group	Basin	2010	2020	2030	2040	2050	2060
Val Verde	Del Rio	Rio Grande	12,898	13,817	14,646	15,314	15,855	16,281
	Laughlin AFB	Rio Grande	1,303	1,296	1,289	1,281	1,276	1,276
	County Other	Rio Grande	2,621	3,274	3,888	4,378	4,766	5,046
	Mining	Rio Grande	118	111	107	104	101	99
	Irrigation	Rio Grande	3,086	2,968	2,852	2,743	2,636	2,535
	Livestock	Rio Grande	767	767	767	767	767	767
	Val Verde County Total		**20,793**	**22,233**	**23,549**	**24,587**	**25,401**	**26,004**

*One acre-foot is equal to 325,851 gallons.

CHAPTER 3

REGIONAL WATER SUPPLY SOURCES

3.1 INTRODUCTION

From the semi-arid Hill Country to the arid Rio Grande Basin, both groundwater and surface water are critical resources for the livelihood of the citizens of the Plateau Region and the environment in which they reside. Chapter 3 explores the current and future availability of all water supply resources in the Region including surface water, groundwater and reuse. The water demand and supply availability analysis developed in Chapters 2 and 3, respectively, form the basis for identifying in Chapter 4 the areas within the Plateau Region that potentially could experience supply shortages in future years. Water quality considerations pertaining to the identified water-supply sources are discussed in Chapter 5.

The City of Kerrville currently uses surface water from the Guadalupe River in conjunction with their groundwater supply. Kerrville also injects excess treated surface water into the Trinity aquifer through an aquifer storage and recovery (ASR) system. The City of Del Rio obtains their water from San Felipe Springs, which issues from the Edwards limestone. The spring water is treated to surface water standards in a new microfiltration plant prior to distribution. Camp Wood in Real County is supplied from Old Faithful Springs on a tributary of the Nueces River. All other communities in the Region are totally dependent on groundwater sources for their supplies.

Water supplies available to meet the demands reported in Chapter 2 are shown in Appendices 3A, 3B and 3C in 10-year intervals for the planning period from the year 2010 to 2060. Appendix 3A lists groundwater and surface water availability by county and river basin. Water source availability analyses are discussed in more detail in Section 3.2.7 (groundwater) and Section 3.3 (surface water). Appendix 3B lists water supplies available to cities and general water use categories based on the ability of each to obtain water supplies. Likewise, Appendix 3C lists water supplies available to wholesale water providers. These abilities primarily include existing infrastructure, water-rights limitations, and groundwater conservation district permit limitations. Appendix 3D lists all authorized surface water rights in the Region, while Appendix 3E lists permitted use between 1990 and 1999 as reported to TCEQ.

3.2 GROUNDWATER RESOURCES

The principal aquifers in the Plateau Region are the Trinity, Edwards-Trinity (Plateau), Edwards (Balcones Fault Zone), Austin Chalk, and Frio River Alluvium (Figure 3-1). Aquifer descriptions provided in this chapter are relatively limited; a more detailed hydrogeologic characterization of the aquifers may be obtained from the references listed at the end of the chapter. The water quality of aquifers is relatively good and a detailed discussion on water-quality characteristics and issues is provided in Chapter 5.

Over much of the Region, water levels generally fluctuate with seasonal precipitation and are highly susceptible to declines during drought conditions. Discharge from the aquifers occurs naturally through springs and artificially by pumping from wells. Some discharge also occurs through leakage from one water-bearing unit to another and through natural down-gradient flow out of the Region.

3.2.1 Trinity Aquifer

Located mostly in the Hill Country Counties of Bandera and Kerr, the Trinity aquifer system is composed of deposits of sand, clay and limestone of the Glen Rose and Travis Peak formations of the Lower Cretaceous Trinity Group. The water-bearing units include, in descending order, the Glen Rose limestone, Hensell sand, Cow Creek limestone, Sligo limestone and Hosston sand. The Glen Rose formation is divided informally into upper and lower members. Based on their hydrologic relationships, the water-bearing rocks of the Trinity Group, collectively referred to as the Trinity aquifer system, are organized into the following aquifer units.

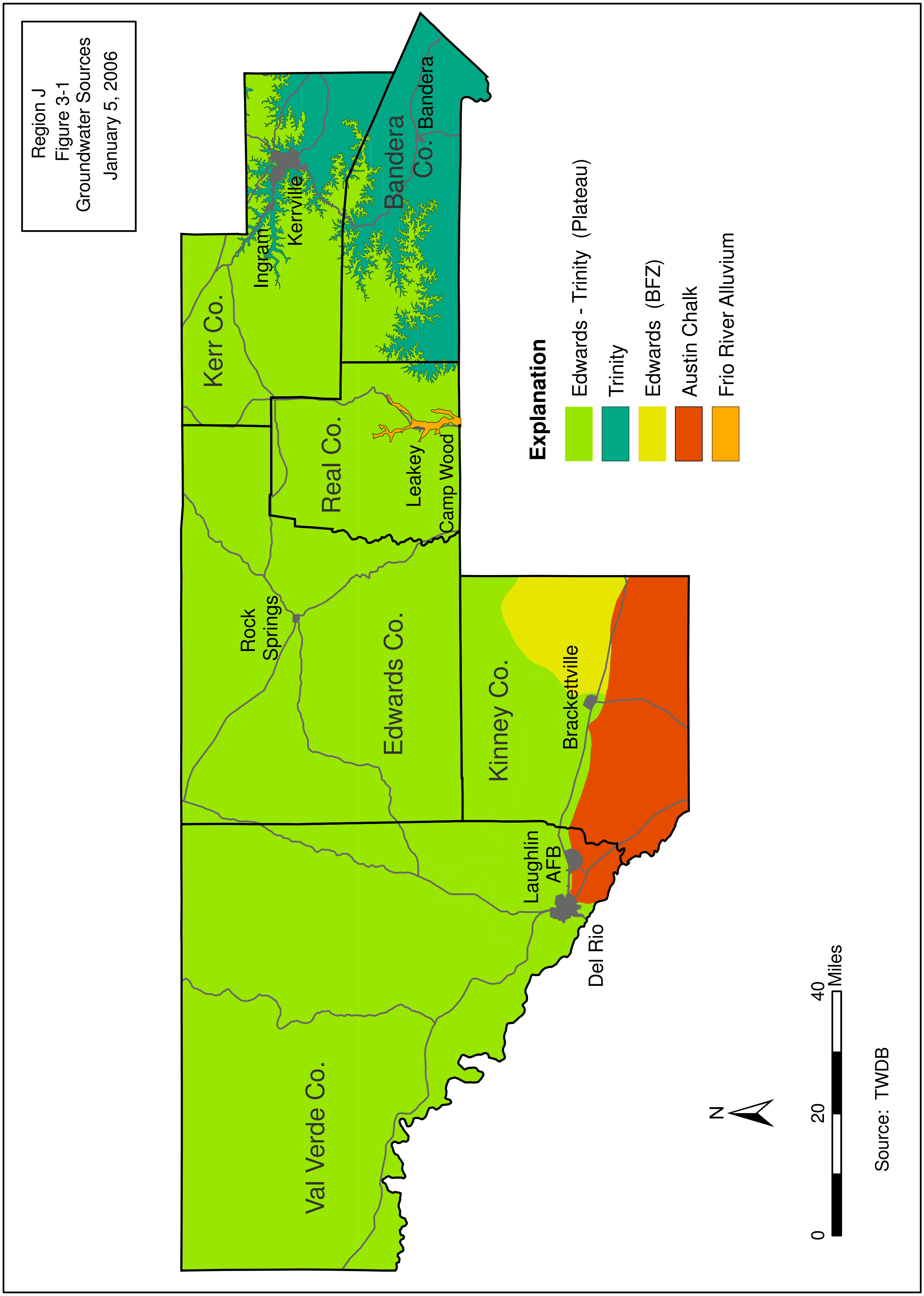

FIGURE 3-1. GROUNDWATER SOURCES

Aquifer	Formations
Upper Trinity	Upper Glen Rose Limestone
Middle Trinity	Lower Member of the Glen Rose Limestone, Hensell Sand and Cow Creek Limestone
Lower Trinity	Sligo Limestone and Hosston Sand

Because of fractures, faults and other hydrogeologic factors, the upper, middle and lower Trinity aquifer units often are in hydraulic communication with one another and collectively should be considered a leaky-aquifer system.

Upper and Middle Trinity Aquifer

The upper member of the Glen Rose, when weathered on the land surface, creates the distinctive "stair-step" topography found throughout the hilly train of the Hill Country. The upper Glen Rose, which forms the Upper Trinity aquifer, often contains water with relatively high concentrations of sulfate. Total dissolved solids (TDS) often exceed 1,000 milligrams per liter (mg/l), especially in wells that penetrate “gyp” (evaporite) beds. Water in evaporite beds has a tendency to be high in sulfate and generally should be sealed off in a well. Upper Trinity wells are generally shallow and are used for domestic and livestock purposes.

The Middle Trinity aquifer, consisting of lower Glen Rose, Hensell, and Cow Creek formations, generally contains TDS of less than 1,000 mg/l. In the Hill Country region, the primary contribution to poor water-quality occurs in wells that do not adequately case off water from evaporite beds in the upper part of the Glen Rose (Upper Trinity aquifer). Water levels in Upper and Middle Trinity wells fluctuate with seasonal precipitation and are highly susceptible to declines during drought conditions.

Lower Trinity Aquifer in Bandera and Kerr Counties

Separating the Middle and Lower Trinity is the Hammett Shale (sometimes referred to as the Pine Island Shale). The approximately 60-foot thick formation acts as a confining bed, or barrier to flowing water in most areas, and thus divides the producing sections of the Middle and Lower Trinity aquifer units.

The Lower Trinity aquifer is composed of sandy limestones, sand, clay and shale of the Sligo and Hosston. The Lower Trinity thins toward the northeast and is completely missing or coalesces with upper Trinity units near the Llano Uplift. The Lower Trinity is principally used to provide water supplies for the Cities of Bandera and Kerrville and for a few private water-supply companies and resorts.

Yields from wells completed into the Lower Trinity are generally unpredictable and vary greatly. The greater depth and difficulty of sealing off the Hammett Shale make completing wells into the lower Trinity more difficult. However, in some areas, the Lower Trinity has higher yields and better water quality than shallower aquifers. Recharge to the Lower Trinity in Bandera and Kerr Counties likely occurs primarily by lateral underflow from the north and west. The overlying Hammett Shale mostly prevents vertical movement of water downward except possibly in highly fractured or faulted areas.

3.2.2 Edwards-Trinity (Plateau) Aquifer

The Edwards-Trinity (Plateau) aquifer consists of lower Cretaceous age saturated limestones and dolomites of the Edwards Group and underlying sediments of the Trinity Group where they occur underlying the Edwards Plateau. The upper Edwards portion of the aquifer system is generally more porous and permeable than the lower Trinity, and where exposed at the land surface, the Edwards-Trinity (Glen Rose) interface gives rise to numerous springs that form the headwaters of several eastward and southerly flowing rivers.

In Kinney and Val Verde Counties, the Edwards aquifer consists of the Devils River Limestone or the Salmon Peak, McKnight and West Nueces limestones. Aquifer thickness is as much as 1,000 feet. All known water wells produce water from the Salmon Peak and

McKnight formations. San Felipe Springs in Val Verde County issues from the Edwards and is the primary municipal supply source for Del Rio.

Recharge to the aquifer occurs primarily by the downward percolation of surface water from streams draining off the Edwards Plateau to the north and west and by direct infiltration of precipitation on the outcrop. Some water enters the region in the aquifer as underflow from counties up-gradient (generally north).

The Glen Rose limestone is the primary unit in the Trinity in the southern part of the Plateau. The aquifer generally exists under water-table conditions; however, where the Glen Rose is fully saturated and a zone of low permeability occurs near the base of the overlying Edwards, artesian conditions exist.

Reported well yields commonly range from less than 50 gallons per minute (gpm) where saturated thickness is thin to more than 1,000 gpm where large-capacity wells are completed in jointed and cavernous limestone. There is little pumpage from the aquifer over most of its extent, and water levels have generally fluctuated only with seasonal precipitation. In some instances, water levels have declined as a result of increased pumpage. Del Rio, Brackettville, Fort Clark, and Rocksprings have municipal wells that produce from this aquifer.

3.2.3 Edwards (BFZ) Aquifer

In the Plateau Region, the Edwards-Balcones Fault Zone (BFZ) aquifer occurs only in eastern Kinney County at its westernmost extent. The Edwards portion of the Edwards-Trinity (Plateau) aquifer and the Edwards of the Edwards (BFZ) aquifer are the same geologic formation and their boundary is arbitrarily established by the TWDB. There is no significant hydrologic boundary between the outcrops of these two aquifer systems, thus groundwater in the Edwards-Trinity freely moves downgradient into the Edwards (BFZ).

The Edwards (BFZ) aquifer exists under water-table conditions in the outcrop and under artesian conditions where it is confined below the overlying Del Rio Clay in its downdip extent. Water in the aquifer generally moves from the recharge zone toward natural discharge points such as Las Moras Springs at Brackettville. Additional water is lost from the

Kinney County area as underflow that leaves the County to the east into Uvalde County (Region L). Very little pumping has occurred from this aquifer in Kinney County, and therefore water levels have remained relatively constant with only minor changes over time.

3.2.4 Austin Chalk Aquifer

The Austin Chalk is located in the southern half of Kinney County and the southernmost part of Val Verde County. Many wells located south of Highway 90 obtain part or all of their water from the Austin Chalk. A veneer of gravel deposits covers much of the southwest portion of Kinney County; some wells penetrate both these gravels and the underlying Austin Chalk.

Source of water in the Austin Chalk is from precipitation recharge and stream loss over the outcrop areas and probably from Edwards aquifer underflow through faults located up-gradient.

A wide range of production rates exists for wells completed in the Austin Chalk. The best production from the aquifer occurs in areas that have been fractured or contain a number of solution openings. Most wells only discharge enough water for domestic or livestock use, but a few wells are large enough for irrigation purposes. The largest reported yield for an Austin Chalk well in Kinney County is 2,000 gpm (Bennett and Sayre, 1962). Most of the more productive wells completed in the Austin Chalk are located along Las Moras Creek. Much less production is apparent in the Nueces River Basin in the eastern part of the county.

3.2.5 Frio River Alluvium Aquifer

The Frio River Alluvium in central Real County extends over an area of approximately 1,120 acres. Recharge to the aquifer is from stream loss and direct infiltration of precipitation. Water supplies for the City of Leakey and other rural domestic homes are derived from this small aquifer. Because of the limited extent of this aquifer and its shallow water table, the aquifer system is readily susceptible to contamination from surface sources and potentially from over pumping.

3.2.6 Other Aquifers

Located along many of the streams and rivers are shallow alluvial floodplains composed of sediments ranging from clay and silt to sand, gravel, cobbles and boulders. Wells completed in these deposits supply small to moderate quantities of water mostly for domestic and livestock purposes. The alluvium is in direct hydraulic connection with the rivers and streams that meander through them. However, because these wells are often shallow, many are prone to going dry during drought conditions.

In addition, the TWDB has identified the downdip extents of the Ellenburger-San Saba and the Hickory aquifers in northeast Kerr County. Because no known wells have penetrated these aquifers in Kerr County, very little is known about their water-bearing characteristics. These aquifers are only mentioned as possible resources but are not included in the supply analysis for this plan.

3.2.7 Groundwater Availability

Base flow to the many rivers and streams that flow through the Plateau Region is principally generated from the numerous springs that issue from rock formations that form the major aquifers in the Region. It is thus recognized that sustaining flow in these important rivers and streams is highly dependent on maintaining an appropriate water level in the aquifer systems that feed the supporting springs. With the sustainability of local water supplies and the economic welfare of the Region in mind, the Plateau Water Planning Group thus defines groundwater availability as **a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions**. The planning group also acknowledges that groundwater conservation districts have regulatory authority over permitted withdrawals.

The concepts of groundwater availability and aquifer sustainability as it relates to the regional water planning process have resulted in significant confusion. The Plateau Region believes that the best interests of the area are served by maintaining an acceptable level of aquifer sustainability. In so defining groundwater availability, the planning group is establishing a policy decision to protect the long-term water supply and related economic needs of the Plateau Region. However, the planning group also acknowledges that additional water does occur in storage within the aquifers and that a portion of that water is capable of being retrieved for desired uses.

For groundwater availability, the TWDB planning guidelines (Exhibit B) require that regional planning groups "Calculate the largest annual amount of water that can be pumped from a given aquifer without violating the most restrictive physical or regulatory or policy conditions limiting withdrawals, under drought-of-record conditions. Regulatory conditions refer specifically to any limitations on pumping withdrawals imposed by groundwater conservation districts through their rules and permitting programs." This guideline requires that planning groups make a policy decision as to the interpretation of the term "most restrictive" as it relates to long-term groundwater availability.

The counties that comprise the Plateau Region contain the headwaters of the Guadalupe, San Antonio, Medina, Sabinal, Frio, Nueces, and West Nueces Rivers; and tributaries to the Colorado River and Rio Grande such as the Pecos, Devils, and South Llano Rivers. Flow in these rivers and streams is critical to the Plateau Region in that it provides municipal drinking water, supplies irrigation and livestock needs, maintains environmental habitats, and supports a thriving ecological and recreational tourist economy. Water users downstream of the Plateau Region (Regions K, L, and M) likewise have a stake in maintaining and protecting river flows.

TWDB Chapter 357 Regional Water Planning Guidelines states that "Once GAM (Groundwater Availability Model) information is accessible for an area within a region, the Planning Group shall incorporate this information in its next planning cycle unless better site-specific information is developed." Following review of available data, the PWPG concludes that in general the two completed GAMs incorporate the most currently available information for the Edwards-Trinity (Plateau) and Hill Country Trinity aquifers, and that the GAMs are an appropriate tool for analyzing groundwater availability in the Plateau Region. Where better site-specific information is available, appropriate alterations have been considered. The aquifer simulation models were thus run by increasing pumping withdrawals at set intervals until reasonably acceptable levels of impact to surface water drains were observed. It should be noted that this means of defining groundwater availability is not directly linked to recharge, but rather to pumping withdrawals that result in acceptable levels of impact. This method of quantifying groundwater availability is significantly different than the method used in the 2001 Plateau Regional Water Plan, and therefore, availability volumes reported in Appendix 3A are likewise significantly different.

Some aquifer areas within the Region were not incorporated into GAMs. In those areas, a reduced percentage of recharge (2% or less of total precipitation) was used to estimate aquifer availability. The areas for aquifer recharge in the Plateau Region were determined by using geographic information system (GIS) coverages, which allowed calculation of specific areas. The volumes were then calculated based on a percent of annual recharge for each aquifer by river basin and county.

The accuracy by which groundwater availability can be estimated is also a function of the amount of data that is available to characterize each aquifer. The lack of such data has been a continuing problem in the planning process. In recognition of this limitation, the TWDB provided funding for the purchase and installation of continuous water-level monitoring equipment in six wells. A supplemental report (LBG-Guyton, 2005) documents the location and activity of these monitoring sites. The monitoring wells have not been in place long enough for the data to be used in the further characterization of the aquifers. However, this data is being incorporated into ongoing studies by the groundwater conservation districts, and will be meaningful during the next round of regional water planning.

3.2.8 Public Supply Use of Groundwater

All communities in the Plateau Region rely partially or completely on groundwater supply sources. Even the spring sources used by Del Rio and Camp Wood originate from aquifers. The higher concentration of wells in Kerr and Bandera Counties related to population growth may present water supply availability problems in the future. Public supply wells serving communities in Edwards, Kinney, Real and Val Verde Counties are not anticipated to have long-term declines due to the relatively smaller quantities of water that are needed to serve these communities. Also, no long-term water-quality deterioration is detected in groundwater supplies for these communities. Long-term viability of the aquifers serving these other communities appears to be acceptable. However, new wells should be located outside the local areas of pumping influence of the existing wells. Although no evidence of contamination from surface sources have been detected in public-supply groundwater sources in the Plateau Region, a wellhead protection program should be considered by all communities.

City of Bandera

The City of Bandera is dependent on several wells completed into the Lower Trinity aquifer. The City must compete for water from the Lower Trinity with numerous other private wells in the county. Long-term viability of the Trinity aquifer as a supply source for Bandera and outlying areas will require implementation of management policies aimed at establishing withdrawals based on the sustainable yield of the aquifer. Sustainable yield of the Lower Trinity has not been established due to lack of available hydrologic data; additional studies based on evaluation of continuous water-level trends is needed.

City of Bandera Well #69-24-202 shows a consistent decline from the 1950s through the 1990s, with a total of approximately 400 feet of water level decline. Most of the water withdrawn by Bandera public supply wells is produced from the Lower Trinity which receives very little vertical recharge and an undetermined amount of lateral underflow from the north and west of the well fields. Because of the continuous water-level decline in these well fields, the city should monitor levels to anticipate production reductions.

City of Kerrville

The City of Kerrville is dependent on conjunctive use of surface water from the Guadalupe River and groundwater from Lower Trinity aquifer wells. Kerrville Wells No. 4 and No. 11 experienced declines of as much as 200 feet through the early to mid-1980s.

Between the early to mid-1980s and the early 1990s, water levels in these two wells increased by as much as 200 feet in response to the decreased pumpage by the City when surface water sources were brought on-line. Since 1998, water levels have remained relatively constant.

The only long-term water-quality degradation trend observed in Kerrville public-supply wells is noted in the increase in sodium, chloride and total dissolved solids in the City's Travis Well #14 during the late 1960s to mid-1970s. The well showed steady increases in sodium (18 to 72 mg/l), chloride (55 to 200 mg/l), and total dissolved solids (417 to 624 mg/l) between 1968 and 1976. This corresponded with the time period that large drawdowns in water levels were occurring in the Kerrville area. Today, the City mixes water from Well #14 with water from all other sources to maintain acceptable overall quality.

The City of Kerrville operates an aquifer storage and recovery (ASR) operation where treated surface water is injected into the Lower Trinity aquifer to maintain aquifer pressure and provide a source for peak demand periods.

Specific strategies to meet Kerrville's future water needs are addressed in Chapter 5. If additional wells are needed for increasing supply needs, the City should consider locating new wells outside the local area of pumping influence. The City should also cooperate with efforts of the local groundwater conservation districts to establish aquifer management policies.

City of Ingram

Ingram Water Supply Inc. operated by Aqua Texas provides water to the City of Ingram from wells completed in the Middle and Lower Trinity aquifers. The supply source appears to be sufficient to meet future needs. However, these wells are completed in the same aquifer as many other wells in the area and thus may be somewhat impacted in the future.

Kerrville South WSC

Kerrville South WSC operates a system that uses three wells in the Trinity aquifer and supplies customers throughout southern Kerr County, including several unincorporated communities.

City of Rocksprings

The City of Rocksprings obtains its water supply from wells completed in the Edwards limestone of the Edwards-Trinity (Plateau) aquifer. This rural community has little competition for groundwater and, thus, its supply is considered dependable.

City of Brackettville and Fort Clark Springs MUD

Water wells completed in the Edwards (BFZ) aquifer produce water used for municipal supply in these two adjacent communities. Las Moras Springs, an identified major spring, also exists at the same location of the Fort Clark Springs wells. Under existing conditions, there appears to be sufficient supply to meet futures needs. The Kinney County Groundwater Conservation District is currently evaluating potential impacts that might result from increased future pumping within the District.

Community of Camp Wood

Camp Wood located in southwestern Real County derives its water supply from Old Faithful Springs. The spring has reportedly always flowed. However, with increasing population and the drilling of additional wells in the area, the spring may experience decreasing flow during drought periods in the future.

City of Leakey

The City of Leakey obtains its water supply from four shallow wells ranging in depth from 34 to 42 feet in the Frio River Alluvium aquifer. An additional well has recently been constructed and an application for an operation permit is being filed with the Real-Edwards

Conservation and Reclamation District. The City must compete for groundwater from this small aquifer with numerous private domestic wells. A local citizens group petitioned the PWPG to include a recommendation in the Regional Plan for aquifer study to better define the availability limits of the aquifer.

City of Del Rio

The City of Del Rio is supplied with water from San Felipe Springs, which issue from the Edwards portion of the Edwards-Trinity (Plateau) aquifer. The water is collected through pumps set in the springs, treated with microfiltration and chlorine and then distributed to the City and to Laughlin Air Force Base.

The average discharge of San Felipe Springs since Lake Amistad was filled is about 110 cubic feet per second or about 80,000 acre-ft per year. During recent droughts, the spring discharge has fallen below 50 cfs or, extrapolated over one year, about 36,000 acre-feet. Recent droughts as compared to the 1950s drought would be appropriate to use as a drought-condition gage because the filling of Amistad Lake has generally increased the springflow after the late 1960s. A minimum flow has not been determined for the threatened species living down stream of the springs and a study is needed to determine the actual amount that would have to be subtracted from the total spring flow to meet these environmental needs.

3.2.9 Agricultural Use of Groundwater

Because of the arid conditions and lack of well-developed soils over much of the Region, irrigated agricultural activities are generally limited in most of the counties. Low well yields common throughout much of the Region also limit the development of large-scale irrigation. Water quality, however, is not generally a limiting factor for irrigation in the Region. Kinney County has the greatest amount of agricultural use of water. The acreage of land irrigated by groundwater in the year 2000 in each county as reported in TWDB Report 347 is, from most to least, Kinney, 4,865 acres; Bandera, 173 acres; Val Verde, 145 acres; Kerr, 57 acres; Edwards, 40 acres; and Real, 15 acres. The PWPG is concerned about the accuracy of the irrigation surveys and believes that there is significantly more irrigation water use than is documented. For example, the Headwaters Groundwater Conservation District in Kerr County documents approximately 700 acres being irrigated just with groundwater.

A review of historical and current data suggests that there has been no long-term change in regional water levels or water quality as a result of agricultural pumping. Local water-level declines occur during the irrigation season but generally recover during the off season. Although irrigation conservation efficiencies could be improved, currently used equipment and practices are not resulting in depletion of the aquifers. At the current rate of agricultural use, groundwater of sufficient quantity in the Edwards-Trinity (Plateau), Edwards (BFZ), and Austin Chalk aquifers should remain available for future agricultural use. However, the competition for Trinity aquifer water between municipal and agricultural needs in Bandera and Kerr Counties is increasing. The Bandera County River Authority and Groundwater District and the Headwaters Groundwater Conservation District are both actively involved in managing the use of groundwater in these counties.

3.2.10 Brackish Groundwater Desalination Sources

As observed in Figure 5-1 in Chapter 5, most groundwater in the Plateau Region contains total dissolved-solids (TDS) concentrations of less than 1,000 mg/l and thus meets drinking water standards. Groundwater of slightly lesser quality (1,000 to 3,000 mg/l) may occur in the Trinity aquifer, specifically in eastern Bandera and Kerr Counties. Elevated levels of calcium-sulfate resulting from the dissolution of evaporate beds in the upper Glen Rose is the primary source of higher TDS groundwater in these two counties. Productivity from this aquifer source makes desalination a marginal option at this time. Thus no desalination strategies are recommended in this current plan. However, the option under appropriate circumstances should remain as a consideration.

3.3 SURFACE WATER SUPPLIES

The Plateau Region is unique within all planning regions in that it straddles several different river basins rather than generally following a single river basin or a large part of a single river basin (Figure 3-2). From west to east, these basins include the Rio Grande, Nueces, Colorado, San Antonio, and Guadalupe. The headwaters of three of these river basins (Nueces, San Antonio, and Guadalupe), as well as major tributaries of the Rio Grande and Colorado River, originate in this Region.

Available surface water supplies under drought-of-record conditions depend on two components: water that is physically present (usually substantially reduced during a drought-of-record since by definition it is the most severe) and the authorized amount per existing water right adjudications. The Texas Commission on Environmental Quality (TCEQ) Water Availability Models (WAMs) perform a simulation of availability and diversion for all water rights in a river basin based on naturalized flows over a specified hydrologic period. These models generally follow an appropriation of water in priority date order, but appropriation order from upstream to downstream may be simulated. The TCEQ WAMs of the five river basins were used to determine surface water availability during a drought-of-record. The simulations used to determine water availability assume that all water rights in each basin are allowed to divert the full authorized amount when water is available, following appropriation in priority date order. They also assume that no return flows are present. These assumptions are known as the “Run 3” scenario. Area-capacity of major reservoirs was adjusted to reflect sedimentation conditions for 2000 and 2060. Drought-of-record supply source amounts by county and river basin are provided in Appendix 3A. Water supply capacity by user category is listed in Appendix 3B.

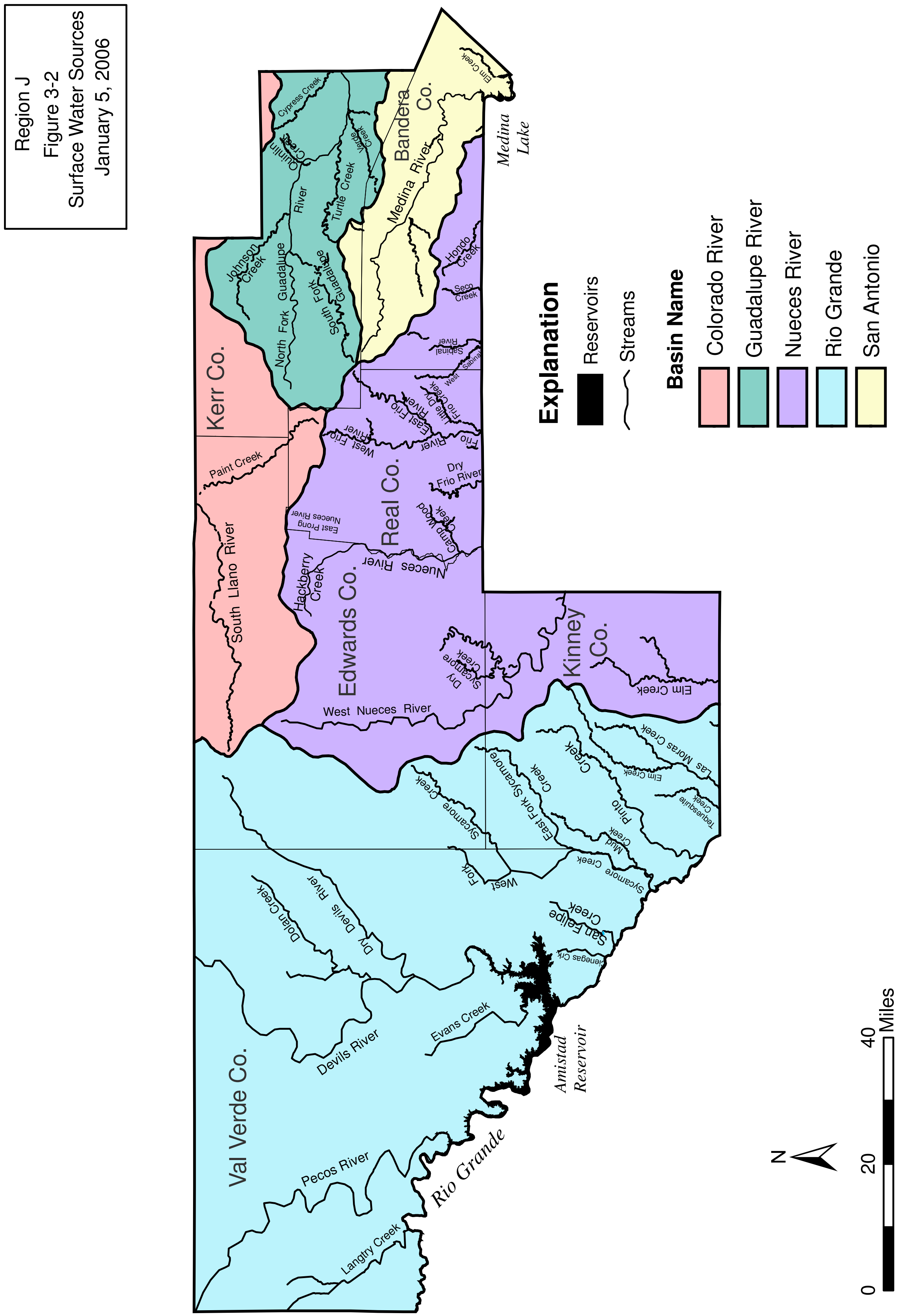

FIGURE 3-2. SURFACE WATER SOURCES

LBG-GUYTON ASSOCIATES

The term "run-of-the-river" is used to distinguish water rights with diversion points directly on a watercourse from water rights with diversion points on a reservoir. Generally, run-of-the-river water rights, also referred to as "direct diversions", are less dependable than water rights on reservoirs because of the lack of storage. However, run-of-the-river diversions are often very convenient, especially for irrigators and small entities, because a diversion point on a watercourse can be located extremely close to the location where the water will actually be consumed, thereby negating the need to pipe the water over long distances.

Diversions under a drought-of-record are extracted from results of a WAM simulation for each basin. For purposes of this plan, a drought-of-record supply for run-of-the-river diversions is categorized by use (municipal, irrigation, industrial and other) and by county. Supply amounts on river segments have always been difficult to assess due to the lack of storage to catch excess flows. In this plan, the reliable supply for run-of-the-river diversions is expressed as the minimum annual diversion for each category during the hydrologic period considered in the water availability models.

Drought-of-record supply amounts for reservoirs are on a firm-yield basis. To understand firm yield, one must understand the concept of "mass balance" - the simple but true principle of physics that mass can neither be created nor be destroyed (i.e., what goes in has to come out). In practical terms as applied to a reservoir, the water going in (inflows from drainage areas of tributaries feeding the reservoir site) equals the water going out (evaporation off the lake surface plus water spilled over the dam plus any water allowed to pass through the dam to satisfy senior water rights downstream plus the demand placed on the reservoir plus other factors which may exist). Engineers and hydrologists simulate the operation of a reservoir under various demands placed on the reservoir, iterating the simulation to find a demand that the reservoir can supply consistently throughout a repeat of the historical hydrologic regime. Demand is termed the "firm yield" of the reservoir if for every year of the historical hydrologic regime (even during a drought-of-record) the reservoir can supply the demand placed on it.

Canyon Reservoir and the Medina/Diversion system are key water supply reservoirs for the Plateau Region's future water needs. Although neither reservoir currently serves a water need within the Region, both reservoirs will likely do so in the near future.

Although recreational use of streams and lakes serves an important function in the Plateau Region, its use has no impact on reservoir yields, as these uses are non-consumptive. However, in some instances, recreational use may harm the water quality of a water supply (e.g., fuel byproducts from boat engines).

3.3.1 Rio Grande Basin (Including the Pecos and Devils River)

The Rio Grande, or Rio Bravo as it is known in Mexico, forms the border between the United States and Mexico. International treaties govern the ownership and distribution of the water in this river. Under The 1906 Treaty, the United States is obligated to deliver 60,000 acre-feet annually from the Rio Grande to Mexico, except in the cases of severe drought or serious accident to the irrigation system in the United States. The 1944 Treaty addresses the waters in the international segment of the Rio Grande from Fort Quitman, Texas to the Gulf of Mexico. The United States receives 1/3 of the flow from six tributaries (Rio Conchos, San Diego, San Rodrigo, Escondido, Salado Rivers, and Las Vacas Arroyo), provided that the running average over a five-year period cannot be less than 350,000 acre-feet per year.

While the International Boundary and Water Commission is responsible for implementing the allocation of water on the U.S. side, the Watermaster office of TCEQ administers the allocation of Texas' share of the international waters. The two reservoirs located in the middle of the lower Rio Grande, the Amistad and Falcon, store the water regulated by the Watermaster. The Watermaster oversees Texas' share of water in the Rio Grande and its Texas tributaries from Fort Quitman to Amistad Dam, excluding drainage basins of the Pecos River and Devils River.

The 3.4 million acre-feet International Amistad Reservoir is located on the Rio Grande in Val Verde County. The reservoir is an important flood control, irrigation and conservation facility for the area. Although the City of Del Rio owns permits to a limited quantity of water from San Felipe Creek, a tributary of the Rio Grande, most of the Rio

Grande water is permitted for downstream users in the Lower Rio Grande Valley. The constraints on Amistad Reservoir as a source of water supply for the Plateau Region are the existing water rights held by water rights holders and enforced by the Watermaster.

The Pecos River forms a portion of the boundary between Terrell County in the Far West Texas Region and Crockett County in Region F before reaching Langtry in Val Verde County in the Plateau Region. The Devils River originates in Sutton County and proceeds generally southward through Val Verde County before reaching Amistad International Reservoir. There are no surface-water rights on the Pecos and Devils Rivers within the Plateau Region.

Flow of the Pecos River within the Plateau Region is inconsistent, with livestock and wildlife watering apparently being the only use made of whatever water that may remain in the River. Independence Creek, a large spring-fed creek in northern Terrell County west of Val Verde County, is the most important of the few remaining freshwater tributaries to the lower Pecos River. Independence Creek's contribution increases the Pecos River water volume by 42 percent at the confluence and reduces the total suspended solids by 50 percent, thus improving both water quantity and quality (Nature Conservancy of Texas descriptive flier).

Flows of the Devils River are gaged by USGS 08449400 at Pafford Crossing near Comstock in Val Verde County. This gage began recording in 1978 and was discontinued in 1985. Therefore, it does not record flows for the 1950s. However, from 1978 through 1985 the flows are consistently between approximately 100 and 300 cfs, with rare spikes ranging from 4,000 cfs up to 50,000 cfs. These spikes result from unusually intense but short rainfall events. In absence of data for the 1950s drought period, and considering the generally low and undependable flows within the Devils River, a realistic estimate of the drought-of-record amount of supply from the Devils River within the Plateau Region is zero.

3.3.2 Amistad International Reservoir on the Rio Grande

The Amistad International Reservoir is located on the border between the United States and Mexico near the City of Del Rio, was constructed jointly by the two nations. It was completed in 1968 with a maximum capacity of 5,250,000 acre-feet, 3,505,000 acre-feet of which is used for water conservation. The water is distributed among downstream users of Mexico and the United States. However, Amistad is not a source of supply for the Plateau Region, as the City of Del Rio and downstream irrigators in Val Verde County obtain their supply primarily from San Felipe Springs and Creek.

Goodenough Spring is inundated by Lake Amistad and was at one time considered the third largest spring in Texas. The spring still undoubtedly provides a significant flow contribution to the Rio Grande.

3.3.3 The Nueces River Basin

The upper part of the Nueces River Basin lies in Edwards, Real, Bandera, and Kinney Counties. The main stem Nueces forms a portion of the border between Real County and Edwards County, while the Frio River traverses central Real County. Headwater tributaries of the Nueces River located in the Plateau Region include the Sabinal River and Hondo Creek in Bandera County, the West Nueces River in Edwards and Kinney Counties, and the Frio, East Frio, and Dry Frio Rivers in Real County. Although undocumented, there appears to be a significant amount of underflow occurring through gravel beds that line long stretches of the river bottom.

Total authorized diversions by water rights on the Nueces River within the Plateau Region are 11,419 acre-ft/yr. Most of this amount (10,116 acre-ft/yr or 88 percent) is for irrigation use. Diversions for municipal use total 1,259 acre-ft/yr. The Community of Camp Wood holds the largest municipal right for 1,000 acre-ft/yr. Small water rights for other uses have a total authorized diversion of 44 acre-ft/yr.

The drought-of-record for the Nueces River Basin appears to have occurred not in the 1950s, but in 1996. USGS gages on the Sabinal River, Hondo Creek and West Nueces River seem to substantiate this assertion; flows at these gages during 1996 were significantly reduced from expected historical flows. The locations of gages USGS 08198500 (Sabinal River at Sabinal in eastern Uvalde County) and USGS 08200700 (Hondo Creek at King Waterhole near Hondo in central Medina County) are outside the Plateau Region, but the gages themselves measure flows from drainage areas lying within counties of the Plateau Region. The location of USGS gage 08190500 on the West Nueces River is near Brackettville in Kinney County.

An internal TWDB memorandum dated May 26, 1998 cites the Sabinal and Hondo gages as having experienced streamflows in calendar years 1994 through 1996 significantly reduced from expected historical flows, and cites the West Nueces gage as having experienced streamflow in calendar years 1994 and 1995 significantly reduced from expected historical flows. The memorandum defines "significantly reduced" as showing a 40 percent or more difference between the historical and the recent year nonexceedance probabilities. (It should be noted that for all three of these gages 1997 flows were higher than the 1994 through 1996 flows.)

Flows for the main stem Nueces River are gaged at USGS 08192000 near Uvalde in Uvalde County. These gaged flows for a period of record of 1939 through 1997 indicate a low annual flow of 3.63 cfs (approximately 2,650 acre-ft/yr), occurring in 1956. Flows for the Frio River are gaged at USGS 08195000 at Concan in Uvalde County. These gaged flows for a period of record of 1930 through 1997 indicate a low annual flow of 8.8 cfs (approximately 6,424 acre-ft/yr), occurring in 1956. For these areas, the 1950s drought was evidently the drought-of-record.

The TCEQ Water Availability Model for the Nueces River Basin was used to evaluate surface water supplies. The model includes data through the year 1996, and therefore addresses the drought-of-record occurring in 1996 for the localized areas on the Sabinal River and Hondo Creek.

3.3.4 Colorado River Basin

The headwaters of the South Llano River, a tributary of the Colorado River, lie in Edwards County. There are three water rights on the South Llano River and Paint Creek within the Plateau Region for irrigation use. The combined authorized amount of these rights is 180 acre-ft/yr.

The TCEQ Colorado River Basin WAM was used to evaluate the supply for these rights. This model covers the period 1940-1998. Hydrologic data for these streams suggest that the drought-of-record occurred during the 1950s. The minimum annual diversion for the three rights is 43 acre-ft/yr.

3.3.5 San Antonio River Basin

Headwaters of the San Antonio River lie in Bandera County. Most water right authorizations from the San Antonio Basin are run-of-the-river diversions for irrigation use. Run-of-the-river diversions exclude authorizations on Medina Lake. Eight authorized water rights on the Medina River main stem total 236 acre-ft/yr. Of these eight water right holders on the River, six use the water for irrigation. The sum of these six irrigation rights totals 227 acre-ft/yr. Of the remaining two water right holders, one is for 9 acre-feet of water per year used by an individual for municipal purposes, and the other is for a non-consumptive recreation reservoir owned by the City of Bandera. This recreation-only reservoir is for non-consumptive use only.

Since the Guadalupe-San Antonio WAM covers the period 1934-1989, it is appropriate to consider if the drought of 1996 exceeded the severity of the drought of the mid 1950s. USGS gage 08178880 on the Medina River at Bandera just downstream of State Highway 173 gives a lowest annual streamflow amount at 33.7 cubic feet per second (cfs) (approximately 24,600 acre-ft/yr) in 1996. However, this gage did not begin recording until 1982, and therefore records from the 1950s drought are missing and cannot be compared directly to the low flows of 1996. Data for the 1950s at the Bandera gage as extracted from the Guadalupe-San Antonio River Basin WAM gives an annual naturalized flow of 10,500 acre-feet in 1956. Regulated flows would be even lower once upstream diversions and impoundments are accounted for. Therefore, based on estimates of the Guadalupe-San Antonio Basins WAM, the drought of the 1950s represents the drought-of-record conditions for the San Antonio Basin in the Plateau Region.

3.3.6 Medina Lake on the Medina River

Medina Lake was constructed in 1911 to provide irrigation water for farmers to the southwest of San Antonio. Although commonly referred to as Medina Lake, the lake is actually a system consisting of Medina Lake and Diversion Lake. Impounded in 1913, Diversion Lake is approximately 4 miles downstream of Medina Lake. Diversions are authorized only from Diversion Lake, as per the water right held by Bexar-Medina-Atascosa Water Control and Improvement District #1 (BMAWCID#1).

BMAWCID#1's Adjudication Certificate No. 19-2130C authorizes the District to divert up to 65,830 acre-ft/yr of water for irrigation, municipal and industrial use, up to 750 acre-ft/yr specifically for domestic and livestock purposes, and up to 170 acre-ft/yr specifically for municipal use.

BMAWCID#1 has signed contracts to supply several irrigators and a development corporation with water. In January 2000, BMAWCID#1 signed a contract with Bexar Metropolitan Water Authority indicating that BMAWCID#1 will sell 20,000 acre-ft/yr to Bexar Metropolitan Water Authority for municipal use.

Bandera County currently has a Water Supply Agreement with BMAWCID#1 for purchase of up to 5,000 acre-ft/yr; however, this agreement is not currently associated with the infrastructure necessary to carry out the purchase and subsequent distribution of the water.

Loss of impounded water from Medina Lake to the Trinity aquifer and Diversion Lake to the Edwards aquifer reduces the firm yield of the system. This loss has long been known to be substantial. Quantification of water recharging the aquifers has been elusive - different estimates of recharge have resulted in different firm-yield estimates for the system. In 1957, a Bureau of Reclamation study estimated the firm annual yield of the Medina Lake/Diversion Lake system to be 27,500 acre-ft/yr if the lake system were operated under an agricultural (irrigation) demand only scenario, but it estimated 29,700 acre-ft/yr as the firm yield for municipal and industrial demand. Due to effects of seepage around the dam and of recharge to groundwater, Espey Huston estimated a firm yield of zero for Medina

Lake in 1994, based on the relationship they found between the Lake stage and recharge. HDR Engineering modified the Espey Huston stage-recharge curves for its Trans-Texas report and cited 8,770 acre-ft/yr as the firm yield. According to personal communication, HDR assumed diversions would be from Medina Lake rather than from Diversion Lake and that all irrigation use would be curtailed. This assumption does not comply with existing conditions as regards to water right authorizations.

The latest USGS report, "Assessment of Hydrogeology, Hydrologic Budget, and Water Chemistry of the Medina Lake Area, Medina and Bandera Counties, Texas," maintains that earlier methods of estimating recharge (Lowry, Espey Huston curves as modified by HDR for the Trans-Texas report) overestimate recharge. Overestimation of recharge would result in an underestimation of firm yield; however, the USGS report did not include a firm-yield estimate for the reservoir system.

The TCEQ Guadalupe-San Antonio River Basins WAM incorporates the HDR Trans-Texas method of estimating recharge and probably provides the best overall data (water rights, inflows determined by water rights) available at this time. The model was used to determine a firm yield of the Medina/Diversion system of 0 acre-ft/yr.

3.3.7 Guadalupe River Basin

Within the Plateau Region, the Guadalupe River Basin occurs almost exclusively within Kerr County. The Basin drains approximately 510 square miles at Kerrville, and approximately 839 square miles at Comfort near the eastern county line. The River originates entirely within western Kerr County as three branches (Johnson Creek, North Fork, and South Fork) merge west of Kerrville to form the main river course. Spring flow contribution to the headwaters of the Guadalupe River is discussed in a report (Ashworth, 2005) prepared for the PWPG (Appendix 3F).

The total amount of authorized water rights for the Guadalupe River within the Plateau Region is 21,020 acre-ft/yr. Municipal use accounts for the highest authorization at 8,076 acre-ft/yr. Holders of these water rights include the City of Kerrville, the Upper Guadalupe River Authority (UGRA), and independent persons.

The City of Kerrville and the Upper Guadalupe River Authority own the largest municipal water rights. Certificate of Adjudication 1996 and Permit 3505 are held solely by Kerrville. UGRA and Kerrville hold Permit 5394 jointly. Authorized diversions from the Guadalupe River associated with these water rights are taken from an 840-acre on-channel reservoir located in the City of Kerrville. Diversions are pumped from the reservoir to Kerrville's water plant for treatment. A summary of the pertinent information for their water rights is shown in Table 3-1.

Texas Parks and Wildlife Department owns a continuous flow-through water right for 5,780 acre-ft/yr used for the Heart of the Hills Fisheries Science Center, consumptive use is approximately 400 acre-ft/yr. Industrial use permits are authorized for 17 acre-ft/yr and irrigation rights for 6,904 acre-ft/yr. The remaining water-rights holders use their water for mining, hydroelectric power, and recreation. One individual holds a water right (35,125 acre-ft/yr) for hydroelectric use; however, this right has not been exercised. Kerr County holds the rights for three non-consumptive recreation-use reservoirs in and near Kerrville.

TABLE 3- 1. MUNICIPAL WATER RIGHTS FOR KERRVILLE AND UGRA

Water Rights Permit	Authorized Diversion (ac-ft/yr)	Permit Holder	Priority Date	Storage (ac-ft)	Restrictions
1996 (amended 4/10/98)	150 (mun) 75 (irr)	Kerrville	April 4, 1914		
3505	3,603	Kerrville	May 23, 1977	840	Max diversion rate = 9.7 cfs Divert only when reservoir is above 1,608 ft msl
5394 (amended 4/10/98)	2,169	Kerrville (Kerrville Municipal use)	January 6, 1992	Utilizes the storage authorized for Permit 3505	Max combined diversion rate for water rights #3505 and #5394 = 15.5 cfs. Minimum instream flow requirements vary from 30 to 50 cfs during year.
	2,000	UGRA (County Municipal use)			

Note: Permit 1996 authorizes a total diversion of 225 acre-feet per year, of which 150 acre-feet per year is designated for municipal use and 75 acre-feet per year for irrigation purposes.

During winter months when there is surplus surface water supply, a portion of the treated water is injected into the Lower Trinity aquifer for subsequent use during the typically dry summer months. This Aquifer Storage and Recovery (ASR) program has been in full operation since 1998.

Both the City of Kerrville and the Upper Guadalupe River Authority have within their authorizations (Permits Nos. 5394B and 5394A respectively) a Special Condition addressing the seasonal distribution of allowed diversions. The Special Condition stipulates that during the months of October through May, the permittees may divert only when the flow of the Guadalupe River exceeds 40 cfs, and during the months of June through September, the permittees are authorized to divert only when the flow of the Guadalupe River exceeds 30 cfs. Another Special Condition common to both permittees is that, when inflows to Canyon Reservoir are less than 50 cfs, each permittee is to restrict diversions to allow a flow of at least 50 cfs to pass through. Yet another Special Condition imposed on both permittees is that diversions may be made only when the level of UGRA Lake is above 1,608 feet above mean sea level.

Pursuant to a Memorandum of Understanding (MOU) between the Guadalupe-Blanco River Authority (GBRA) and the Commissioner's Court of Kerr County, the South Central Texas Water Planning Group (Region L) recognizes a potential commitment of approximately 2,000 ac-ft/yr from the firm yield of Canyon Reservoir for the calendar years 2021 through 2050. GBRA's hydrology studies indicate that a commitment of about 2,000 acre-ft/yr would be necessary to allow permits for 6,000 ac-ft/yr to be issued by TCEQ for diversions in Kerr County.

Data from the Corps of Engineers show a computed inflow into Lake Canyon of 132,900 acre-ft/yr in 1996. The Guadalupe-San Antonio WAM estimates naturalized flows to be 27,800 acre-ft in 1956. The USGS gage 08167000 on the Guadalupe River at Comfort gives a lowest annual streamflow amount of 14.5 cfs (approximately 10,585 acre-ft/yr) occurring in 1956. This gage has been recording since 1939. Interestingly, statistics for the gage include the fact that, for water years 1939 through 1997, the mean annual runoff was 157,800 acre-feet or approximately 216 cfs, and that 90 percent of these flows exceeded 25 cfs. This puts the 1956 occurrence of 14.5 cfs within the 0 to 10 percent nonexceedance category. In calendar year 1996, the annual mean was 151 cfs and the median was 85 cfs. The mean and median for 1997 exceeded the 1996 values. These facts seem to substantiate that the drought-of-record for Kerr County occurred in 1956, not in 1996, as consistent with most other areas of the State.

3.3.8 Canyon Reservoir

The construction of Canyon Reservoir was completed and impoundment commenced in June 1964. This reservoir controls approximately 1,425 square miles of drainage area and serves to impound water for various uses (mostly appropriated to the GBRA for use primarily in the South Central Texas Region). Canyon is also an Army Corps of Engineers (COE) Reservoir and as such operates under the Army COE Operations Manual as occasionally modified by request of GBRA (and agreed to by county judges of the downstream counties). Canyon Reservoir is also subject to the Federal Emergency Management Agency's (FEMA) requirements as to daily releases. The Army COE and FEMA operations and release requirements are incorporated into the updated TCEQ WAM for the Guadalupe-San Antonio River Basin. GBRA’s TCEQ permit currently authorizes an average annual diversion from Canyon Reservoir of 90,000 ac-ft/yr. The firm yield of Canyon Reservoir used in the Region L Plan ranges from 88,232 ac-ft/yr to 87,484 ac-ft/yr in years 2000 and 2060 respectively.

3.3.9 San Felipe Springs

The City of Del Rio has a water right authorizing it to divert 11,416 acre-ft/yr from San Felipe Springs for municipal use. San Felipe Manufacturing and Irrigation Company has a water right authorizing it to divert 4,962 acre-ft/yr for irrigation use and 50 acre-ft/yr for industrial use. No data exists for flows during the drought of the 1950s. The only available records are from USGS gage 08452800 maintained by the IBWC at San Felipe Springs that covers the period of February 1961 to present. The minimum annual amount during this time period was 36,580 acre-ft/yr (occurring in 1963).

3.3.10 Old Faithful Springs

Issuing from the upper Glen Rose limestone and shallow creek alluvium, Old Faithful Springs is the sole-source water supply for the Community of Camp Wood. The Spring has been a dependable source and was reported to have continuously flowed during the 1950s drought. There is current concern that the increase in the number of wells being drilled in the area may lower the local water table and thus negatively impact spring flow.

3.3.11 Surface Water Rights

The right to use water from streams and lakes is permitted through the State of Texas. Current permit holders in the Region are listed in Appendix 3D, while permitted water use from 1990 through 1999 as reported to TCEQ are listed in Appendix 3E. The following permits are due to expire during the 50-year planning period:

- WR #5401 - a non-consumptive recreational use, on Turtle Creek in Kerr County (Guadalupe Basin), expires 12/31/2012
- WR #5097 - a consumptive irrigation use for 120 acre-ft/yr, on West Prong of Medina River in Bandera County (San Antonio Basin), expires 02/02/2016
- WR #3853 - a non-consumptive recreational use, on Spires Creek in Bandera County (San Antonio Basin), expires 04/12/2018

Major downstream water rights include those in Region L supplied by the Guadalupe-Blanco River Authority out of Canyon Lake and by the Bexar-Medina-Atascosa WCID#1 out of the Medina/Diversion system. The firm yields of Canyon and Medina limit the amount of water available for appropriation in both the Plateau Region and Region L. Major downstream water rights in Region M (i.e., cities and irrigators on the Rio Grande downstream from Amistad Reservoir) do not limit the amount of water available for appropriation in the Plateau Region because currently the Plateau Region does not depend on the Falcon-Amistad system. TCEQ’s Lower Rio Grande Watermaster allocates water rights on the Rio Grande according to the supply in the Amistad Reservoir and in accordance with the 1944 International Treaty with Mexico.

3.4 GROUNDWATER/SURFACE WATER RELATIONSHIP

In the natural environment, water is constantly in transition between the land surface and underground aquifers. Under certain conditions, stream losses percolate downward to underlying aquifers as recharge; while in other cases, aquifers give up water to the land surface in the form of springs and seeps.

Most of the Plateau Region occurs at higher elevations that constitute the headwaters of the numerous streams and tributaries that frequent this Region. At these elevations, significant quantities of water exit the aquifer systems through springs and form the base flow of the surface streams (Figure 3-3). Downstream, only a portion of that water may renter the underground system. For this reason, these streams are generally gaining throughout much of their extent within the Plateau Region. Spring flows are also environmentally important in that they are the primary source of water for wildlife in the area. These discharges from springs are thus the primary source of continuous flow to the rivers downstream and, therefore, their protection is warranted.

Some of the largest springs in the Region, such as San Felipe Springs (Val Verde County) and Las Moras Springs (Kinney County), issue from the Edwards limestone. However, numerous other springs issue from either the Edwards or Glen Rose limestones. Many of the springs, such as Fessenden Spring (Kerr County), issue near the contact between the Edwards and the upper Glen Rose limestones. Smaller springs are more prevalent where they issue from the Glen Rose, particularly in Bandera and Kerr Counties.

Most springs located in the headwaters of rivers that traverse the eastern part of the Region issue from the contact between the Edwards limestone and underlying upper Glen Rose limestone. Most well production in this area is from deeper aquifers and, therefore, little impact to spring flow from the pumping is anticipated. However, as new development expands to the west, care should be given to potential water level declines that could diminish spring flow and base flow to the rivers.

Springs located in the western part of the region issue primarily from the Edwards limestone. Because of limited pumping of groundwater from wells in the Del Rio area, San Felipe Springs has not had to compete for source water. A significant increase in groundwater pumpage immediate updip and to the east of the springs may lower the water table sufficiently to affect flow from the springs. Because much of the recharge areas for the contributing zones of these western springs occur in remote areas, very little information is available concerning the relationship between the springs and the underlying aquifers.

Gain/loss studies are needed to identify stream segments that are critical to aquifer recharge and spring discharge. The studies can be used to identify where recharge structures would be most efficient and where most river base-flow gain occurs. Specific candidate areas occur over the plateau area that is underlain by Edwards limestone, especially in the upper tributaries of all the rivers. Gain/loss studies of tributaries in the vicinity of Del Rio would be beneficial in understanding the recharge areas that contribute to San Felipe Springs.

Two supplemental study reports were prepared for the Plateau Region Water Plan that address springs. The first report (Ashworth and Stein, 2005) considers the location and geohydrology of springs in Kinney and Val Verde Counties, and the second report (Ashworth, 2005) relates springflow in western Kerr County to base flow in the three branches of the upper Guadalupe River. Conclusions of these two reports are provided in Appendix 3F.

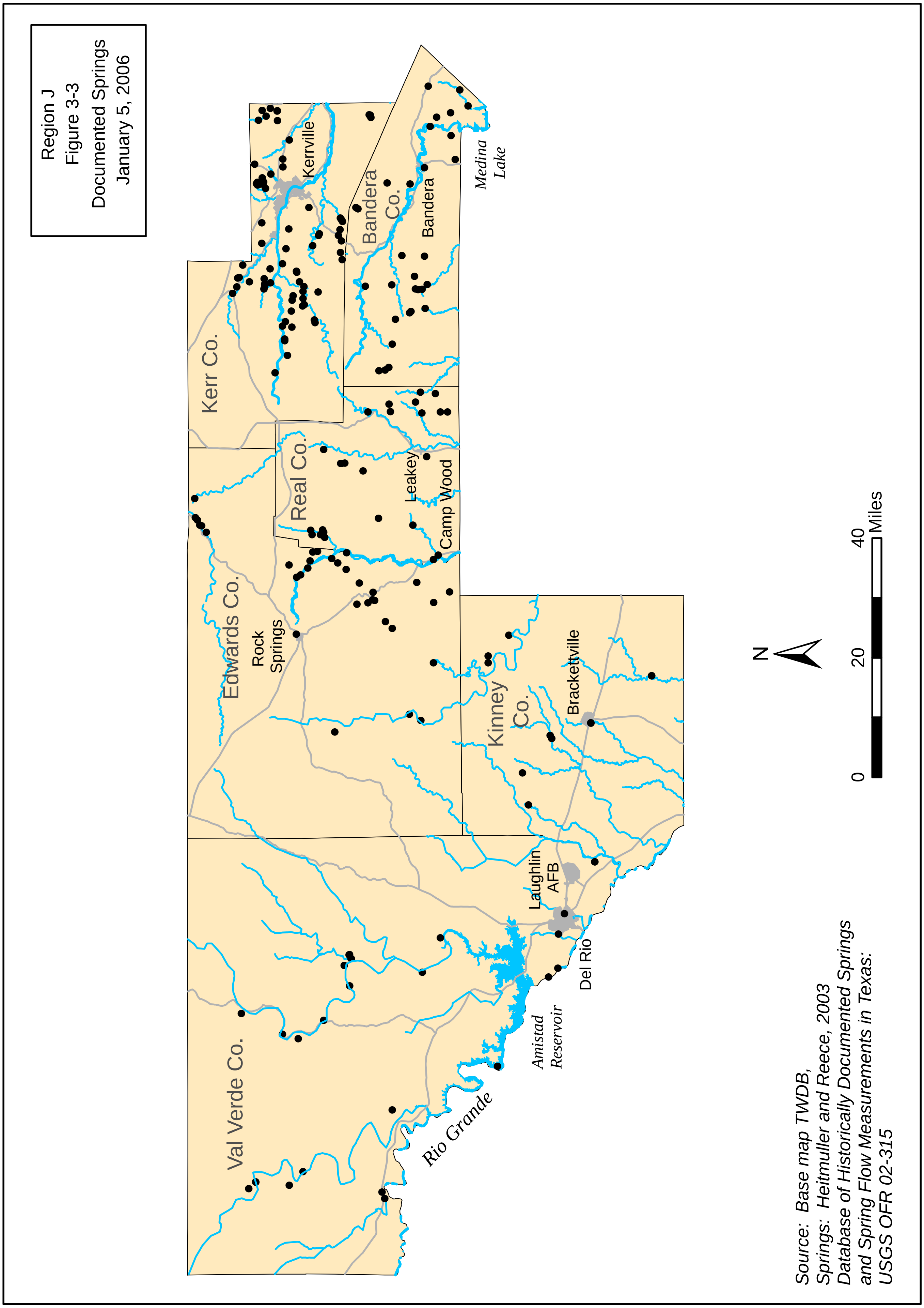

FIGURE 3-3. LOCATION OF DOCUMENTED SPRINGS

LBG-GUYTON ASSOCIATES

3.5 WATER REUSE

While recycling is a term generally applied to aluminum cans, glass bottles, and newspapers, water can be recycled as well. Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a groundwater aquifer (referred to as groundwater recharge or ASR for aquifer storage and recovery). Water is sometimes recycled and reused onsite; for example, when an industrial facility recycles water used for cooling processes. A common type of recycled water is water that has been reclaimed from municipal wastewater, or sewage. The term "water recycling" is generally used synonymously with water reclamation and water reuse.

In Kerrville, wastewater is treated to strict government standards. In fact, Kerrville treats its wastewater to the strictest set of standards in the State of Texas. Because of the high level of treatment, Kerrville's wastewater nearly meets drinking water standards. Treated wastewater is pumped through a dedicated pipeline for reuse as irrigation water for the Scott Schreiner Municipal Golf Course, the Hill Country Youth Soccer Fields, and the golf course at Comanche Trace Ranch & Golf Club. Additional treated water is sold by the truckload for construction projects. The remaining wastewater is released into Third Creek, which flows into Flatrock Lake on the Guadalupe River. That water is then available for use downstream of Kerrville. Future expansion of Kerrville's reuse project is anticipated to yield approximately 1 million gallons per day. The current thinking within city leadership is that potable reuse is a better use for that water than irrigation.

The Community of Camp Wood also has a water reuse program. Treated wastewater is used to irrigate hay fields in the near vicinity of town.

3.6 REFERENCES

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APPENDIX 3A

WATER SOURCE AVAILABILITY

APPENDIX 3A. WATER SOURCE AVAILABILITY
(Acre-Feet/Year)

COUNTY	AQUIFER / RIVER	RIVER BASIN	SOURCE AVAILABILITY (All Decades)
BANDERA	Edwards-Trinity	Guadalupe	860
	Edwards-Trinity	San Antonio	11,250
	Edwards-Trinity	Nueces	5,200
	Trinity	Nueces	5,969
	Trinity	San Antonio	12,589
	Livestock Local Supply	San Antonio	72
	Upper Guadalupe River	Guadalupe	3
	Medina River	San Antonio	0
	Medina Lake/Reservoir	San Antonio	0
	Sabinal River	Nueces	7
	Hondo Creek	Nueces	20
	COUNTY TOTAL		**35,970**
EDWARDS	Edwards-Trinity	Colorado	2,610
	Edwards-Trinity	Nueces	3,480
	Edwards-Trinity	Rio Grande	2,609
	Livestock Local Supply	Colorado	61
	Livestock Local Supply	Nueces	62
	Nueces River	Nueces	138
	West Nueces River	Nueces	5
	South Llano River	Colorado	43
	COUNTY TOTAL		**9,008**
KERR	Edwards-Trinity	Colorado	4,250
	Edwards-Trinity	Guadalupe	11,500
	Edwards-Trinity	San Antonio	330
	Edwards-Trinity	Nueces	330
	Trinity	Guadalupe	15,492
	Trinity	San Antonio	1,832
	Livestock Local Supply	Colorado	20
	Livestock Local Supply	Guadalupe	73
	Livestock Local Supply	San Antonio	12
	Upper Guadalupe River	Guadalupe	1,221
	COUNTY TOTAL		**35,060**

COUNTY	AQUIFER / RIVER	RIVER BASIN	SOURCE AVAILABILITY
KINNEY	Edwards-Trinity	Nueces	1,432
	Edwards-Trinity	Rio Grande	21,000
	Edwards (BFZ)	Nueces	6,925
	Edwards (BFZ)	Rio Grande	1,800
	Austin Chalk	Rio Grande	4,928
	Livestock Local Supply	Nueces	45
	Livestock Local Supply	Rio Grande	90
	Mud Creek	Rio Grande	120
	Pinto Creek	Rio Grande	95
	Las Moras Creek	Rio Grande	669
	Elm Creek	Rio Grande	43
	Rio Grande	Rio Grande	176
	COUNTY TOTAL		**37,323**
REAL	Edwards-Trinity	Colorado	200
	Edwards-Trinity	Nueces	5,537
	Trinity	Nueces	380
	Frio River Alluvium	Nueces	1,120
	Livestock Local Supply	Nueces	25
	Livestock Local Supply	Colorado	24
	Old Faithful Springs	Nueces	0
	Nueces River	Nueces	648
	Frio River	Nueces	1,514
	COUNTY TOTAL		**9,448**
VAL VERDE	Edwards-Trinity	Rio Grande	49,607
	Livestock Local Supply	Rio Grande	153
	Devils River	Rio Grande	0
	Pecos River	Rio Grande	0
	Rio Grande	Rio Grande	125
	Cienagas Creek	Rio Grande	794
	San Felipe Creek	Rio Grande	13,016
	COUNTY TOTAL		**63,695**

APPENDIX 3B

WATER USER GROUP

WATER SUPPLY CAPACITY

APPENDIX 3B. WATER USER GROUP WATER SUPPLY CAPACITY[a]

(Based on Current Infrastructure and Regulatory Caps)(Acre-Feet/Year)

County	Water User Group	Source Basin	Specific Source Name	Water Supply Capacity (All Decades)
Bandera	Bandera	San Antonio	Trinity	1,210
Bandera	County Other	Guadalupe	Edwards-Trinity (Plateau)	31
Bandera	County Other	San Antonio	Edwards-Trinity (Plateau)	803
Bandera	County Other	San Antonio	Trinity	9870
Bandera	County Other	San Antonio	Medina River	0
Bandera	County Other	Nueces	Edwards-Trinity (Plateau)	115
Bandera	County Other	Nueces	Trinity	689
Bandera	County Other	Nueces	Sabinal River	2
Bandera	Mining	San Antonio	Trinity	24
Bandera	Irrigation [f]	Guadalupe	Upper Guadalupe River	3
Bandera	Irrigation [f]	San Antonio	Trinity	207
Bandera	Irrigation [f]	San Antonio	Medina River	0
Bandera	Irrigation [f]	Nueces	Trinity	118
Bandera	Irrigation [f]	Nueces	Hondo Creek	20
Bandera	Irrigation [f]	Nueces	Sabinal River	5
Bandera	Livestock	Guadalupe	Edwards-Trinity (Plateau)	6
Bandera	Livestock	San Antonio	Trinity	158
Bandera	Livestock	San Antonio	Edwards-Trinity (Plateau)	32
Bandera	Livestock	San Antonio	Local Supply	72
Bandera	Livestock	Nueces	Trinity	80
Bandera	Livestock	Nueces	Edwards-Trinity (Plateau)	15
Edwards	Rocksprings	Colorado	Edwards-Trinity (Plateau)	322
Edwards	Rocksprings	Nueces	Edwards-Trinity (Plateau)	180
Edwards	County Other	Colorado	Edwards-Trinity (Plateau)	121
Edwards	County Other	Nueces	Edwards-Trinity (Plateau)	411
Edwards	County Other	Rio Grande	Edwards-Trinity (Plateau)	72
Edwards	Mining	Colorado	Edwards-Trinity (Plateau)	6
Edwards	Irrigation	Colorado	Edwards-Trinity (Plateau)	53
Edwards	Irrigation	Colorado	South Llano River	43
Edwards	Irrigation	Nueces	Edwards-Trinity (Plateau)	54
Edwards	Irrigation	Nueces	Nueces River	138
Edwards	Irrigation	Nueces	West Nueces River	5
Edwards	Irrigation	Rio Grande	Edwards-Trinity (Plateau)	53
Edwards	Livestock	Colorado	Edwards-Trinity (Plateau)	164
Edwards	Livestock	Colorado	Local Supply	61
Edwards	Livestock	Nueces	Edwards-Trinity (Plateau)	168
Edwards	Livestock	Nueces	Local Supply	62
Edwards	Livestock	Rio Grande	Edwards-Trinity (Plateau)	164

Kerr [b]	Kerrville	Guadalupe	Trinity	2,890 [c]
			Upper Guadalupe River (+ ASR)	150
	Ingram	Guadalupe	Trinity	585
	Kerrville South WC	Guadalupe	Trinity	420
	County Other	Colorado	Edwards-Trinity (Plateau)	251
		Guadalupe	Edwards-Trinity (Plateau)	5,547
			Trinity	6,084
			Upper Guadalupe River	15
		San Antonio	Edwards-Trinity (Plateau)	125
			Trinity	627
	Manufacturing	Guadalupe	Trinity	12
			Edwards-Trinity (Plateau)	30
			Upper Guadalupe River	9
	Mining	Colorado	Edwards-Trinity (Plateau)	13
		Guadalupe	Trinity	159
			Edwards-Trinity (Plateau)	4
			Upper Guadalupe River	89
	Irrigation [f]	Guadalupe	Trinity	406
			Upper Guadalupe River	958
	Livestock	Colorado	Edwards-Trinity (Plateau)	105
			Local Supply	20
		Guadalupe	Trinity	122
			Edwards-Trinity (Plateau)	160
			Local Supply	73
		San Antonio	Edwards-Trinity (Plateau)	22
			Local Supply	12
		Nueces	Edwards-Trinity (Plateau)	12

Kinney [d]	Brackettville	Rio Grande	Edwards (BFZ)	645
			Las Moras Creek	2
	Fort Clark Springs	Rio Grande	Edwards (BFZ)	1,120
	County Other	Nueces	Edwards (BFZ)	41
			Edwards-Trinity (Plateau)	7
		Rio Grande	Edwards-Trinity (Plateau)	24
			Austin Chalk	64
	Irrigation [e]	Nueces	Edwards (BFZ)	4,382
			Edwards-Trinity (Plateau)	0
		Rio Grande	Edwards-Trinity (Plateau)	20,813
			Austin Chalk	3,872
			Mud Creek	120
			Pinto Creek	95
			Los Moras Creek	665
			Elm Creek	43
			Rio Grande	176
	Livestock	Nueces	Edwards (BFZ)	130
			Edwards-Trinity (Plateau)	159
			Local Supply	45
		Rio Grande	Edwards-Trinity (Plateau)	159
			Austin Chalk	92
			Local Supply	90
Real	Camp Wood	Nueces	Old Faithful Springs	0
	County Other (+ Leakey)	Colorado	Edwards-Trinity (Plateau)	34
		Nueces	Edwards-Trinity (Plateau)	491
			Other Aquifer (Frio Aluv.)	997
			Nueces River	0
	Mining	Colorado	Edwards-Trinity (Plateau)	6
	Irrigation	Nueces	Edwards-Trinity (Plateau)	349
			Nueces River	648
			Frio River	1,514
	Livestock	Nueces	Edwards-Trinity (Plateau)	180
			Local Supply	25
		Colorado	Edwards-Trinity (Plateau)	15
			Local Supply	24

Val Verde	Del Rio	Rio Grande	San Felipe Springs	7,461
			Edwards-Trinity (Plateau)	9,116
	Laughlin AFB	Rio Grande	Purchase from Del Rio	2,178
			Edwards-Trinity (Plateau)	121
	County Other	Rio Grande	Supplied by Del Rio	1,631
			Edwards-Trinity (Plateau)	4,413
	Mining	Rio Grande	Edwards-Trinity (Plateau)	156
	Irrigation	Rio Grande	Edwards-Trinity (Plateau)	363
			Cienagas Creek	794
			San Felipe Springs	5,555
			Rio Grande	125
	Livestock	Rio Grande	Edwards-Trinity (Plateau)	614
			Local Supply	153

Remarks:
(a) Water supply capacity is the volume of water apportioned to a Water User Group (WUG) from each current existing, connected, and accessible water source, during drought-of-record conditions, taking into consideration all constraints that limit the supply amount.
(b) Kerr County - Headwaters Groundwater Conservation District has pumping limitations on Trinity aquifer wells.
(c) Kerrville groundwater capacity based on GCD cap. Actual Kerrville infrastructure capacity is 6,625 ac-ft per year.
(d) Kinney County - Kinney County Groundwater Conservation District has a high-use pumping cap of 69,800 ac-ft per year.
(e) Kinney County irrigation based on Kinney County Groundwater Conservation District year-2005 permitted allocation as of 4-23-05.
(f) Irrigation groundwater use in Bandera and Kerr Counties is mostly from river alluvium that is hydrologically connected to the Trinity aquifer.

APPENDIX 3C

WHOLESALE WATER PROVIDER

WATER SUPPLY CAPACITY

APPENDIX 3C. DEL RIO WHOLESALE SUPPLY PROJECTION

(Acre-Feet/Year)

Wholesale Water Provider	County	Basin	Receiving Entity	2010	2020	2030	2040	2050	2060
Del Rio	Val Verde	Rio Grande	City of Del Rio	16,577	16,577	16,577	16,577	16,577	16,577
			Laughlin AFB	2,178	2,178	2,178	2,178	2,178	2,178
			County Other	1,631	1,631	1,631	1,631	1,631	1,631
			Total Supply	**20,386**	**20,386**	**20,386**	**20,386**	**20,386**	**20,386**

APPENDIX 3D

AUTHORIZED SURFACE WATER RIGHTS

APPENDIX 3D. AUTHORIZED SURFACE WATER RIGHTS AS EXTRACTED FROM TNRCC'S ACTIVE WATER RIGHTS MASTER FILE

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2027-000	6	Bandera	7720000000	ROBERT L PARKER SR ET AL	VERDE CRK	IRRG	8	3		
2028-000	6	Bandera	7750000000	HOWARD E BUTT	PALMER CRK	OTHER			30	
2103-000	6	Bandera	5903000000	O S PETTY	HONEY CRK	IRRG	96	38		
2104-000	6	Bandera	5902000000	CLARENCE E LAUTZENHEISER ET UX	N PRONG MEDINA RIVER	IRRG	20.24	23.85		AMEND 9/29/88, 8/22/89
2105-000	6	Bandera	5901500000	STEVEN L PRICHARD TRUSTEE	MICKLE	IRRG	5.44	8.16	5	
2105-000	6	Bandera	5901500000	NEAL INCORPORATED	MICKLE	IRRG	7.32	10.99	5	
2106-000	6	Bandera	5901450000	BREWINGTON LAKE RANCH ASSN	BREWINGTON CRK	REC	190		190	
2107-000	6	Bandera	5901100000	JOEL HELD, TRUSTEE/JJJ RANCH	N PRONG MEDINA RIVER	IRRG	19	25		OUT OF A 1666.5 ACRE TRACT
2108-000	6	Bandera	5900100000	BEN & KAY MAYBERRY FAM PART	ROCKY CRK	IRRG	19.82	14.41		ALSO KERR CO
2108-000	6	Bandera	5900100000	WALTER A WILLOUGHBY	ROCKY CRK	IRRG	24.18	17.59		ALSO KERR CO
2109-000	6	Bandera	5897200000	NEVIN MARR	N PRONG MEDINA RIVER	IRRG	2	10		AMEND 1-21-83 INCREASE ACRES
2110-000	6	Bandera	5897000000	DONALD F & MARTHA M MEAD	N PRONG MEDINA RIVER	IRRG	21	12		
2111-000	6	Bandera	5896000000	TEXAS PETROLEUM CO. TR EST	COLLINS CRK	IRRG	4	2	16	
2112-000	6	Bandera	5894500000	MRS MARY WINKENHOWER	ELAM CRK	IRRG	27	27		JOINTLY OWNS 27 AF TO IRR 27 ACRES
2113-000	6	Bandera	5894000000	SUSAN CRAWFORD TRACY	W PRONG MEDINA RIVER	IRRG	35	45		OUT OF A 156 ACRE TRACT
2114-000	6	Bandera	5892000000	PHIL A GROTHUES ET UX	UNNAMED TRIB	IRRG	5.705	20.715		
2114-000	6	Bandera	5892000000	INMANN T DABNEY JR ET UX	UNNAMED TRIB	IRRG	6.542	23.756		
2114-000	6	Bandera	5892000000	RICHARD E WILSON	UNNAMED TRIB	IRRG	3.753	13.629		
2115-000	6	Bandera	5891500000	DAVID R SCHMIDT MD ET AL	BAUERLEIN CRK	IRRG	15	16		
2116-000	6	Bandera	5891000000	PAUL LAVON GARRISON	W PRONG MEDINA RIVER	IRRG	36	36		
2116-000	6	Bandera	5891000000	GEORGE C. YAX	W PRONG MEDINA RIVER	IRRG	15	15	162	
2117-000	6	Bandera	5889000000	G. MILTON JOHNSON, ET UX	MEDINA RIVER	IRRG	7	7		OUT OF A 175.5 ACRE TRACT
2118-000	6	Bandera	5888870000	DAVID J BRASK	UNNAMED TRIB	IRRG	16	16		
2119-000	6	Bandera	5888090000	RAYMOND HICKS	MEDINA RIVER	IRRG	3	8		
2120-000	6	Bandera	5888051000	BANDERA ELECTRIC COOP INC	MEDINA RIVER	IRRG	2	4		7/8/82 ADD DIV PT
2121-000	6	Bandera	5888087000	ANN DARTHULA MAULDIN	INDIAN CRK	IRRG	31.03	8.27		

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2121-000	6	Bandera	5888087000	TOLBERT S WILKINSON ET UX	INDIAN CRK	IRRG	69.47	18.53		AMEND 7/30/90
2121-000	6	Bandera	5888087000	JOHN W DINSE ET UX	INDIAN CRK	IRRG	49.5	13.2		
2122-000	6	Bandera	5887330000	DON HICKS	MEDINA RIVER	MUNI	9			
2123-000	6	Bandera	5887150000	DON F TOBIN	MEDINA RIVER	IRRG	152	61		OUT OF A 452 ACRE TRACT
2124-000	6	Bandera	5887130000	EVANGELINE RATCLIFFE WILSON	SAN JULIAN CRK	IRRG	3	5		
2125-000	6	Bandera	5887129000	PETER K SHAVER ET UX	SAN JULIAN CRK	IRRG	18	30		
2126-000	6	Bandera	5887105000	STANLEY D ROSENBERG ET UX	MEDINA RIVER	IRRG	47	36		
2127-000	6	Bandera	5887100000	JERRY B PARKER ET AL	MEDINA RIVER	IRRG	16	8		
2128-000	6	Bandera	5887050000	JOE H BERRY	SADDLE CRK	IRRG	14	12	3	
2129-000	6	Bandera	5887000000	JOE H BERRY	PRIVILEGE CRK	IRRG	40	33	110	
2135-000	6	Bandera	5660000000	KITTIE NELSON FERGUSON	SAN GERONIMO CRK	IRRG	5	5	28	
3176-000	6	Bandera	2851020000	TEXAS PARKS & WILDLIFE DEPT	CAN CRK	MUNI	7			
3176-000	6	Bandera	2851020000	TEXAS PARKS & WILDLIFE DEPT	CAN CRK	IRRG		3		
3177-000	6	Bandera	2850500000	BETTY F LEIGHTON	SABINAL RIVER	MUNI	4			
3178-000	6	Bandera	2850000000	KING & JEWEL FISHER	SABINAL RIVER	IRRG	40	56	2	AMENDED 6/21/96
3179-000	6	Bandera	2825000000	JOHN K HARRELL	SABINAL RIVER	IRRG	28.196	95.257		
3179-000	6	Bandera	2825000000	BARBARA JEAN GROTH ET VIR	SABINAL RIVER	IRRG	8.804	29.743		
3184-000	6	Bandera	2675000000	ENRIQUE S PALOMO ET UX	SPRING CRK	IRRG	10	5	42	
3185-000	6	Bandera	2651700000	W H THOMPSON JR	WILLIAMS CRK	IRRG	15	5	2	CURRENT OWNER UNKNOWN, 5/98
3186-000	6	Bandera	2651500000	DOROTHY BAIRD MATTIZA	WILLIAMS CRK	IRRG	128	88	73	
3187-000	6	Bandera	2651000000	CHESTER N POSEY ET UX	WILLIAMS CRK	IRRG	23	21	15	
3188-000	6	Bandera	2650000000	W J SCHMIDT	HONDO CRK	IRRG	24	47	16	
3693-000	1	Bandera	5887260000	GERALD H PERSYN	UNNAMED TRIB BANDERA CRK	REC			11	
3824-000	1	Bandera	5887295000	CITY OF BANDERA	MEDINA RIVER	REC			22	
3825-000	1	Bandera	7718000000	ROBERT L PARKER SR ET AL	VERDE CRK	REC			277	
3853-000	1	Bandera	5888230000	ROCK CLIFF RESERVOIR LAND ASSN	SPIRES CRK	REC			925.4	AMENDED 2/17/98: IMPOUNDMENT AND EXP
3909-000	1	Bandera	5888150000	MAUDEEN M MARKS	MONTAGUE HOLLOW	REC			500	DOMESTIC, LIVESTOCK & REC
3944-000	1	Bandera	5887120000	CONOCO INCORPORATED	UNNAMED TRIB MEDINA RIVER	REC			180	2 DAMS

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3949-000	1	Bandera	5886550000	CASTLE LAND & LIVESTOCK CO INC	BEAR CRK	REC	33		33	DOM & LIVESTOCK - SC
4	1	Bandera	5887125000	HILL COUNTRY MANAGEMENT CORP	SAN JULIAN	REC			3	ALSO DOM & LIVESTOCK
5097-000	1	Bandera	5890300000	DON CODY ET UX	W PRONG MEDINA RIVER	IRRG	120	72		EXP 2/2/2016 BY CONTRACT 1610;AMEND 9/94
5186-000	1	Bandera	2824000000	HILL COUNTRY SPRING WATER TX	SPRING	MUNI	161			BOTTLED WATER, .049 RES
5204-000	1	Bandera	2840000000	ROGER E. CANTER ET UX	SABINAL RIVER	IRRG	60	20		
5305-000	1	Bandera	2621000000	UTOPIA SPRING WATER INC	W SECO CRK	MUNI	72			
5339-000	1	Bandera	5888089000	YMCA/GREATER HOUSTON AREA	INDIAN CRK	REC			30	
5342-000	1	Bandera	5890200000	RENE H GRACIDA	W PRONG MEDIA	REC			7	
5475-000	1	Bandera	2850600000	GALLERIA HOLDING, LTD	JERNIGAN CRK	IRRG	26	18	63	2 RESERVOIRS
5575-000	1	Bandera	2850900000	ALBERT R GAGE ET UX	MARLER CRK	IRRG	12	6		SC: FLOW RESTRICTIONS
1527-000	6	Edwards	1750010000	ADDISON LEE PFLUGER	HUFFMAN SPRING	IRRG	32	20	1	
1528-000	6	Edwards	1735000000	RUTH MCLEAN BOWERS	PAINT CREEK	IRRG	60	54	58	CO 134, 2 RES
2451-000	6	Edwards	1750000000	ADDISON LEE PFLUGER ET AL	S LLANO RIVER	IRRG	88	74	7	AMEND 5/9/83
3017-000	6	Edwards	9520000000	RAY H EUBANK	RUTH DRAW	IRRG	50	50		AMEND 7/3/84
3023-000	6	Edwards	9195000000	DONALD P TARPEY	NUECES RIVER	IRRG	108	27		
3024-000	6	Edwards	9170000000	DOUGLAS B & MARGARET MARSHALL	NUECES RIVER	IRRG	65	43		
3038-000	6	Edwards	8900000000	ROYCE I REID ESTATE	PULLIAM CRK	IRRG	48	20		
3039-000	6	Edwards	8800000000	OLGA H. CLOUDT, ET AL	PULLIAM CRK	IRRG	75	50	8	
3039-000	6	Edwards	8800000000	OLGA H. CLOUDT, ET AL	PULLIAM CRK	IRRG	30	20		
3040-000	6	Edwards	8790000000	J R WILLIAMS ET AL	PULLIAM CRK	IRRG	34	17		
3041-000	6	Edwards	8780000000	JOSEPH C WILLIAMS	PULLIAM CRK	IRRG	60	44		1/2 INTEREST IN 60 AF FOR IRR OF 44 AC
3042-000	6	Edwards	8779000000	J R WILLIAMS ET AL	PULLIAM CRK	IRRG	22	13		
3043-000	6	Edwards	8760000000	JOY JERNIGAN OWENS	PULLIAM CRK	IRRG	32	16		
3044-000	6	Edwards	8700010000	SUSAN PETTY ARNIM ET AL	CEDAR CRK	IRRG	6	12		
3044-000	6	Edwards	8700010000	SUSAN PETTY ARNIM ET AL	CEDAR CRK	IRRG	20			
3044-000	6	Edwards	8700010000	SUSAN PETTY ARNIM ET AL	CEDAR CRK	IRRG	4	20		
3046-000	6	Edwards	8460500000	NORMA JEAN EASLEY	PULLIAM CRK	IRRG	30	59		
3047-000	6	Edwards	8400000000	BRUCE I HENDRICKSON ET UX	CLEAR CRK	IRRG	6	6	11	

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3048-000	6	Edwards	8340000000	L A MALACHEK ET AL	PULLIAM CRK	IRRG	27	14		
3049-000	6	Edwards	7630010000	EDWARDS CO INVEST. PARTNER	PULLIAM CRK	IRRG	250	400		
3049-000	6	Edwards	7630010000	BRUCE I HENDRICKSON ET UX	PULLIAM CRK	IRRG	350	150		
3070-000	6	Edwards	7041600000	E B CARRUTH, JR, TRUST	W NUECES RIVER	IRRG	200	184		
3070-000	6	Edwards	7041600000	E B CARRUTH, JR, TRUST	W NUECES RIVER	REC			19	
3957-000	1	Edwards	8550000000	S A WILLIAMS	CEDAR CRK	IRRG	40	40		AMEND 1/13/87
4006-000	1	Edwards	8790100000	BAY-HOUSTON TOWING CO	PULLIAM	IRRG	150	75		
4278-000	1	Edwards	8920000000	BERRYMAN INVESTMENTS INC	PULLIAM CRK	IRRG	4.34	7.38		OWNS DAM & RESERVOIR
4278-000	1	Edwards	8920000000	SAM P WORDEN ET UX	PULLIAM CRK	IRRG	5.66	9.62		
1930-000	6	Kerr	9570000000	HERSHEL REID ET UX	FLAT ROCK CRK	IRRG	69	66	35	
1932-000	6	Kerr	9560000000	PRESBYTERIAN MO-RANCH ASSEMBLY	N FRK GUADALUPE RIVER	MUNI	60			AMEND 6/7/94
1932-000	6	Kerr	9560000000	PRESBYTERIAN MO-RANCH ASSEMBLY	N FRK GUADALUPE RIVER	IRRG	14	7		AMEND 6/7/94
1932-000	6	Kerr	9560000000	PRESBYTERIAN MO-RANCH ASSEMBLY	N FRK GUADALUPE RIVER	REC	25		20	AMEND 6/7/94
1934-000	6	Kerr	9527000000	CHARLES K HICKEY JR ET AL	DRY CRK	IRRG	0.45	0.68		
1934-000	6	Kerr	9527000000	KATHY JAN FREEMAN	DRY CRK	IRRG	1.55	2.32		
1935-000	6	Kerr	9525100000	CHARLES K HICKEY JR ET AL	N FRK GUADALUPE RIVER	IRRG	8	8		
1936-000	6	Kerr	9523000000	WILLIAM H ARLITT JR ET UX	N FRK GUADALUPE RIVER	IRRG	17	6	5	
1936-000	6	Kerr	9523000000	WILLIAM H ARLITT JR ET UX	INDIAN CRK	IRRG	134	48		
1937-000	6	Kerr	9515200000	BOY SCOUTS- ALAMO AREA	BEAR CRK	REC			10	
1938-000	6	Kerr	9515000000	LOUIS H STUMBERG	N FRK GUADALUPE RIVER	IRRG	2	4		
1938-000	6	Kerr	9515000000	LOUIS H STUMBERG	N FRK GUADALUPE RIVER	IRRG	15	22		
1939-000	6	Kerr	9512000000	LOUIS H STRUMBERG	GRAPE CRK	IRRG	3	6	6	
1940-000	6	Kerr	9511000000	B E QUINN III ET AL	N FRK GUADALUPE RIVER	IRRG	32	16	10	
1941-000	6	Kerr	8154502000	DELMAR SPIER AGENT	TURTLE CRK	IRRG	6	9	5	
1943-000	6	Kerr	9505000000	J CONRAD PYLE, ET AL	N FRK GUADALUPE RIVER	MUNI	14			
1945-000	6	Kerr	9485010000	JOHN P HILL	N FRK GUADALUPE RIVER	IRRG	25	20		
1946-000	6	Kerr	9485000000	JOHN P HILL ADMINISTRATOR	N FRK GUADALUPE RIVER	IRRG	11	9		
1947-000	6	Kerr	9480000000	GUAD VALLEY LOT OWNERS ASSN	N FRK GUADALUPE RIVER	IRRG	6	10		AMEND 3/6/91

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1947-000	6	Kerr	9480000000	GUAD VALLEY LOT OWNERS ASSN	N FRK GUADALUPE RIVER	MUNI	3			
1948-000	6	Kerr	9489000000	JOHN H DUNCAN	BRUSHY CRK	IRRG	7	7		
1949-000	6	Kerr	9488000000	WILLIAM O CARTER, TRUSTEE	HONEY CRK	IRRG	6	2		OUT OF A 80 ACRE TRACT
1949-000	6	Kerr	9488000000	WILLIAM O CARTER, TRUSTEE	HONEY CRK	IRRG	27	9		
1950-000	6	Kerr	9487000000	JOHN H DUNCAN	HONEY CRK	IRRG	6	20	13	ALSO USE 7
1953-000	6	Kerr	9476000000	LAURA B LEWIS ET VIR	N FRK GUADALUPE RIVER	IRRG	40	24		
1956-000	6	Kerr	9897000000	RIVER INN ASSOC OF UNIT OWNERS	S FRK GUADALUPE RIVER	REC			50	
1956-000	6	Kerr	9897000000	RIVER INN ASSOC OF UNIT OWNERS	S FRK GUADALUPE RIVER	MUNI	10			AMEND 4/19/84, 1/4/85
1957-000	6	Kerr	9880000000	BILLIE R VALICEK	S FRK GUADALUPE RIVER	REC			10	
1958-000	6	Kerr	9780000000	T J MOORE ESTATE	CYPRESS CRK	IRRG	20	10	100	
1961-000	6	Kerr	9670000000	LAVERNE CRIDER MOORE ET VIR	S FRK GUADALUPE RIVER	MUNI	3			
1961-000	6	Kerr	9670000000	LAVERNE CRIDER MOORE ET VIR	S FRK GUADALUPE RIVER	IRRG	1	3		
1963-000	6	Kerr	9620000000	LAWRENCE L GRAHAM ET AL	S FRK GUADALUPE RIVER	IRRG	2	12	21	AMEND 9/10/85
1963-000	6	Kerr	9620000000	LAWRENCE L GRAHAM ET AL	S FRK GUADALUPE RIVER	REC			16	AMENDS 5/26/83 CHG PUR USE & ADD RES
1964-000	6	Kerr	9400000000	VIRGINIA MOORE JOHNSTON	TEGENER	IRRG	10	10	12	
1967-000	6	Kerr	9305000000	SARAH HICKS BUSS	UNNAMED TRIB GUADALUPE RIVER	REC	20			ALSO USE 1, AMEND 3/19/91
1968-000	6	Kerr	9261000000	LOUIS DOMINGUES	GUADALUPE RIVER	IRRG	10	20		
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	GUADALUPE RIVER	INDU	15		15	USE 2: MILLING
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	KELLY CRK	IRRG	49	80		USE 3 - DIVERTING FROM KELLY CREEK
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	GUADALUPE RIVER	IRRG	59			USE 3 - DIVERTING FROM GUADALUPE RIVER
1969-000	6	Kerr	9260000000	TOMMIE SMITH BLACKBURN	GUADALUPE RIVER	HYDRO				USE 5; NONCONSUMPTIVE
1970-000	6	Kerr	9220000000	CARL HAWKINS	GUADALUPE RIVER	MUNI	10			
1970-000	6	Kerr	9220000000	CARL HAWKINS	GUADALUPE RIVER	IRRG	32	25		
1971-000	6	Kerr	9140000000	COUNTY OF KERR	GUADALUPE RIVER	REC			450	
1972-000	6	Kerr	9110000000	WESLEY ELLEBRACHT	WELSH BR	IRRG	0.8	0.8		
1972-000	6	Kerr	9110000000	WELCH CREEK PARTNERS LTD	WELSH BR	IRRG	5.15	5.15		
1972-000	6	Kerr	9110000000	ARANSAS BAY COMPANY	WELSH BR	IRRG	0.05	0.05		
1973-000	6	Kerr	9100000000	SHELTON RANCHES INC	SMITHS BR	IRRG	10	10	6	

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1974-000	6	Kerr	9050000000	SHELTON RANCHES INC	SMITHS BR	IRRG	70	35	15	ALSO JOHNSON CREEK
1975-000	6	Kerr	9025000000	TEXAS PARKS & WILDLIFE DEPT	FESSENDEN BR	INDU	400			FISH HATCHERY & GAME PRESERVE
1975-000	6	Kerr	9025000000	TEXAS PARKS & WILDLIFE DEPT	FESSENDEN BR	INDU	5780		72	2 IMP & A POND; USES 3, 1 & 7; EXP 2012
1976-000	6	Kerr	8950000000	F P ZOCH III TRUST & ZEE RANCH	FESSENDEN BR	IRRG	29	14		
1976-000	6	Kerr	8950000000	F P ZOCH III TRUST & ZEE RANCH	FESSENDEN BR	REC			184	
1977-000	6	Kerr	8839000000	TEXAS CATHOLIC BOYS' HOME	JOHNSON CRK	IRRG	23	23	23	
1978-000	6	Kerr	8815000000	A J RUST	JOHNSON CRK	IRRG	33	65		
1979-000	6	Kerr	8808000000	KEITH S MEADOW	BYAS CRK	IRRG	18	6		
1980-000	6	Kerr	8805000000	A L MOORE	JOHNSON CRK	IRRG	12	6		
1981-000	6	Kerr	8800000000	JACK D CLARK JR ET AL	JOHNSON CRK	IRRG	32	16		
1981-000	6	Kerr	8800000000	JACK D CLARK JR ET AL	JOHNSON CRK	IRRG	143	76		OUT OF A 111.9 ACRE TRACT
1982-000	6	Kerr	8775000000	LOLA DEAN SMITH	JOHNSON CRK	IRRG	133	50	12	
1983-000	6	Kerr	8770000000	N V MAMIMAR	JOHNSON CRK	IRRG	32	17		JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1983-000	6	Kerr	8770000000	N V MAMIMAR	JOHNSON CRK	IRRG	67	35		JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1983-000	6	Kerr	8770000000	DAVID J COPELAND ET UX	JOHNSON CRK	IRRG				JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1983-000	6	Kerr	8770000000	DAVID J COPELAND ET UX	JOHNSON CRK	IRRG				JOINTLY OWN 32 & 67 AF TO IRR 17 & 35 AC
1984-000	6	Kerr	8750000000	MICHAEL E & GAIL SEARS	JOHNSON CRK	IRRG	1	2		
1985-000	6	Kerr	8746000000	ROBERT B O'CONNOR JR ET UX	JOHNSON CRK	IRRG	80	31		
1987-000	6	Kerr	8744000000	REGINALD E WARREN JR	JOHNSON CRK	IRRG	90	30		
1988-000	6	Kerr	8720000000	JIMMIE L QUERNER SR ESTATE	FALL BR	IRRG	128	64		ALSO GILLESPIE CO
1990-000	6	Kerr	8650000000	DOROTHY L JENKINS ET AL	JOHNSON CRK	IRRG	3	1		
1991-000	6	Kerr	8615001000	LAZY HILLS GUEST RANCH INC	HENDERSON BR	IRRG	21	28		
1992-000	6	Kerr	8600000000	MARK A RYLANDER ET AL	JOHNSON CRK	IRRG	23	15		
1993-000	6	Kerr	8550000000	ROY LITTLEFIELD	JOHNSON CRK	IRRG	50	50	4	
1994-000	6	Kerr	8500000000	M H & MARY FRANCES MONTGOMERY	GUADALUPE RIVER	IRRG	5	4		
1995-000	6	Kerr	8451000000	HENRY GRIFFIN CONSTRUCTION CO	GOAT CRK	IRRG	11	11	6	
1996-000	6	Kerr	8287000000	KERRVILLE, CITY OF	GUADALUPE RIVER	MUNI	150			AMEND 3/19/91, 4/10/98: DIV PT #4.SC.

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
1996-000	6	Kerr	8287000000	KERRVILLE, CITY OF	GUADALUPE RIVER	IRRG	75	44	75	AMEND 3/19/91, 4/10/98: DIV PT #4.SC.
1997-000	6	Kerr	8310000000	DARRELL G LOCHTE ET AL	GUADALUPE RIVER	MINE	143			
1997-000	6	Kerr	8310000000	DARRELL G LOCHTE ET AL	GUADALUPE RIVER	INDU	2			
1998-000	6	Kerr	8295000000	C W SUNDAY	TOWN CRK	IRRG	22.3	22.3	10	
1998-000	6	Kerr	8295000000	JOSE A LOPEZ ET UX	TOWN CRK	IRRG	4.18	4.18		
1999-000	6	Kerr	8297000000	KERRVILLE STATE HOSPITAL	UNNAMED TRIB GUADALUPE RIVER	REC	44		44	
2000-000	6	Kerr	8260010000	RIVERHILL COUNTRY CLUB INC	GUADALUPE RIVER	IRRG	350	160	70	8/31/87
2001-000	6	Kerr	8255000000	CARL D. MEEK	GUADALUPE RIVER	IRRG	295	194		AMEND 4/9/92,5/12/95.DIFF PRIORITY DATES
2002-000	6	Kerr	8230000000	COMANCHE TRACE RANCH & GOLF CL	GUADALUPE RIVER	IRRG	136	99		
2003-000	6	Kerr	8250000000	WHEATCRAFT, INC.	GUADALUPE RIVER	IRRG	42	21		
2003-000	6	Kerr	8250000000	SHELTON RANCH CORPORATION	GUADALUPE RIVER	MINE	10			
2004-000	6	Kerr	8200000000	COUNTY OF KERR	GUADALUPE RIVER	REC			720	ALSO USE 8
2005-000	6	Kerr	8185500000	HARRIET BOCKHOFF ESTATE	GUADALUPE RIVER	IRRG	59	98		
2006-000	6	Kerr	8174000000	FARM CREDIT BANK OF TEXAS	GUADALUPE RIVER	IRRG	179.06	512.55		AMEND 2/3/88,6/18/90. MAX COMB. CFS:4.0
2006-000	6	Kerr	8174000000	FARM CREDIT BANK OF TEXAS	GUADALUPE RIVER	IRRG	83.94			AMEND 2/3/88, 6/18/90
2006-000	6	Kerr	8174000000	1967 SHELTON TRUSTS PART ET AL	GUADALUPE RIVER	IRRG	106.9	78.55		AMEND 2/3/88, 6/18/90
2006-000	6	Kerr	8174000000	1967 SHELTON TRUSTS PART ET AL	GUADALUPE RIVER	IRRG	50.1			AMEND 2/3/88, 6/18/90
2006-000	6	Kerr	8174000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	34.04			AMEND 2/3/88, 6/18/90, 11/22/96
2006-000	6	Kerr	8174000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	15.96			AMEND 2/3/88, 6/18/90, 11/22/96
2006-000	6	Kerr	8174000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	100	76		AMEND 2/3/88, 6/18/90, 11/22/96
2007-000	6	Kerr	8160000000	RAY ELLISON JR	SPRING CRK	IRRG	31	31	50	
2008-000	6	Kerr	8156160000	LUTHERAN CAMP CHRYSALIS	TURTLE CRK	MUNI	11		12	
2009-000	6	Kerr	8155750000	FRANCIS C & WILLADEAN BOLEN	BUSHWACK CRK	IRRG	5	5	5	
2010-000	6	Kerr	8155700000	G ROBERT SWANTNER JR ET UX	BUSHWACK CRK	IRRG	7	5	5	OUT OF 68.8 ACRE TRACT
2011-000	6	Kerr	8155000000	H J GRUY	TURTLE CRK	IRRG	80	50	10	
2012-000	6	Kerr	8154501000	SANDRA BLAIR	TURTLE CRK	IRRG	1	1	5	
2013-000	6	Kerr	8154500000	FELIX R & LILLIAN STEILER REAL	WEST CRK	IRRG	11	12		
2014-000	6	Kerr	8152000000	LEAH MARTHA STEPHENS	TURTLE CRK	IRRG	6.36	5.63		

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2014-000	6	Kerr	8152000000	BENNO OOSTERMAN ET UX	TURTLE CRK	IRRG	6.36	5.63		
2014-000	6	Kerr	8152000000	JOHN M LEBOLT TRUSTEE	TURTLE CRK	IRRG	9.02	7.98		
2015-000	6	Kerr	8151000000	JAMES E NUGENT	GUADALUPE RIVER	IRRG	27	21		
2016-000	6	Kerr	8150500000	DORIS J HODGES	GUADALUPE RIVER	IRRG	8	8		
2017-000	6	Kerr	8050000000	COUNTY OF KERR	GUADALUPE RIVER	REC			87	ALSO USE 8
2018-000	6	Kerr	8049000000	LEE ANTHONY MOSTY	GUADALUPE RIVER	IRRG	154	94		
2020-000	6	Kerr	7970000000	ROBERT LEE MOSTY	GUADALUPE RIVER	IRRG	60	30		
2021-000	6	Kerr	7940000000	RAYMOND F MOSTY ET AL	GUADALUPE RIVER	IRRG	103	45	5	
2022-000	6	Kerr	7950000000	ROBERT LEE MOSTY	GUADALUPE RIVER	IRRG	17	119	20	
2023-000	6	Kerr	7935000000	ROY A GREEN	GUADALUPE RIVER	IRRG	7	3		
2024-000	6	Kerr	7924990000	CARL E RHODES	GUADALUPE RIVER	IRRG	114	125		
2025-000	6	Kerr	7925000000	HARRY J WRAY	GUADALUPE RIVER	IRRG	155	80		JOINTLY OWNS 155 AF TO IRR 80 ACRES
2025-000	6	Kerr	7925000000	DAVID B WRAY	GUADALUPE RIVER	IRRG				JOINTLY OWNS 155 AF TO IRR 80 ACRES
2025-000	6	Kerr	7925000000	BYNO SALSMAN ET UX	GUADALUPE RIVER	IRRG				JOINTLY OWNS 155 AF TO IRR 80 ACRES
2026-000	6	Kerr	7920000000	ELGIN JUNG	GUADALUPE RIVER	IRRG	3.309	2.118		
2026-000	6	Kerr	7920000000	ZANE H ROBINSON ET UX	GUADALUPE RIVER	IRRG	53.945	34.52		
2026-000	6	Kerr	7920000000	RONNIE W SCHLOTTMAN ET UX	GUADALUPE RIVER	IRRG	17.83	11.41		
2026-000	6	Kerr	7920000000	KENNETH W WHITEWOOD ET UX	GUADALUPE RIVER	IRRG	149.916	44.72		AMENDED 11/22/96
2029-000	6	Kerr	7710000000	ROLAND WALTERS	PRISON CANYON	IRRG	25	200	420	& CO 010, 10/5/82 ADD DIV PT
2030-000	6	Kerr	7704000000	JAMES S ERNST	UNNAMED TRIB VERDE CRK	IRRG	247		120	
2030-000	6	Kerr	7704000000	PETE R SMITH	UNNAMED TRIB VERDE CRK	IRRG	19			
2031-000	6	Kerr	7701000000	JOSEPH PAUL MILLER ET UX	GUADALUPE RIVER	IRRG	115	80		AMEND 11/4/85
2032-000	6	Kerr	7700700000	DAVID M LEIBOWITZ ET UX	GUADALUPE RIVER	IRRG	10	6		
2033-000	6	Kerr	7699900000	JAVIER G REYES ET UX	GUADALUPE RIVER	IRRG	90	90		
2034-000	6	Kerr	7699500000	CHESTER P HEINEN ET AL	GUADALUPE RIVER	IRRG	2	6		
2037-000	6	Kerr	7652500000	GENE ARTHUR ALLERKAMP	CYPRESS CRK	IRRG	5	6.33		
2037-000	6	Kerr	7652500000	JANICE CHARLOTTE BULLARD	CYPRESS CRK	IRRG	5	6.34		
2037-000	6	Kerr	7652500000	ROMAN LUNA ET UX	CYPRESS CRK	IRRG	10	12.67		
2037-000	6	Kerr	7652500000	CURTIS BERNARD ALLERKAMP	CYPRESS CRK	IRRG	5	6.33		

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2037-000	6	Kerr	7652500000	WERNER WAYNE ALLERKAMP	CYPRESS CRK	IRRG	5	6.33		
2038-000	6	Kerr	7652000000	HARRY E REEH	CYPRESS CRK	IRRG	15	15		
2039-000	6	Kerr	7650500000	FRED SAUR	CYPRESS CRK	IRRG	7	7		
2040-000	6	Kerr	7650000000	A C & DOROTHY PFEIFFER	CYPRESS CRK	IRRG	10	5		
2041-000	6	Kerr	7645000000	THOMAS L BRUNDAGE ET AL	CYPRESS CRK	IRRG	134	57		AMEND 2/1/85
2042-000	6	Kerr	7644800000	E J & VIRGINIA DOWER	CYPRESS CRK	IRRG	209	125		
2043-000	6	Kerr	7644600000	MARY LEE EDWARDS	CYPRESS CRK	IRRG	19.57	14.68		
2043-000	6	Kerr	7644600000	EDGAR SEIDENSTICKER ET UX	CYPRESS CRK	IRRG	16.85	12.63		
2043-000	6	Kerr	7644600000	L J MANNERING ET UX	CYPRESS CRK	IRRG	3.58	2.69		
2437-000	6	Kerr	9550000000	CHLOE CULLUM KEARNEY ET AL	N FRK GUADALUPE RIVER	REC			100	D&L. RESERVOIR JOINTLY OWNED BY SEVERAL.
2437-000	6	Kerr	9550000000	DAN W BACON ET UX	N FRK GUADALUPE RIVER	REC				D&L. RESERVOIR JOINTLY OWNED BY SEVERAL.
2438-000	6	Kerr	9528000000	LUTZ ISSLIEB ET AL	N FRK GUADALUPE RIVER	IRRG	30	18	30	
2439-000	6	Kerr	9510000000	DALE B AND MARSHA G ELMORE	N FRK GUADALUPE RIVER	IRRG	8	8	20	AMEND 10/29/90
2440-000	6	Kerr	9507000000	L F SCHERER	N FRK GUADALUPE RIVER	IRRG	1	1		
2441-000	6	Kerr	9490000000	SILAS B RAGSDALE	N FRK GUADALUPE RIVER	IRRG	21	105		
2442-000	6	Kerr	9486000000	LUTHER GRAHAM	HONEY CRK	IRRG	28	14	17	
2443-000	6	Kerr	9476500000	JOHN H DUNCAN	HONEY CRK	IRRG	40	20	25	
2444-000	6	Kerr	9980000000	BRUCE F. HARRISON	S FRK GUADALUPE RIVER	IRRG	6	3	10	
2444-000	6	Kerr	9980000000	BRUCE F. HARRISON	S FRK GUADALUPE RIVER	REC			17	
2445-000	6	Kerr	9680000000	CAMP MYSTIC INC	CYPRESS CRK	IRRG	12	15		
2445-000	6	Kerr	9680000000	CAMP MYSTIC INC	CYPRESS CRK	MUNI	14		20	
2446-000	6	Kerr	9675000000	BOB/KAT INC	S FRK GUADALUPE RIVER	IRRG	10	10		
2446-000	6	Kerr	9675000000	BOB/KAT INC	S FRK GUADALUPE RIVER	MUNI	10			
2447-000	6	Kerr	9625000000	CAMP LA JUNTA INC	S FRK GUADALUPE RIVER	IRRG	26	15	30	
2447-000	6	Kerr	9625000000	CAMP LA JUNTA INC	S FRK GUADALUPE RIVER	MUNI	14			& RECREATION
2448-000	6	Kerr	9350000000	ALICE CYNTHIA SIMKINS	TEGENER CRK	IRRG	6	5		
2449-000	6	Kerr	9310000000	BILLIE ZUBER ET AL	GUADALUPE RIVER	IRRG	17	25.5		AMEND 9/24/93:ADD ACREAGE.JUNIOR PRIORTY
2450-000	6	Kerr	7999000000	ROBERT L MOSTY ET AL	GUADALUPE RIVER	IRRG	158	117		

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3769-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	3603		840	
3769-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	IRRG		192		USING 2450 AF WASTEWATER FROM SEWAGE.SC
3846-000	1	Kerr	7715000000	T & R PROPERTIES	PALMER CRK	REC	322		322	
3896-000	1	Kerr	8276000000	KENNETH W & MARCIA C MULFORD	RATTLESNAKE	MUNI			13	3 TRACTS 34.55 AC, ALSO REC
3904-000	1	Kerr	8275500000	CITY OF KERRVILLE	QUINLAN CRK	IRRG	80	56	10	& REC-2 RES-146-AC TR-EXPIRES 20 YEARS
4007-000	1	Kerr	7703100000	PECAN VALLEY RANCH OWNERS ASSO	ELM CRK	REC			157	ALSO DOMESTIC & LIVESTOCK
4034-000	1	Kerr	9040000000	SHELTON RANCHES INC	JOHNSON CRK	REC			122	2 RES, SEE FILE, & ADJ 1974
4223-000	1	Kerr	9105000000	SHELTON RANCHES INC	JOHNSON CRK	IRRG	20	14	39	
4298-000	1	Kerr	8294800000	ALISON B MENCAROW LIVING TRUST	TOWN CRK	IRRG	12	18		AMEND 12/10/91
4486-000	1	Kerr	7644900000	JAY & HILDA POTH	CYPRESS CRK	IRRG	70	35		RATE SEE 18-2041
5060-000	1	Kerr	8710000000	HORACE COFER ASSOCIATES, INC	FALL BR CRK	IRRG	10	12		
5122-000	1	Kerr	8150800000	JAMES C STORM	GUADALUPE RIVER	IRRG	75	50	8	
5208-000	1	Kerr	7701500000	JAMES F HAYES & MARY K HAYES	VERDE CRK	IRRG	40	40		
5315-000	1	Kerr	8294000000	DANA G KIRK TRUSTEE	E TOWN CRK	OTHER				PRIVATE WATER
5322-000	1	Kerr	8705000000	E RAND SOUTHARD ET UX	FALL BR	REC				
5331-000	1	Kerr	9660000000	KATHLEEN B FLOURNOY, ET AL	S FRK GUADALUPE RIVER	MUNI	15		30	& RECREATION
5331-000	1	Kerr	9660000000	KATHLEEN B FLOURNOY, ET AL	S FRK GUADALUPE RIVER	IRRG	96	30		
5348-000	1	Kerr	9526000000	BRYON DONZIS	N FRK GUADALUPE RIVER	IRRG	5	4		
5352-000	1	Kerr	9650000000	BONITA OWNERS ASSOC INC	S FRK GUADALUPE RIVER	IRRG	2	2		
5394-000	1	Kerr	8300010000	UPPER GUADALUPE RIVER AUTH	GUADALUPE RIVER	MUNI	1661			FIRM YIELD BASIS. AMENDED 4/10/98. SCS.
5394-000	1	Kerr	8300010000	UPPER GUADALUPE RIVER AUTH	GUADALUPE RIVER	MUNI	339			FIRM YIELD BASIS. AMENDED 4/10/98. SCS.
5394-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	761			FIRM YIELD BASIS. AMENDED 4/10/98. SCS.
5394-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	339			RUN OF RIVER BASIS. AMENDED 4/10/98.SCS
5394-000	1	Kerr	8300010000	CITY OF KERRVILLE	GUADALUPE RIVER	MUNI	1069			RUN OF RIVER BASIS. AMENDED 4/10/98.SCS
5401-000	1	Kerr	8156130000	H E BUTT GROCERY CO	TURTLE CRK	REC			16	EXP 12/31/2012
5402-000	1	Kerr	8155300000	TURTLE CREEK INDUSTRIES INC	TURTLE CRK	REC				
5444-000	1	Kerr	8490000000	EUGENE D ELLIS ET UX	GUADALUPE RIVER	IRRG	10	25.5		

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5479-000	1	Kerr	7701250000	CITY SOUTH MANAGEMENT CORP	GUADALUPE RIVER	IRRG	566	283		AMENDED 3/13/98
5495-000	1	Kerr	9800000000	LOIS & JOSEPH WESSENDORF ET AL	S FRK GUADALUPE RIVER	REC			9	
5521-000	1	Kerr	8300050000	DON D WILSON	GUADALUPE LAKE	IRRG	30	30		GUADALUPE RIVER
5531-000	1	Kerr	8185700000	LEE ROY COSPER ET UX	GUADALUPE RIVER	IRRG	80	40		
5536-000	1	Kerr	7701350000	ROBERT H & CHARLOTTE JENNINGS	GUADALUPE RIVER	IRRG	400	200		
5541-000	1	Kerr	9476150000	BASHARDT LTD	N FRK GUADALUPE RIVER	IRRG	14	15		
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	IRRG	134900	45000		& CO 162, AMEND 8/22/86,9/22/88,10/30/98
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	MUNI	2049			AMEND 8/22/86,9/22/88,10/30/98
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	REC	196			AMEND 8/22/86,9/22/88,10/30/98
2671-000	6	Kinney	4950000000	MAVERICK CO WCID 1	RIO GRANDE	HYDRO	1085966			AMEND 8/22/86,9/22/88,10/30/98
2673-000	6	Kinney	4950000000	LENDELL MARTIN ET UX	MUD CRK	IRRG	52	35	16	
2674-000	6	Kinney	4950000000	CLYDE M BRADLEY	MUD CRK	IRRG	20	15		RATE SEE 23-2673
2675-000	6	Kinney	4950000000	SHERWOOD GAINES TRUSTEE	MUD CRK	IRRG	60	30		RATE SEE 23-2673
2676-000	6	Kinney	4950000000	JEWEL FOREMAN ROBINSON	PINTO CRK	IRRG	252	126		
2677-000	6	Kinney	4950000000	MARLIN E BRAUCHLE	PINTO CRK	IRRG	21	14		
2678-000	6	Kinney	4950000000	JOHNNY E RUTHERFORD	PINTO CRK	IRRG	135	90		
2679-000	6	Kinney	4950000000	CITY OF BRACKETTVILLE	LAS MORAS SPRING	MUNI	3			
2680-000	6	Kinney	4950000000	ELISE AULGUR HUNTSMAN ET AL	LAS MORAS CRK	IRRG	15	15		JOINT OWNER OF 15 AF TO IRR 15 ACRES
2680-000	6	Kinney	4950000000	ANN A LEGG & ERNESTINE A LOPEZ	LAS MORAS CRK	IRRG				JOINT OWNER OF 15 AF TO IRR 15 ACRES
2681-000	6	Kinney	4950000000	EARL H NOBLES	LAS MORAS CRK	IRRG	10	10		
2682-000	6	Kinney	4950000000	BERNARD C MEISCHEN ET AL	LAS MORAS CRK	IRRG	25	25		
2682-000	6	Kinney	4950000000	CHARLES W GAEBLER ET AL	LAS MORAS CRK	IRRG	75	75		+50 AF FROM 7 RES FOR STOCK RAISING
2683-000	6	Kinney	4950000000	ANDREW P MALINOVSKY JR	LAS MORAS CRK	IRRG	60	30		
2684-000	6	Kinney	4950000000	BEN S JONES	ELM CRK	IRRG	47	26	6	
2685-000	6	Kinney	4950000000	EARL A KELLEY	ELM CRK	IRRG	53	35	15	
2686-000	6	Kinney	4950000000	ROBERT H MEISCHEN, ET AL	LAS MORAS CRK	IRRG	300	300		
2686-000	6	Kinney	4950000000	ROBERT H MEISCHEN, ET AL	LAS MORAS CRK	MUNI	50			4 RESERVOIRS
2687-000	6	Kinney	4950000000	CELIA R DE PLAZA, ET AL	LAS MORAS CRK	IRRG	110	55		
2913-000	6	Kinney	4950000000	MOODY RANCHES INC	RIO GRANDE	IRRG	5500	3000	17	

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2913-000	6	Kinney	4950000000	MOODY RANCHES INC	RIO GRANDE	IRRG	500	250		
3071-000	6	Kinney	7023010000	LLOYD L DAVIS	W NUECES RIVER	OTHER			25	IMPOUNDMENT
4365-000	1	Kinney	7028000000	ROBERT L MOODY JR	SPRING BR	REC	10		42	4 RES
4389-000	1	Kinney	4950000000	FORT CLARK SPRINGS ASSOC INC	LAS MORAS CRK	REC				
4517-000	1	Kinney	4950000000	FORT CLARK SPRINGS ASSOC INC	LAS MORAS CRK	REC			3	
1610-000	9	Medina	5700000000	L KEN EVANS	MEDINA RIVER	IRRG	20			LAKE MEDINA, EXP 2016
3016-000	6	Real	9615000000	JOHN H WATTS III ET UX	E PRONG NUECES RIVER	IRRG	4	2		SC. TWO PRIORITY DATES. AMEND 7/10/98
3016-000	6	Real	9615000000	JOHN H WATTS III ET UX	E PRONG NUECES RIVER	IRRG	54	27		SC. TWO PRIORITY DATES. AMEND 7/10/98
3018-000	6	Real	9450000000	LEWIS CLECKLER ET UX	SPRING CRK	IRRG	22.7	12.1		BULLHEAD HOLLOW
3018-000	6	Real	9450000000	EL CAMINO GIRL SCOUT COUNCIL	SPRING CRK	IRRG	7.3	3.9		BULLHEAD HOLLOW
3019-000	6	Real	9410000000	SARAH M DAVIS	BULLHEAD CRK	IRRG	80	40		
3019-000	6	Real	9410000000	SARAH M DAVIS	BULLHEAD CRK	IRRG		13		
3020-000	6	Real	9320000000	H C MCCARTY JR ET UX	BULLHEAD CRK	IRRG	34.736	17.368		
3020-000	6	Real	9320000000	F WALTER CONRAD JR ET UX	BULLHEAD CRK	IRRG	85.264	42.632		
3021-000	6	Real	9198500000	DSD, INC	BULLHEAD CRK	IRRG	418	210		
3022-000	6	Real	9190000000	MARVIN L BERRY	UNNAMED TRIB NUECES RIVER	IRRG	259	300	14	TRIB OF NUECES RIVER
3022-000	6	Real	9190000000	MARVIN L BERRY	UNNAMED TRIB NUECES RIVER	IRRG	485			
3025-000	6	Real	9150000000	WILLIAM C & WANDA LEA LANE	DRY CRK	IRRG	40	20	1	
3026-000	6	Real	9075000000	JOHN A DANIEL ET UX	DRY CRK	IRRG	16	8	90	
3027-000	6	Real	9050000000	J F ALSOP	DRY CRK	IRRG	20	10		
3028-000	6	Real	9040000000	CLARENCE W HARRISON ET UX	DRY CRK	IRRG	15.43	7.72	43	
3028-000	6	Real	9040000000	CLARENCE W HARRISON ET UX	DRY CRK	REC			4	
3028-000	6	Real	9040000000	W THOMAS TAYLOR ET UX	DRY CRK	IRRG	4.36	2.18		
3029-000	6	Real	9008000000	HENRY D ENGELKING	NUECES RIVER	IRRG	43	52		
3034-000	6	Real	9004000000	HERBERT C JEFFRIES ET UX	NUECES RIVER	IRRG		2		SEE ADJ 3030
3036-000	6	Real	9000000000	SALVADOR ORTIZ ET AL	NUECES RIVER	IRRG	125	50		
3037-000	6	Real	8950000000	DAVID WELDON TINDLE	NUECES RIVER	IRRG	25	25		
3050-000	6	Real	8000000000	W A MALEY	E CAMP WOOD CRK	IRRG	28	14		

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3051-000	6	Real	7980000000	ROBERT J LLOYD ET UX	E CAMP WOOD CRK	IRRG	1.42	1.42		
3051-000	6	Real	7980000000	WANNA LOU LLOYD	E CAMP WOOD CRK	IRRG	4.08	4.08		
3052-000	6	Real	7970000000	BARRY BLANKS MCHALEK ET UX	E CAMP WOOD CRK	IRRG	5	5		SEE ADJ 3051
3053-000	6	Real	7960000000	BARRY BLANKS MCHALEK ET UX	E CAMP WOOD CRK	IRRG	1	1		SEE ADJ 3051
3054-000	6	Real	7950000000	JOHN CHAMBERS ET AL	E CAMP WOOD CRK	IRRG	10	10		SEE ADJ 3051
3055-000	6	Real	7900000000	WILLIAM C & PATRICIA K SUTTON	E CAMP WOOD CRK	IRRG	105	130	2	
3056-000	6	Real	7810000000	ROY GIBBENS	E CAMP WOOD CRK	IRRG	18	9	4	
3056-000	6	Real	7810000000	ROY GIBBENS	E CAMP WOOD CRK	IRRG	2			
3057-000	6	Real	7800000000	MAGELEE V SWIFT	E CAMP WOOD CRK	IRRG	21	16	8	SEE ADJ 3056
3057-000	6	Real	7800000000	MAGELEE V SWIFT	E CAMP WOOD CRK	IRRG	10	4	4	
3058-000	6	Real	7740000000	DOROTHY MERRITT ANDERSON	NUECES RIVER	IRRG	8	8		
3059-000	6	Real	7730000000	F L JR & CHARLOTTE HATLEY	NUECES RIVER	IRRG	11	7		
3060-000	6	Real	7631000000	E E GILDART	NUECES RIVER	IRRG	42	21		
3060-000	6	Real	7631000000	E E GILDART	NUECES RIVER	IRRG	54	26		
3060-000	6	Real	7631000000	E E GILDART	NUECES RIVER	IRRG	35	46		
3061-000	6	Real	7630000000	E E GILDART	NUECES RIVER	IRRG	31	31		
3062-000	6	Real	7550000000	JOANNE FRIEND	NUECES RIVER	IRRG	46	46		
3145-000	6	Real	3900000000	GEORGE S HAWN INTERESTS ET AL	S P/L P W FRIO RIVER	REC			27	
3145-000	6	Real	3900000000	GEORGE S HAWN INTERESTS ET AL	S P/L P W FRIO RIVER	REC			68	
3145-000	6	Real	3900000000	GEORGE S HAWN INTERESTS ET AL	S P/L P W FRIO RIVER	IRRG	156	78		
3146-000	6	Real	3850000000	JAMES W HALE ET AL	W FRIO RIVER	REC			16	
3147-000	6	Real	3810000000	DIAMOND J RANCH INC	W FRIO RIVER	IRRG	165	55		
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	3.5		10	
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	6.5	2		UPPER SINGING HILLS RESERVOIR
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	11		11	UNNAMED DOWNSTREAM RESERVOIR (D-0340)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	34.8	12.9		UNNAMED RESERVOIR (D-0340)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	6.7	2.5		UNNAMED RESERVOIR (D-0340)

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3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	25.08		25.08	LINNET'S WINGS DAM (D-0220);AMEND 3/91
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	3.2	1.2		LINNET'S WINGS DAM (D-0220)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	34		68.7	LAITY LODGE DAM (D-0240);AF/WATERFALL
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	4	2		LAITY LODGE DAM (D-0240)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	5.51		5.51	LOWER SINGING HILLS DAM (D-0280)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	IRRG	4.1	1.5		LOWER SINGING HILLS DAM (D-0280)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	2.64		2.64	SILVER CREEK DAM (D-0300)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	0.24		0.24	LOWER SILVER CREEK DAM (D-0320)
3148-000	6	Real	3750000000	H. E. BUTT FOUNDATION	E FRIO RIVER	REC	17.86		17.86	ECHO VALLEY DAM (D-0360)
3149-000	6	Real	3660000000	ORA L ROGERS ESTATE	E FRIO RIVER	IRRG	30	28		
3150-000	6	Real	3655000000	R F BINDOCK	E FRIO RIVER	IRRG	3	11		
3151-000	6	Real	3620000000	KATHERINE MAXINE MORELAND	E FRIO RIVER	IRRG	67	30		
3152-000	6	Real	3600000000	DAN AULD, JR	E FRIO RIVER	IRRG	324	162		
3153-000	6	Real	3490000000	JOHN J BURDITT, ET AL	UNNAMED TRIB E FRIO RIVER	IRRG	15	50		
3153-000	6	Real	3490000000	JOHN J BURDITT, ET AL	UNNAMED TRIB E FRIO RIVER	IRRG	23			
3154-000	6	Real	3430000000	JAMES TREES	YOUNGBLOOD SPRING	IRRG	2	6		
3155-000	6	Real	3420000000	LOTTIE N WRIGHT	FRIO RIVER	IRRG	164	43		
3156-000	6	Real	3400000000	H P COOPER ET AL	FRIO RIVER	IRRG	20	22		
3156-000	6	Real	3400000000	H P COOPER ET AL	FRIO RIVER	IRRG	2			
3157-000	6	Real	3350000000	E F BAYOUTH, MD PENSION PLAN	FRIO RIVER	IRRG	250	125		AMEND 1/9/85. CURRENT OWNER UNKNOWN 5/98
3158-000	6	Real	3375000000	LOMBARDY IRRIGATION CO	FRIO RIVER	IRRG	1600	800	6	ALSO COUNTY 232
3159-000	6	Real	3294000000	SAM G HARRISON	FRIO RIVER	IRRG	140	70		
3160-000	6	Real	3290000000	GRACIA BASSETT HABY	FRIO RIVER	IRRG	60	100		JOINTLY OWNS 60 AF TO IRR 100 ACRES
3160-000	6	Real	3290000000	THEODORE R REED TRUSTEE	FRIO RIVER	IRRG				JOINTLY OWNS 60 AF TO IRR 100 ACRES
3161-000	6	Real	3289500000	R L HUBBARD	DRY FRIO CRK	IRRG	17	21		
3162-000	6	Real	3287500000	CARL A. DETERING, JR., ET AL	UNNAMED TRIB BUFFALO CRK	IRRG	5	25	15	

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
3180-000	6	Real	2799000000	LANA J STORMONT	UNNAMED TRIB W SABINAL RIVER	IRRG	5	10		
3878-000	1	Real	3645000000	C B SLABAUGH	CYPRESS CRK	IRRG	40	30		68-AC TR, SC, AMEND 11/12/84
3978-000	1	Real	9421000000	N M FITZGERALD JR ESTATE	FLYNN CRK	IRRG	187	63		156.95-AC TR, SC
4008-000	1	Real	9172500000	DOUGLAS B & MARGARET MARSHALL	NUECES RIVER	IRRG	400	200		AMEND 12/15/81 INCR AC-FT, ACRES, CFS
4094-000	1	Real	3905500000	GEORGE S HAWN INTERESTS ET AL	W FRIO RIVER	IRRG	56	28	9	OUT OF 1118 ACRES
4169-000	1	Real	7910000000	ROARING SPRINGS RANCH INC	CAMP WOOD CRK	IRRG	15	10	41	6 RES & REC
4169-000	1	Real	7910000000	ROARING SPRINGS RANCH INC	CAMP WOOD CRK	MUNI	15			
4405-000	1	Real	7760000000	CITY OF CAMP WOOD	UNNAMED TRIB NUECES RIVER	MUNI	1000			
4405-000	1	Real	7760000000	CITY OF CAMP WOOD	UNNAMED TRIB NUECES RIVER	IRRG	83	16		
4413-000	1	Real	8240000000	WILLIAM C SUTTON ET UX	CAMP WOOD CRK	REC			2	
5009-000	1	Real	3830000000	JACKSON L BABB ET AL	W FRIO RIVER	IRRG	60	30		
2653-000	6	Val Verde	4950000000	PHIL B FOSTER	CIENEGAS CRK &/OR THE RIO GRANDE	IRRG	122.25	61.13		AMEND 10/15/91
2653-000	6	Val Verde	4950000000	DAVID B TERK ET AL	CIENEGAS CRK	IRRG	27.75	13.87		AMEND 10/15/91
2654-000	6	Val Verde	4950000000	THURMAN W OWENS	CIENEGAS CRK	IRRG	26	13		RATE SEE 23-2653
2655-000	6	Val Verde	4950000000	JOSE C OVIEDO ET UX	CIENEGAS CRK	IRRG	28	14		RATE SEE 23-2653
2656-000	6	Val Verde	4950000000	RANDOLPH J N & SHARON M ABBEY	CIENEGAS CRK	IRRG	68	43		RATE SEE 23-2653
2657-000	6	Val Verde	4950000000	RONALD J PERSYN ET UX	CIENEGAS CRK	IRRG	150	75		RATE SEE 23-2653
2657-000	6	Val Verde	4950000000	RONALD J. PERSYN, ET UX	CIENEGAS CRK	IRRG	150	68		SEE 23-2653 RATE; AMEND 10/89
2657-000	6	Val Verde	4950000000	RONALD J. PERSYN, ET UX	CIENEGAS CRK	IRRG		89		AMEND 8/2/94
2659-000	6	Val Verde	4950000000	JOHN F QUALIA	CIENEGAS CRK	IRRG	112	56		FOR RATE SEE 23-2653
2660-000	6	Val Verde	4950000000	JOSE A CORTINAS ET AL	CIENEGAS CRK	IRRG	16	5		
2660-000	6	Val Verde	4950000000	LJB ENTERPRISES	CIENEGAS CRK	IRRG	296	99		
2661-000	6	Val Verde	4950000000	BARBARA GULICK RATHKE, ET AL	CIENEGAS CRK	IRRG	120	40	10	
2662-000	6	Val Verde	4950000000	CAPITOL AGGREGATES INC	CIENEGAS CRK	MINE	166	17		AMEND 11/2/87

Water Right Number	Type	County	River Order Permit	Name	Stream	Use	Amount in Ac-Ft/Yr	Acreage	Res Cap in Ac-Ft	Remarks
2663-000	6	Val Verde	4950000000	ALFREDO GUTIERREZ JR	CIENEGAS CRK	IRRG	24	8		
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	IRRG	4950	1700		AMEND 12/16/88, 10/31/94
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	IRRG	6		6	IMPOUNDMENT #1
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	IRRG	6		6	IMPOUNDMENT #2
2664-000	6	Val Verde	4950000000	SAN FELIPE A MFG & I COMPANY	SAN FELIPE CRK	INDU	50			AMENDMENT EXP 12/31/96
2665-000	6	Val Verde	4950000000	JOSE OVIEDO JR ET UX	SAN FELIPE CRK	IRRG	60	40		AMENDED 9/13/96
2666-000	6	Val Verde	4950000000	PETRA ABREGO MUNOZ	SAN FELIPE CRK	IRRG	23.56	7.85		
2669-000	6	Val Verde	4950000000	RODOLFO MOTA	SAN FELIPE CRK	IRRG	6	2		
2670-000	6	Val Verde	4950000000	VICTOR D BOLNER	SAN FELIPE CRK	IRRG	6	3		
2672-000	6	Val Verde	4950000000	CITY OF DEL RIO	SAN FELIPE CRK	MUNI	4416			
2672-000	6	Val Verde	4950000000	CITY OF DEL RIO	SAN FELIPE CRK	MUNI	7000			
2811-000	6	Val Verde	4950000000	RIO BRAVO INC	CIENEGAS CRK &/OR THE RIO GRANDE	IRRG	51.08	997.97	47	& REC/DOM, AMEND 1/84,6/91
2811-000	6	Val Verde	4950000000	DAVID B TERK	CIENEGAS CRK	IRRG	114.64	95.38		
2912-000	6	Val Verde	4950000000	MOODY RANCHES INC	SAN FELIPE CRK	IRRG	800	400	10	
3880-000	1	Val Verde	4950000000	SOUTH TEXAS ELECTRIC CO-OP INC	RIO GRANDE	HYDRO	1500000			AMEND 12/14/87. POWER POOL WITH MEDINA.
3880-000	1	Val Verde	4950000000	MEDINA ELECTRIC CO-OP INC	RIO GRANDE	HYDRO				AMEND 12/14/87. POWER POOL WITH S.TX.EL.
5506-000	1	Val Verde	4950000000	DEL RIO, CITY OF	SAN FELIPE CRK	REC			0.19	WATER PARK LANDING POOL

APPENDIX 3E

SURFACE WATER PERMITS AND

USE REPORTED TO TCEQ

APPENDIX 3E

SURFACE WATER PERMITS AND USE REPORTED TO TCEQ

COA/ Permit	Auth Amt	Owner	Basin	Stream	County	River Order Permit	Use	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1969-400	15	TOMMIE SMITH BLACKBURN	18	GUAD & KELLY	Kerr	9260000000	IND	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	1
1970-400	10	CARL M. HAWKINS ETUX	18	GUADALUPE RIVER	Kerr	9220000000	MUN	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	0
1996-400	150	KERRVILLE CITY OF	18	GUADALUPE RIVER	Kerr	8287000000	MUN	DNR	150	102	150	150	DNR	DNR	1	152	150
1996-401	75	KERRVILLE CITY OF	18	GUADALUPE RIVER	Kerr	8287000000	IRR	DNR	3	1	4	2	2	0	2	3	8
2000-400	350	RIVERHILL COUNTRY CLUB INC	18	GUADALUPE RIVER	Kerr	8260010000	IRR	DNR	100	247	292	220	275	300	249	281	347
2001-400	295	CARL D. MEEK	18	GUADALUPE RIVER	Kerr	8255000000	IRR	DNR	36	15	55	71	85	175	17	87	117
2002-400	136	COMANCHE TRACE RANCH & GOLF CLUB	18	GUADALUPE RIVER	Kerr	8230000000	IRR	DNR	DNR	DNR	DNR	DNR	47	DNR	DNR	DNR	50
2003-400	42	WHEATCRAFT INC	18	GUADALUPE RIVER	Kerr	8250000000	IRR	DNR	DNR	DNR	DNR	11	3	DNR	DNR	0	DNR
2003-401	10	WHEATCRAFT INC	18	GUADALUPE RIVER	Kerr	8250000000	MIN	DNR	DNR	DNR	DNR	3	DNR	DNR	DNR	DNR	DNR
2005-400	59	PEGGY & BILL BOCKHOFF	18	GUADALUPE RIVER	Kerr	8185500000	IRR	DNR	DNR	DNR	DNR	DNR	DNR	22	DNR	23	8
2006-400	263	FARM CREDIT BANK OF TEXAS	18	GUADALUPE RIVER	Kerr	8174000000	IRR	DNR	83	90	195	345	DNR	3	1	50	DNR
2006-420	150	KENNETH W WHITEWOOD ETUX	18	GUADALUPE RIVER	Kerr		IRR	DNR	DNR	DNR	DNR	DNR	DNR	9	27	23	19
2018-400	154	LEE ANTHONY MOSTY	18	GUADALUPE RIVER	Kerr	8049500000	IRR	DNR	6	DNR	DNR	DNR	DNR	DNR	DNR	12	DNR
2020-400	60	ROBERT L. MOSTY ET AL	18	GUADALUPE RIVER	Kerr	7970000000	IRR	DNR	10	4	DNR	DNR	DNR	DNR	24	10	4
2021-400	102.66	SCOTT N. MOSTY ET AL	18	GUADALUPE RIVER	Kerr	7940000000	IRR	0.0	14	18	33	21	32	36	26	44	55
2022-400	17	ROBERT L. MOSTY ET AL	18	GUADALUPE RIVER	Kerr	7950000000	IRR	DNR	DNR	1	DNR	DNR	DNR	DNR	17	DNR	8
2024-400	114	CARL E. RHODES	18	GUADALUPE RIVER	Kerr	7930000000	IRR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	11	19
2025-400	57.35	BYNO & IMA JEAN SALSMAN	18	GUADALUPE RIVER	Kerr	7925000000	IRR	DNR	DNR	DNR	DNR	DNR	3	19	7	10	14
2026-400	3.309	**SOLD AND COMBINED WITH 2024-440T	18	GUADALUPE RIVER	Kerr	7920000000	IRR	DNR	DNR	DNR	DNR	DNR	1	DNR	DNR	DNR	DNR
2026-410	53.945	ZANE H. ROBINSON	18	GUADALUPE RIVER	Kerr	7920000000	IRR	DNR	DNR	DNR	DNR	DNR	DNR	6	DNR	DNR	DNR
2026-440	153.225	KENNETH W. WHITEWOOD ETUX E. MARJ	18	GUADALUPE RIVER	Kerr	7920000000	IRR	DNR	DNR	DNR	DNR	8	5	9	31	26	12
2031-400	115	JOSEPH PAUL MILLER	18	GUADALUPE RIVER	Kerr	7701000000	IRR	DNR	DNR	DNR	DNR	DNR	DNR	38	13	50	62
2449-400	17	BILLIE ZUBER ET AL	18	GUADALUPE RIVER	Kerr	7999000000	IRR	DNR	DNR	DNR	0	9	0	0	0	1	1
2450-400	158	ROBERT L. MOSTLY ET AL	18	GUADALUPE RIVER	Kerr	9195000000	IRR	DNR	14	7	DNR	DNR	DNR	92	25	23	DNR
3505-400	3603	CITY OF KERRVILLE TEXAS	18	GUADALUPE RIVER	Kerr		SEC	DNR	2511	1084	2212	3175	3158	3054	3405	3634	2466
3505-401	2450	CITY OF KERRVILLE TEXAS	18	GUADALUPE RIVER	Kerr		IRR	DNR	DNR	DNR	411	DNR	268	288	DNR	DNR	DNR
5479-400	566	CITY SOUTH MANAGEMENT CORP	18	GUADALUPE RIVER	Kerr		IRR	DNR	DNR	DNR	DNR	1	0	DNR	3	47	55
5531-100	80	LEE ROY COSPER AND WIFE JUDITH MC B	18	GUADALUPE RIVER	Kerr			DNR	DNR	DNR	DNR	DNR	DNR	3	DNR	3	DNR
2117-300	7	G. MILTON JOHNSON ETUX	19	MEDINA RIVER	Bandera	5889000000	IRR	DNR	1	DNR	2	3	4	4	1	2	4
2119-300	3	RAYMOND HICKS	19	MEDINA RIVER	Bandera	5888090000	IRR	DNR	DNR	1	6	DNR	DNR	1	DNR	DNR	DNR
2120-300	2	BANDERA ELECTRIC COOPERATIVE INC	19	MEDINA RIVER	Bandera	5888051000	IRR	DNR	1	2	1	0	DNR	0	DNR	DNR	DNR
2121-300	31.03	ANN DARTHULA MAUDLIN	19	INDIAN CREEK	Bandera	5888087000	IRR	DNR	1	0	DNR	DNR	DNR	DNR	DNR	DNR	DNR
2120-310	69.47	TOLBERT S. WILKINSON ETUX	19	INDIAN CREEK	Bandera		IRR	DNR	0	DNR	0	DNR	0	DNR	DNR	DNR	DNR
2121-320	49.5	JOHN W DINSE ETUX	19	INDIAN CREEK	Bandera	5887150000	IRR	DNR	DNR	0	DNR	DNR	DNR	DNR	DNR	DNR	DNR
2123-300	152	DON F. TOBIN	19	MEDINA RIVER	Bandera	5887130000	IRR	DNR	6	DNR	DNR	DNR	19	13	DNR	114	11
2124-300	3	EVANGELINE RATCLIFFE WILSON	19	SAN JULIAN CR	Bandera	5887105000	IRR	DNR	1	0	1	DNR	DNR	DNR	DNR	0	DNR
2126-300	47.5	STANLEY D. ROSENBERG ETUX (SANDNRA)	19	MEDINA RIVER	Bandera	9310000000	IRR	DNR	1	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR
3023-100	108	DONALD P. TARPEY	21	NUECES RIVER	Edwards	9170000000	IRR	DNR	3	13	DNR	DNR	DNR	DNR	DNR	DNR	33
3024-100	65	DOUGLAS B. & MARGARET C. MARSHALL	21	NUECES RIVER	Edwards	3420000000	IRR	DNR	DNR	DNR	DNR	3	DNR	DNR	DNR	DNR	DNR
3155-100	164	FRIO PECAN FARM	21	FRIO RIVER	Real	2850500000	MUN	0.2	22	20	7	50	61	95	42	81	88
3177-100	4	BETTY F. LEIGHTON	21	SABINAL RIVER	Bandera	2850000000	IRR	0.0	3	3	3	4	4	4	4	4	4
3178-100	40	KING & JEWEL FISHER	21	SABINAL RIVER	Bandera		MUN	DNR	DNR	DNR	DNR	DNR	9	7	23	4	14
3717-100	400	DOUGLAS B. & MARGARET C. MARSHALL	21	NUECES RIVER	Real	7701250000	IRR	DNR	DNR	DNR	DNR	3	DNR	19	DNR	DNR	DNR
2662-100	166	CAPITOL AGGREGATES INC	23	CIENAGAS CREEK	Val Verde	4950000000	MIN	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	127	70
2664-100	5012	SAN FELIPE A MFG & I COMPANY	23	SAN FELIPE CREEK	Val Verde	4950000000	IRR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	2941	DNR
2672-100	11416	CITY OF DEL RIO	23	SAN FELIPE CREEK	Val Verde	4950000000	MUN	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	8949	DNR
5506-100	1	CITY OF DEL RIO	23	SAN FELIPE CREEK	Val Verde	4950000000	REC	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	2	DNR

DNR = Did not report diversion

APPENDIX 3F

TWO SPRING STUDIES

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Kinney Cover - PDF

CONCLUSIONS: SPRINGS OF KINNEY AND VAL VERDE COUNTIES

Base flows of the rivers and streams that flow through Kinney and Val Verde Counties is principally generated from the numerous springs that occur in the headwaters of these surface drainages. Sustaining flow in these important rivers and streams is highly dependent on maintaining an appropriate water level in the aquifer systems that feed the supporting springs. Spring discharge rates can be negatively impacted by nearby wells if the pumping withdrawals lower the water table in the aquifer that contributes to the spring. If the water-level elevation drops below the elevation of the land surface at the point of spring discharge the spring will cease to flow.

With the sustainability of local water supplies and the economic welfare of the region in mind, the Plateau Regional Water Planning Group defines groundwater availability as <u>a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions</u>.

To evaluate the potential effect that pumping might have on springs and subsequent base flow to rivers and streams, several pumping scenarios were run using the TWDB Edwards-Trinity (Plateau) aquifer groundwater availability model (GAM). The aquifer simulation model was run by increasing pumping withdrawals at set intervals until reasonably acceptable levels of impact to surface water drains (non-specified springs) were observed. For regional planning purposes, this exercise resulted in a maximum pumping level from the Edwards-Trinity (Plateau) aquifer in Kinney County of 22,432 ac-ft per year, and in Val Verde County of 49,607 ac-ft per year. However, it is important to recognize that this amount of pumping is assumed to be evenly spaced over the extent of the aquifer. Concentrating pumping in smaller areas would increase the impact potential on springs in the general vicinity. Also, these model runs assumed average rainfall/recharge conditions. Less than normal recharge would intensify the pumping impact.

Kerr County Study Cover - PDF

CONCLUSIONS: SPRING FLOW CONTRIBUTION TO THE HEADWATERS OF THE GUADALUPE RIVER IN WESTERN KERR COUNTY, TEXAS

Base flow in the three branches of the upper Guadalupe River is derived from the many springs that occur within the branch tributaries. These springs represent outflow from the underlying groundwater system, and thus provide the direct link that connects groundwater to surface water. Aquifer management is thus a critical step in the overall protection of both the groundwater and surface water resources in western Kerr County.

Tributary flow measurements provide insight into the overall contribution of springs without having to measure flow in each individual spring. Figure 12 illustrates those tributary sub-basins that contribute the most to flow in the three upper Guadalupe branches. However, it should not be assumed that protection of springs by restricting groundwater development only in these preferred sub-basins would insure continued base flow in the river. The groundwater system that feeds the springs is not restricted to the individual sub-basins, but rather is a much larger system from which each spring-fed tributary receives a portion. While it may be important to restrict groundwater withdrawals in the near vicinity of springs in order to maintain their flow, it is also important to guard against overdevelopment of the entire contributing aquifer system.

CHAPTER 4

WATER MANAGEMENT STRATEGIES

4.1 INTRODUCTION

Chapter 4 contains a comparison of projected water demands for each water-use category from Chapter 2 with water supplies available to meet those demands from Chapter 3. Water supply strategy recommendations are then made for those water users that have projected water supply deficits based on the comparison between demand and supply. In the development of the water management strategies, existing water rights, water contracts, and option agreements (including those associated with Amistad International Reservoir) are recognized and fully protected. A socioeconomic impact of unmet water needs analysis prepared by the Texas Water Development Board is provided in Appendix 4A.

In determining water management strategies, it is important to note that population centers and subsequent municipal and manufacturing water demands are not evenly distributed. In fact, municipal and manufacturing demands are often concentrated in high-density nodes creating large water supply demands in relatively small geographic areas. The supply and demand estimates for Kerr County in Table 4-1 may be misleading because the numbers were calculated assuming even demand distribution, when in fact, growth is likely to occur in concentrated nodes. Though Kerr County, as a whole, may have enough groundwater supply to meet projected demands for the various user groups, groundwater may not be available where needed. Concentrated growth will necessitate additional management strategies to supplement the limited groundwater supply in the small geographic areas.

4.2 WATER SUPPLY AND DEMAND COMPARISON

Table 4-1 compares available supplies for each water user (Appendix 3B) with their corresponding future projected demands (Table 2-2). Water supply deficits are thus identified where the demand exceeds the supply. Supply deficits were identified for the City of Kerrville, Kerrville South WSC, Community of Camp Wood, and irrigation use in Bandera and Kerr Counties. Table 4-2 provides a similar comparison for the City of Del Rio as the Region’s only wholesale water provider.

TABLE 4-1. WATER SUPPLY CAPACITY AND WATER DEMAND COMPARISON BY RIVER BASIN (Acre-Feet/Year) (Shaded areas designate shortages)

Bandera County

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Bandera	San Antonio	S	1,210	1,210	1,210	1,210	1,210	1,210
		D	259	284	312	332	351	371
			951	**926**	**898**	**878**	**859**	**839**
County Other	Guadalupe	S	31	31	31	31	31	31
		D	1	2	2	3	3	3
			30	**29**	**29**	**28**	**28**	**28**
	San Antonio	S	10,673	10,673	10,673	10,673	10,673	10,673
		D	2,425	3,381	4,330	4,817	4,932	5,232
			8,248	**7,292**	**6,343**	**5,856**	**5,741**	**5,441**
	Nueces	S	806	806	806	806	806	806
		D	183	255	327	386	439	491
			623	**551**	**479**	**420**	**367**	**315**
Mining	San Antonio	S	24	24	24	24	24	24
		D	24	24	24	24	24	24
			0	**0**	**0**	**0**	**0**	**0**
Irrigation	Guadalupe	S	3	3	3	3	3	3
		D	0	0	0	0	0	0
			3	**3**	**3**	**3**	**3**	**3**
	San Antonio	S	207	207	207	207	207	207
		D	283	283	283	283	283	283
			-76	**-76**	**-76**	**-76**	**-76**	**-76**
	Nueces	S	143	143	143	143	143	143
		D	181	181	181	181	181	181
			-38	**-38**	**-38**	**-38**	**-38**	**-38**
Livestock	Guadalupe	S	6	6	6	6	6	6
		D	6	6	6	6	6	6
			0	**0**	**0**	**0**	**0**	**0**
	San Antonio	S	262	262	262	262	262	262
		D	218	218	218	218	218	218
			44	**44**	**44**	**44**	**44**	**44**
	Nueces	S	95	95	95	95	95	95
		D	91	91	91	91	91	91
			4	**4**	**4**	**4**	**4**	**4**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Edwards County								
Rocksprings	Colorado	S	322	322	322	322	322	322
		D	174	179	172	164	160	154
			148	**143**	**150**	**158**	**162**	**168**
	Nueces	S	180	180	180	180	180	180
		D	98	100	96	92	90	86
			82	**80**	**84**	**88**	**90**	**94**
County Other	Colorado	S	121	121	121	121	121	121
		D	35	36	34	33	32	31
			86	**85**	**87**	**88**	**89**	**90**
	Nueces	S	411	411	411	411	411	411
		D	118	121	116	111	108	104
			293	**290**	**295**	**300**	**303**	**307**
	Rio Grande	S	72	72	72	72	72	72
		D	20	20	19	19	18	17
			52	**52**	**53**	**53**	**54**	**55**
Mining	Colorado	S	6	6	6	6	6	6
		D	5	5	5	5	5	5
			1	**1**	**1**	**1**	**1**	**1**
Irrigation	Colorado	S	96	96	96	96	96	96
		D	43	41	39	38	36	34
			53	**55**	**57**	**58**	**60**	**62**
	Nueces	S	197	197	197	197	197	197
		D	87	84	81	77	74	71
			110	**113**	**116**	**120**	**123**	**126**
	Rio Grande	S	53	53	53	53	53	53
		D	23	22	21	20	19	18
			30	**31**	**32**	**33**	**34**	**35**
Livestock	Colorado	S	225	225	225	225	225	225
		D	175	175	175	175	175	175
			50	**50**	**50**	**50**	**50**	**50**
	Nueces	S	230	230	230	230	230	230
		D	230	230	230	230	230	230
			0	**0**	**0**	**0**	**0**	**0**
	Rio Grande	S	164	164	164	164	164	164
		D	157	157	157	157	157	157
			7	**7**	**7**	**7**	**7**	**7**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Kerr County								
Kerrville	Guadalupe	S	3,040	3,040	3,040	3,040	3,040	3,040
		D	4,362	4,746	4,918	4,937	5,152	5,262
			-1,322	**-1,706**	**-1,878**	**-1,897**	**-2,112**	**-2,222**
Ingram	Guadalupe	S	585	585	585	585	585	585
		D	220	238	242	229	212	200
			365	**347**	**343**	**356**	**373**	**385**
Kerrville South WC	Guadalupe	S	420	420	420	420	420	420
		D	405	437	448	424	393	371
			15	**-17**	**-28**	**-4**	**27**	**49**
County Other	Colorado	S	251	251	251	251	251	251
		D	58	62	63	60	56	52
			193	**189**	**188**	**191**	**195**	**199**
	Guadalupe	S	12,182	12,182	12,182	12,182	12,182	12,182
		D	2,246	2,429	2,469	2,494	2,632	2,716
			9,936	**9,753**	**9,713**	**9,688**	**9,550**	**9,466**
	San Antonio	S	125	125	125	125	125	125
		D	18	19	19	18	17	16
			107	**106**	**106**	**107**	**108**	**109**
Manufacturing	Guadalupe	S	51	51	51	51	51	51
		D	30	33	36	39	41	44
			21	**18**	**15**	**12**	**10**	**7**
Mining	Colorado	S	13	13	13	13	13	13
		D	13	12	12	12	12	12
			0	**1**	**1**	**1**	**1**	**1**
	Guadalupe	S	252	252	252	252	252	252
		D	154	153	152	151	150	149
			98	**99**	**100**	**101**	**102**	**103**
Irrigation	Guadalupe	S	1,364	1,364	1,364	1,364	1,364	1,364
		D	1,821	1,761	1,706	1,652	1,599	1,548
			-457	**-397**	**-342**	**-288**	**-235**	**-184**
Livestock	Colorado	S	125	125	125	125	125	125
		D	125	125	125	125	125	125
			0	**0**	**0**	**0**	**0**	**0**
	Guadalupe	S	355	355	355	355	355	355
		D	324	324	324	324	324	324
			31	**31**	**31**	**31**	**31**	**31**
	San Antonio	S	34	34	34	34	34	34
		D	34	34	34	34	34	34
			0	**0**	**0**	**0**	**0**	**0**
	Nueces	S	12	12	12	12	12	12
		D	4	4	4	4	4	4
			8	**8**	**8**	**8**	**8**	**8**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Kinney County								
Brackettville	Rio Grande	S	647	647	647	647	647	647
		D	583	583	582	582	581	582
			64	**64**	**65**	**65**	**66**	**65**
Fort Clark Springs	Rio Grande	S	1,120	1,120	1,120	1,120	1,120	1,120
		D	626	653	678	704	723	727
			494	**467**	**442**	**416**	**397**	**393**
County Other	Nueces	S	48	48	48	48	48	48
		D	35	21	13	8	4	3
			13	**27**	**35**	**40**	**44**	**45**
	Rio Grande	S	88	88	88	88	88	88
		D	32	31	31	31	31	31
			56	**57**	**57**	**57**	**57**	**57**
Irrigation	Nueces	S	4,382	4,382	4,382	4,382	4,382	4,382
		D	338	323	310	296	284	271
			4,044	**4,059**	**4,072**	**4,086**	**4,098**	**4,111**
	Rio Grande	S	25,784	25,784	25,784	25,784	25,784	25,784
		D	13,169	12,605	12,063	11,547	11,053	10,582
			12,615	**13,179**	**13,721**	**14,237**	**14,731**	**15,202**
Livestock	Nueces	S	334	334	334	334	334	334
		D	187	187	187	187	187	187
			147	**147**	**147**	**147**	**147**	**147**
	Rio Grande	S	341	341	341	341	341	341
		D	258	258	258	258	258	258
			83	**83**	**83**	**83**	**83**	**83**
Real County								
Camp Wood	Nueces	S	0	0	0	0	0	0
		D	172	172	166	160	163	167
			-172	**-172**	**-166**	**-160**	**-163**	**-167**
County Other	Colorado	S	34	34	34	34	34	34
		D	11	11	11	10	11	11
			23	**23**	**23**	**24**	**23**	**23**
	Nueces	S	1,488	1,488	1,488	1,488	1,488	1,488
		D	417	416	400	386	394	402
			1,071	**1,072**	**1,088**	**1,102**	**1,094**	**1,086**
Mining	Colorado	S	6	6	6	6	6	6
		D	5	5	5	5	5	5
			1	**1**	**1**	**1**	**1**	**1**
Irrigation	Nueces	S	2,511	2,511	2,511	2,511	2,511	2,511
		D	392	377	361	346	330	314
			2,119	**2,134**	**2,150**	**2,165**	**2,181**	**2,197**
Livestock	Nueces	S	205	205	205	205	205	205
		D	148	148	148	148	148	148
			57	**57**	**57**	**57**	**57**	**57**
	Colorado	S	39	39	39	39	39	39
		D	28	28	28	28	28	28
			11	**11**	**11**	**11**	**11**	**11**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Val Verde County								
Del Rio	Rio Grande	S	16,577	16,577	16,577	16,577	16,577	16,577
		D	12,898	13,817	14,646	15,314	15,855	16,281
			3,679	**2,760**	**1,931**	**1,263**	**722**	**296**
Laughlin AFB	Rio Grande	S	2,299	2,299	2,299	2,299	2,299	2,299
		D	1,303	1,296	1,289	1,281	1,276	1,276
			996	**1,003**	**1,010**	**1,018**	**1,023**	**1,023**
County Other	Rio Grande	S	6,044	6,044	6,044	6,044	6,044	6,044
		D	2,621	3,274	3,888	4,378	4,766	5,046
			3,423	**2,770**	**2,156**	**1,666**	**1,278**	**998**
Mining	Rio Grande	S	156	156	156	156	156	156
		D	118	111	107	104	101	99
			38	**45**	**49**	**52**	**55**	**57**
Irrigation	Rio Gande	S	6,837	6,837	6,837	6,837	6,837	6,837
		D	3,086	2,968	2,852	2,743	2,636	2,535
			3,751	**3,869**	**3,985**	**4,094**	**4,201**	**4,302**
Livestock	Rio Grande	S	767	767	767	767	767	767
		D	767	767	767	767	767	767
			0	**0**	**0**	**0**	**0**	**0**

TABLE 4- 2. DEL RIO WHOLESALE SUPPLY-DEMAND PROJECTION (Acre-Feet/Year)

Wholesale Water Provider	County	Basin	Receiving Entity	Supply / Demand	2010	2020	2030	2040	2050	2060
Del Rio	Val Verde	Rio Grande	City of Del Rio	Supply	16,577	16,577	16,577	16,577	16,577	16,577
			Laughlin AFB		2,178	2,178	2,178	2,178	2,178	2,178
			County Other		1,631	1,631	1,631	1,631	1,631	1,631
			Total Supply		**20,386**	**20,386**	**20,386**	**20,386**	**20,386**	**20,386**
			City of Del Rio	Demand	12,898	13,817	14,646	15,314	15,855	16,281
			Laughlin AFB		1,238	1,231	1,225	1,217	1,212	1,212
			County Other		708	884	1,050	1,182	1,287	1,362
			Total Demand		**14,844**	**15,932**	**16,921**	**17,713**	**18,354**	**18,855**
			Supply Surplus		**5,542**	**4,454**	**3,465**	**2,673**	**2,032**	**1,531**

4.3 STRATEGY EVALUATION PROCESS

A specific process was used in the selection and evaluation of water management strategies and is summarized in the flow chart illustrated in Figure 4-1. The process started with a consideration of potentially feasible strategies to meet the needs of each entity or category with a supply deficit. From this list, the Plateau Water Planning Group (PWPG) selected specific strategies for further feasibility and impact analysis. Impacted entities were notified of the strategy recommendation process and asked to review and comment on suggested strategies. After considering the analysis, the PWPG selected all the evaluated strategies for inclusion in the Regional Plan.

The strategy evaluation procedure was designed to provide a side-by-side comparison such that all strategies could be assessed based on the same factors. Table 4-3 lists all strategies considered and provides a comparison of the following evaluated factors.

- Quantity of water supply generated
- Water quality considerations
- Reliability
- Cost (total capital cost, annual cost, and cost per acre-foot) (Table 4-4).
- Environmental impacts (Table 4-5)

- Impacts to other water resources
- Impacts to agricultural resources
- Impact to natural resources
- Impacts to recreational

Management officials of the Kerrville South WSC were notified of the planning and strategy process and expressed disagreement with the deficit analysis. Numerous attempts to convince the officials to participate in the process were made with no response, and therefore, the PWPG chose to dismiss the entity from the strategy portion of the Plan. The deficit is still recognized and is considered in terms of County Other category use.

Although Table 4-1 does not forecast a supply deficit for the Kerr County Other category, the PWPG is concerned that future population growth in the unincorporated areas of the county could result in supply problems. A special strategy, which incorporates the Upper Guadalupe River Authority's intent to be a wholesale water provider, is included in this plan to meet this potential need.

Municipal strategies are discussed in Sections 4.4 and 4.5. The evaluation of irrigation strategies for Bandera and Kerr Counties differs slightly in that these strategies represent recommended best management practices. These strategies are discussed in detail in Section 4.6 and are summarized in Table 4-6.

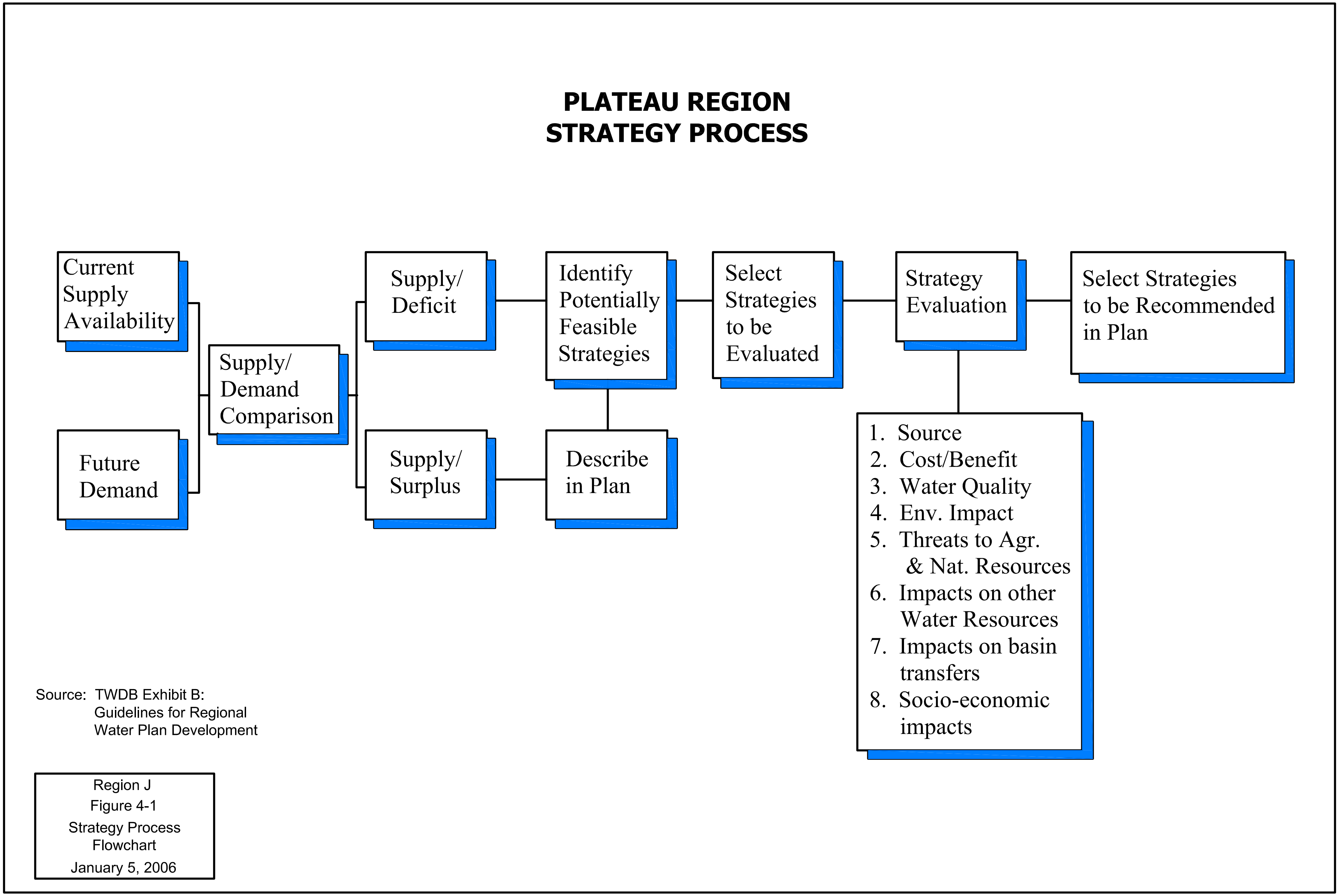


FIGURE 4-1. STRATEGY PROCESS FLOW CHART

LBG-GUYTON ASSOCIATES

TABLE 4-3. SUMMARY OF WATER MANAGEMENT STRATEGY EVALUATIONS

Water User Group	County Used	Basin	Strategy	Strategy ID	Supply (Acre-Feet/Year) 2010	2020	2030	2040	2050	2060	Source	Total Capital Cost (Table 4-4)	Quality *	Reliability**	Recreation***	Environmental Factors (Table 4-5)	Strategy Impacts**** Water Resources (1-5)	Agricultural Resources (1-5)	Natural Resources (1-5)
City of Kerrville	Kerr	Guadalupe	Purchase water from UGRA	J-1			3,840	3,840	3,840	5,450	Guadalupe River	$0	2	1	2	2	2	2	2
			Additional wells in a remote well field	J-2	3,000	3,000	3,000	5,500	5,500	5,500	Edwards-Trinity (Plateau) Aquifer	$7,512,000	1	1 or 2	2	2 to 4	3	3	3
			Increased water treatment and ASR capacity	J-4	5,600	5,600	5,600	5,600	5,600	5,600	Guadalupe River and Trinity Aquifer	$6,650,000	1	2	2	2 to 3	2	2	2
			Conservation: Water audit and loss audit	J-5	44	47	49	49	52	53	Conservation	NA	NA	NA	2	NA	1	1	1
			Conservation: Public information	J-6	NA	NA	NA	NA	NA	NA	Conservation	NA	NA	NA	2	NA	1	1	1
Kerr County Other (UGRA)	Kerr	Guadalupe	Purchase water from UGRA	J-7	NA	NA	NA	NA	NA	NA	Guadalupe River and Trinity Aquifer	$0	1 or 2	2	2	NA	NA	NA	NA
Town of Camp Wood	Real	Nueces	Drill groundwater wells	J-8	172	172	172	172	172	172	Edwards-Trinity (Plateau) Aquifer	$206,000	1	1 or 2	2	2	3	3	3
			Conservation: Water audit and loss audit	J-9	2	2	2	2	2	2	Conservation	NA	NA	NA	2	NA	1	1	1
			Conservation: Public information	J-10	NA	NA	NA	NA	NA	NA	Conservation	NA	NA	NA	2	NA	1	1	1
Irrigation	Bandera	San Antonio	Irrigation scheduling	J-11	58	58	58	58	58	58	Conservation	NA	NA	NA	2	NA	1	1	1
			Volumetric measurement of water use	J-12	NA	NA	NA	NA	NA	NA	Conservation	NA	NA	NA	2	NA	1	1	1
			Crop residue management and conservation tillage	J-13	125	125	125	125	125	125	Conservation	NA	NA	NA	2	NA	1	1	1
			On-farm irriagtion audit	J-14	NA	NA	NA	NA	NA	NA	Conservation	NA	NA	NA	2	NA	1	1	1
			Low pressure center pivot sprinkler systems	J-15	3	3	3	3	3	3	Conservation	$1,600	NA	NA	2	NA	1	1	1
		Nueces	Low pressure center pivot sprinkler systems	J-21	1	1	1	1	1	1	Conservation	$800	NA	NA	2	NA	1	1	1
Irrigation	Kerr	Guadalupe	Irrigation scheduling	J-16	398	398	398	398	398	398	Conservation	NA	NA	NA	2	NA	1	1	1
			Volumetric measurement of water use	J-17	NA	NA	NA	NA	NA	NA	Conservation	NA	NA	NA	2	NA	1	1	1
			Crop residue management and conservation tillage	J-18	865	865	865	865	865	865	Conservation	NA	NA	NA	2	NA	1	1	1
			On-farm irriagtion audit	J-19	NA	NA	NA	NA	NA	NA	Conservation	NA	NA	NA	2	NA	1	1	1
			Low pressure center pivot sprinkler systems	J-20	2	2	2	2	2	2	Conservation	$1,200	NA	NA	2	NA	1	1	1

Table 4-1 does not forecast a supply deficit for Kerr County Other.

* Quality range: 1= Meets safe drinking-water standards; 2=Must be treated or mixed to meet safe drinking-water standards.

** Reliability range: 1=Sustainable; 2=Interruptible during droughts; 3=Non-sustainable.

*** Recreation: 1=Provides additional recreational opurtunities; 2=Has no impact on recreation; 3=Reduces existing recreational opurtunities.

**** Strategy impact range: 1=positive; 2=no new; 3=minimal negative; 4=moderate negative; 5=significant negative.

TABLE 4-4. SUMMARY OF WATER MANAGEMENT STRATEGY COST

Cost estimates in U.S. dollars are discounted and are shown in in terms of present value.

Water User Group	Strategy	Strategy ID	Total Capital Cost	O&M Cost/Year						Cost per Acre-Foot/Year					
				2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
City of Kerrville	Purchase water from UGRA	J-1	$0	Undetermined								$1,000	$1,000	$1,000	$1,000
	Additional wells in a remote well field	J-2	$7,512,000	$596,189	$596,189	$596,189	$248,941	$248,941	$248,941	$199	$199	$199	$45	$45	$45
	Increased water treatment and ASR capacity	J-4	$6,650,000	$815,441	$815,441	$815,441	$337,000	$337,000	$337,000	$146	$146	$146	$60	$60	$60
	Conservation: Water audit and loss audit	J-5	NA	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000	$454	$426	$408	$408	$385	$377
	Conservation: Public information	J-6	NA	Undetermined						Undetermined					
Kerr County Other (UGRA)	Purchase water from UGRA	J-7	$0	Undetermined						$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
Town of Camp Wood	Drill groundwater wells	J-8	$206,000	$20,986	$20,986	$20,986	$6,165	$6,165	$6,165	$122	$122	$122	$36	$36	$36
	Conservation: Water audit and loss audit	J-9	NA	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$500	$500	$500	$500	$500	$500
	Conservation: Public information	J-10	NA	Undetermined						Undetermined					
Bandera County Irrigation	Irrigation scheduling	J-11	NA	Water and land management practices only						NA					
	Volumetric measurement of water use	J-12	NA												
	Crop residue management and conservation tillage	J-13	NA												
	On-farm irriagtion audit	J-14	NA												
	Low pressure center pivot sprinkler systems	J-15	$1,600	$124	$124	$124	$124	$124	$124	$41	$41	$41	$41	$41	$41
	Low pressure center pivot sprinkler systems	J-21	$800	$62	$62	$62	$62	$62	$62	$62	$62	$62	$62	$62	$62
Kerr County Irrigation	Irrigation scheduling	J-16	NA	Water and land management practices only						NA					
	Volumetric measurement of water use	J-17	NA												
	Crop residue management and conservation tillage	J-18	NA												
	On-farm irriagtion audit	J-19	NA												
	Low pressure center pivot sprinkler systems	J-20	$1,200	$93	$93	$93	$93	$93	$93	$47	$47	$47	$47	$47	$47

Where applicable, capital costs include: construction, engineering, and easement, environmental, interest during construction, and purchased water.

Engineering, contingency, construction management, financial and leagal costs are estimated at 30 percent of construction costs for pipelines and 35 percent for pump stations and treatment facilities.

Permitting and mitigation for transmission and treatment projects are estimated at 1 percent of total construction costs.

Surface water treatment costs are estimated at $0.35 per 1,000 gallons for a conventional plant.

Annual costs include operations and maintenance, power cost, and debt service at 6% over 30 years.

TABLE 4-5. SUMMARY OF ENVIRONMENTAL ASSESSMENTS

Water User Group	Strategy	Strategy ID	* Total Acres Impacted in the Year 2010	Wetland Acres Impacted	**Total Number of Rare, Threatened & Endangered Species in County (species impacted is undetermined)	Environmental Impact Factors ***						Comments
						Envir. Water Needs (1-5)	Habitat (1-5)	Cultural Resources (1-5)	Envir. Water Quality (1-5)	Bays & Estuaries	Overall Envir. Impact (1-5)	
City of Kerrville	Purchase water from UGRA	J-1	NA	NA	39	2	2	2	2	NA	2	Will likely observe current low-flow restrictions.
	Additional wells in a remote well field	J-2	A&B	0	39	3 to 4	3 to 4	2	3		2 to 4	Potential to influence local spring flow.
	Increased water treatment and ASR capacity	J-4	7	0	39	2 to 3	2 to 3	2 to 3	2 to 3		2 to 3	Will decrease dependence on new groundwater.
	Conservation: Water audit and loss audit	J-5	0	0	39	1	1	1	1		NA	Intended to reduce water use.
	Conservation: Public information	J-6	0	0	39	1	1	1	1		NA	Intended to reduce water use.
Kerr County Other [A] (UGRA)	Purchase conjunctive-use water from UGRA	J-7	NA	NA	39	NA	NA	NA	NA		NA	Will likely observe current low-flow restrictions.
Community of Camp Wood	Drill groundwater wells	J-8	5	0	35	2	2	2	2		2	No new impact assumes wells are drilled away from Old Faithful Spring.
	Conservation: Water audit and loss audit	J-9	0	0	35	1	1	1	1		NA	Intended to reduce water use.
	Conservation: Public information	J-10	0	0	35	1	1	1	1		NA	Intended to reduce water use.
Bandera County Irrigation	Agricultural irrigation BMPs	J-11-15 & 21	NA	NA	32	NA	NA	NA	NA		NA	Intended to reduce water use.
Kerr County Irrigation	Agricultural irrigation BMPs	J16-20	NA	NA	39	NA	NA	NA	NA		NA	Intended to reduce water use.

[A] Kerr County Other is not projected to have a supply deficit in Table 4-1; therefore a full environmental analysis was not performed.

*** Total Acres Impacted:**

A - Temporary excavation for pipelines and ditches

B - Temporary local land disturbance while drilling and repairing water wells

C - Disturbance of cultivated land

**** Texas Parks & Wildlife Department's Natural Diversity Database of rare, threatened, and endangered species.**

***** Strategy impact range: 1=positive; 2=no new; 3=minimal negative; 4=moderate negative; 5=significant negative**

4.4 MUNICIPAL WATER MANAGEMENT SYSTEMS

4.4.1 City of Kerrville

The City of Kerrville has developed a conjunctive-use policy for both surface water and groundwater, and passed a comprehensive Water Management Plan in early 2004. The policy specifies that (1) surface water will be used to the maximum extent that it is available, (2) groundwater will be a supplemental source of supply, and (3) water consumption will be reduced through conservation.

The TCEQ Guadalupe River WAM Run 3 drought-of-record analysis yields 150 acre-ft/yr of surface water as reliable for the City of Kerrville. For planning purposes, the City proposes to use this estimate of available surface water, even though the estimate is significantly less than the permitted amount based on availability during a drought-of-record. Kerrville will develop additional surface and groundwater supplies, storage options or modifications to the existing permits, expansion of the Aquifer Storage and Recovery (ASR) system, and a remote groundwater well field, if it can be shown that there are periods when the City will not be able to use the permitted water from the Guadalupe River.

The City of Kerrville has been operating an ASR system for the past several years. In this system, a portion of treated Guadalupe River surface water is injected into the Lower Trinity aquifer during months of water surplus and recovered from the aquifer for subsequent use during dry summer months. Currently, the ASR has two wells that serve for both injection and recovery. The capacity of the storage in the ASR is virtually unlimited, but the rates of injection and recovery are limited to 1 million gallons per day (mgd) in each of the two wells. A third well with equal capacity is in the planning stages. As of December 2005, the total storage in the ASR was 453 million gallons (1,390 acre-feet).

The analysis of current availability from surface water diversions for the City of Kerrville includes the storage and back up supply provided by the ASR system. This analysis considers the availability from surface water diversion under existing water rights with the Guadalupe WAM, storage in the on-channel reservoir in the Guadalupe River, injections into the ASR during periods of surplus, and recovery during periods when surface water is not sufficient to meet municipal demands. The maximum reliable supply during a drought-of-record (similar to the historical drought during the period 1949-1956) depends on the ASR storage as shown below.

Storage needed in the ASR system for different levels of reliable supply

Maximum reliable supply for Kerrville (Acre-Feet per Year)	Storage in ASR at the beginning of the drought-of-record (Acre-Feet)
135	1,000
150	**1,230**
245	2,000
350	3,000
450	4,000
550	5,000

Assuming that a drought-of-record starts immediately, the maximum reliable supply for the City of Kerrville is 150 acre-feet per year using the volume stored in the aquifer as of December 2005. Permit 1996 would provide an additional 150 acre-feet for municipal use for a total of 300 acre-feet per year. However, the ASR storage does not recover quickly, and if there are multiple drought years, the ASR may not have enough storage for a reliable supply to cover the entire drought period. Therefore, a reliable surface water supply of 150 acre-feet per year for the City of Kerrville is recommended.

Based on current groundwater availability estimates, the firm yield of the Lower Trinity aquifer is estimated at 4,250 acre-ft/yr in the Kerrville area. The City of Kerrville uses a figure of 3 mgd, or 3,360 acre-ft/yr as an available groundwater supply during a drought year. In the past decade, the City has not had to curtail surface water use; therefore, groundwater production has been significantly below what could have been pumped. The City continues to rely on the Lower Trinity aquifer as a dependable source of water. Through the City's conjunctive use policy, groundwater is reserved for meeting peak demand in a normal year and base demand in a drought year. For planning purposes, the estimates of available groundwater are 5 mgd (5,600 acre-ft/yr) for peak demand and 3 mgd (3,360 acre-ft/yr) for average demand.

The City has identified its need to develop agreements with the Guadalupe Blanco River Authority (GBRA) that will provide for subordination of GBRA's Canyon Reservoir authorization to the City of Kerrville's existing permits. The City has also identified the possibility of modifying its own existing water permits. Currently the City's ability to divert under its existing permits is dependent on whether more senior water right holders exercise their rights, and is also affected by the City's Special Conditions written into its permits. If the City had more reliability from the Guadalupe River, and more latitude in its ability to divert during certain months of the year, the City could more fully utilize its ASR facility.

The City of Kerrville's water treatment capacity also limits its utilization of its ASR facility. The City needs a combined ASR/treatment system with capacity to treat and store a total pumping capacity of 3 mgd during periods of higher streamflow; the current ASR system is limited to 2 mgd. The City has included an expansion to this system in its five-year capital improvement program. The City and UGRA have discussed expanding existing water treatment capacity.

Kerrville passed a comprehensive water management plan in 2004. This plan focuses on water conservation and efficient management of local water resources. The plan outlines water conservation activities and provides guidance for the various stages of emergency water conservation measures and enforcement. 2003 water use surveys indicate that Kerrville is using approximately 189 gallons per capita per day (GPCD). If a 1 percent annual reduction in demand is adopted, Kerrville would reach the Texas Water Conservation Taskforce recommended target of 140 GPCD around 2030.

The availability of water will become a factor limiting the growth of both Kerrville and Kerr County. Water management strategies that the City can consider as possible future sources of supply include:

- Contracting with UGRA for additional water supply to be delivered to Kerr County.
- Increased water treatment capacity.
- Increasing water treatment capacity in conjunction with growth of ASR.
- Development of a remote well fields to provide additional groundwater sources beyond the Lower Trinity in the Kerrville area.
- Municipal conservation savings

4.4.2 Upper Guadalupe River Authority (UGRA)

One of UGRA's major objectives is to provide for conjunctive use of surface water and groundwater in high-density growth areas within Kerr County. Because both UGRA and the City of Kerrville desire to obtain more water from the Guadalupe River than they are currently using, amending permits 5394A and 5394B should be a priority. The permits should be amended to firm supply and to allow water from UGRA's permit to be used in the City of Kerrville.

UGRA intends to implement an ASR facility in the near future. The system is intended to provide a means of storing excess Guadalupe River supplies for use during drought or reduced surface water flows. A more thorough understanding of the geology and hydrology is necessary before such a system will be proposed.

UGRA desires to obtain a greater portion of the water that is available in the Guadalupe River. One way to accomplish this is to buy existing water rights on the Guadalupe River or its tributaries. A study to determine the most reliable rights would be needed to guide UGRA in its decisions on selecting the best water rights to purchase. Such a study would involve a methodology, using the Water Availability Model, to identify rights that are both reliable and that have senior priorities. Another priority is to subordinate GBRA's Canyon Lake hydroelectric and Canyon Lake diversion rights for future UGRA and City of Kerrville use.

4.4.3 Town of Camp Wood

The Town of Camp Wood derives all of its municipal water from "Old Faithful" (also known as Krueger Spring or Camp Wood Spring) that issues from alluvial gravel overlying the Glen Rose limestone of the Edwards-Trinity (Plateau) aquifer. Discharge from the spring is occasionally insufficient to meet all current needs, and the Town is considering developing an alternate source of supply. Other significant problems in the past with the spring have been the occurrence of Giardia (in late 1988) and intermittent high turbidity.

Currently, Camp Wood is dependent on a pump set into Old Faithful Springs for the Community's water supply. The demand is projected to be as high as 172 ac-ft/yr within the next 50 years. The TCEQ Nueces River WAM results indicate that there is no reliable water available from the spring during a repeat of the drought-of-record. However, Old Faithful did not cease to flow during the drought of the 1950s.

During a drought, the Town could rely on water wells completed into the Trinity aquifer to supplement the spring. At 172 ac-ft/yr total demand, wells capable of producing a combine yield of about 110 gallons per minute (gpm) on a sustained basis will be needed. The potential of constructing wells capable of producing at this desired rate is good, although exploratory drilling and testing will likely be needed before this strategy can be relied upon as a dependable source. A minimum of two wells capable of producing 50 to 70 gpm each will be needed to supply the anticipated 172 ac-ft/yr at an estimated total capital cost of $206,000.

Sufficient groundwater is likely available from the Trinity aquifer, however, local water-level declines could be expected as a result of pumping new wells. Because the source of Old Faithful Springs is at least partially from the Trinity aquifer, some spring flow reduction may occur as a result of pumping wells. Accordingly, any new wells should be located as far from Old Faithful Springs as possible. Chemical quality of the water from wells should be acceptable providing the wells are properly constructed. The Trinity can have gypsum beds in the Glen Rose that may cause elevated sulfates and total dissolved solids. If these are present, these gypsum intervals in the limestone should be cased and cement off in the well.

4.5 MUNICIPAL WATER MANAGEMENT STRATEGIES

4.5.1 Strategy J-1

WATER USER NAME:

Water User Name: City of Kerrville

County: Kerr County

River Basin: Guadalupe

Source: Guadalupe River

STRATEGY NAME:

Purchase water from UGRA

STRATEGY DESCRIPTION:

If the City of Kerrville annexes areas that the UGRA is intending to serve, then the City would supplement its existing water permits on the Guadalupe River by purchasing water from UGRA. Presumably the purchase of water from UGRA will involve a contractual agreement between the two entities allowing the City to divert more water from the Guadalupe River than it is authorized under its current permits - the additional water diverted being accounted for under UGRA's existing permits. This strategy will provide water to supply only those areas to be annexed by the City of Kerrville.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): Supply needed by 2030.

Long Term (from the year 2030 to the year 2060): Additional supplies needed by 2060.

QUANTITY OF WATER:

No quantity has been specified thus far. The City's objective in obtaining more water from the Guadalupe River is to have more reliability from the River flows and more latitude in its ability to divert during certain months of the year. This would allow the City to more fully utilize its ASR facility. Up to 3,840 acre-feet is needed by the year 2030 and an additional 1,610 acre-feet by 2060 for a total of 5,450 acre-feet.

RELIABILITY OF WATER:

The reliability is dependent on the amount of water physically present within the Guadalupe River. UGRA and the City both take from the same source (Guadalupe River). The term "regulated stream flow" is generally synonymous with water that is physically present within a water body. It is noted that the Upper Guadalupe River's minimum regulated stream flow (flow during drought-of-record), as determined by TCEQ's WAM Run 3, is 6,867 acre-ft/yr. However, the sum of authorized water rights is 12,128 acre-ft/yr. This means that during a drought-of-record, the water present in the Upper Guadalupe River is only half the amount of water authorized for diversion.

COST:

The cost to purchase water from UGRA has not been determined. Estimated cost per acre-foot is $1,000.

ENVIRONMENTAL ISSUES:

The existing water permits of both UGRA and the City contain Special Conditions that allow diversions only when flows of the Guadalupe are above a minimum level. These restrictions help protect instream flows and the aquatic environment, in addition to serving as key water supply indicators. Any water purchase contract will likely have to contain the same or similar stream flow restrictions because TCEQ and TPWD are interested in maintaining minimum flows regardless of where the water is purchased.

IMPACT ON OTHER WATER RESOURCES:

No impact foreseen.

THREATS TO AGRICULTURE:

No impact foreseen.

THREATS TO NATURAL RESOURCES:

Natural resources that are dependent on flow in the River are protected by the Special Conditions requirement included in the use permit (see Environmental Issues).

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No negative social and economic impacts are anticipated from this strategy.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

The source of the water is Guadalupe River water through a purchase contract with UGRA, or a subordination and purchase contract with GBRA. All water purchase contracts must be approved by TCEQ, just as new or amended water rights must be approved by TCEQ. This means that - although TCEQ staff will not conduct a full hydrologic study for a contract - the agency will likely investigate any implications of the proposed contract on the Special Conditions outlined within the City's existing water permit. See "Environmental Issues" above. Bookkeeping within the TCEQ master water rights database would simply show the City's new diversions as a contract keyed to the water right of whichever entity provides the water.

4.5.2 Strategy J-2

WATER USER NAME:

Water User Name: City of Kerrville

County: Kerr

River Basin: Guadalupe

Source: Edwards-Trinity (Plateau) Aquifer

STRATEGY NAME:

Additional wells in a remote well field

STRATEGY DESCRIPTION:

Current City of Kerrville wells and many other competing wells are located within urban areas. This causes some problems especially during droughts where a larger number of wells are competing for a limited groundwater resource. If a well field was located in more remote areas either relatively nearby to the south or west or in the very western portion of the county in the Edwards-Trinity (Plateau) aquifer, then less competition for the groundwater resources would occur, even during droughts. The most optimal arrangement of wells would be to stagger them along the length of a pipeline, which also means that the diameter of the line could be telescoped with possibly a smaller 12-inch diameter to a larger 20-inch diameter pipeline near the destination point.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): Partial 25 mile pipeline telescoping with about 20-inch diameter near destination and 6 wells.

Long Term (from the year 2030 to the year 2060): Complete 25 miles and 6 more wells for a total of 12 wells.

QUANTITY OF WATER:

The specific quantity can only be determined after exploration and testing of wells is performed. An estimate of yield of typical wells in the Kerrville area is about 400 to 600 gpm. At 400 gpm each, 6 wells would have the capacity of 2,400 gpm. If the wells are run 78 percent of the time then the yield would be about 3,000 ac-ft/yr. With a 20-inch diameter pipeline, the total wells could be doubled for the long term, which would also almost double the quantity of water to 5,500 ac-ft/yr.

RELIABILITY OF WATER:

If the well field is located in the Edwards-Trinity (Plateau) aquifer away from current pumping centers, then the overall reliability is good. Some water-level declines in the well field can be expected during severe drought. Specific details as to how much potential decline may occur can only be estimated when specific aquifer parameters are determined through testing.

COST:

Cost for drilling an initial 14-inch diameter hole to 200-foot depth with 10-inch diameter steel casing pressure cemented, then drilled to 800-foot depth with 10-inch open hole is estimated at $67,000. Cost for a 50-horsepower submersible pump capable of producing 400 gpm with wiring and control box and 300 feet of 5-inch diameter column pipe is estimated at $28,000. With cost for other appurtenances and engineering, the total estimated price is $120,000. The total cost for the first 6 wells is estimated at $720,000 and another $720,000 for the second six wells. For estimation purposes a 16-inch diameter pipeline is used. The line may actually telescope from 12-inch to 20-inch diameter. Estimated price for a 16-inch pipeline with appurtenances is about $41 per foot length or about $217,000 per mile. If the pipeline is 10 miles then the cost is $2,170,000. If the pipeline is 25 miles, then the cost is $5,412,000. Adding in the cost of the wells, then the cost is $2,890,000 for 6 wells and a 10-mile pipeline or $6,132,000 for wells and a 25-mile pipeline. The total number of wells could be doubled to 12 wells for an additional $720,000.

An estimate for right-of-ways is $5 per foot length or $26,400 per mile, which includes some property for locating well sites. Total for 25 miles is $660,000. Total capital cost for 25-miles of pipeline averaging 16-inch diameter and 12 wells is $7,512,000. Additional cost for debt retirement was calculated using the TWDB program. Operation and maintenance is estimated on the basis of $0.11 per 1,000 gallons.

ENVIRONMENTAL ISSUES:

The potential exists that any additional pumping in the western part of the county could result in local water level declines and thus potentially impact nearby springs. A spring/river flow study was performed to evaluate this surface water/groundwater relationship and to serve as a tool in identifying least detrimental areas for potential groundwater withdrawals. Diminished spring flow can impact quantity and quality of local aquatic habitat.

IMPACT OF STRATEGY ON OTHER WATER RESOURCES:

Local water-level declines may occur which potentially may affect water levels in wells on surrounding properties. If the well field is located away from other wells and well spacing between wells in the field are optimized, then effects can be minimized. If the deeper aquifer is targeted, then local springs that feed into surface streams should not be affected.

THREATS TO AGRICULTURE:

Declining water levels could potentially impact shallow livestock wells in the near vicinity of a new well field.

THREATS TO NATURAL RESOURCES:

See Environmental Issues above.

4.5.3 Strategy J-4

WATER USER NAME:

Water User Name: City of Kerrville

County: Kerr County

River Basin: Guadalupe

Source: Guadalupe River and Trinity Aquifer

STRATEGY NAME:

Increased Water Treatment Plant and ASR Capacity

STRATEGY DESCRIPTION:

The City of Kerrville will expand their existing water treatment plant from its current capacity of 3 mgd to 5 mgd. Also, the ASR system will be expanded to include two additional wells.

TIME INTENDED TO IMPLEMENT:

The time line is very aggressive, with the expanded plant envisioned to be operable in year 2010.

QUANTITY OF WATER:

The City's own existing water permits on the Guadalupe River will be supplemented by agreement(s) with the Upper Guadalupe River Authority that will provide for subordination of GBRA's Canyon Reservoir authorization to the City's permits. Water treatment capacity will be expanded from 3 mgd to 5 mgd, and the ASR expansion will result in a total ASR pumping capacity of 3 mgd from its current capacity of 2 mgd. Upon completion, this strategy will generate 2,240 acre-ft/yr.

RELIABILITY OF WATER:

The City's current water treatment capacity limits its utilization of its ASR facility. The City has identified the need for an additional 2 mgd of treatment capacity to take care of peak use, take advantage of periods when higher streamflows occur in the Guadalupe River, and thus fully utilize its ASR. The increased storage capacity provided by the expanded ASR operation will make available water supplies more reliable. However, during drought-of-record conditions, water available from the upper Guadalupe River may be limited or nonexistent.

COST:

The capital cost of the water treatment plant expansion to a 5 mgd capacity is approximately $6,000,000. The expansion of the ASR system includes the conversion of an existing city well (utilizing existing pumping equipment) at a cost of approximately $250,000 and the drilling and completion of a new well at an approximate cost of $400,000. Total cost for this strategy is $6,650,000.

ENVIRONMENTAL ISSUES:

No environmental issues are anticipated.

IMPACT ON OTHER WATER RESOURCES:

The impact of the regional water treatment plant itself is not the issue. Both UGRA and the City of Kerrville plan to obtain more water from the Guadalupe River than they are currently using under their existing water permits. A thorough hydrologic and water availability study should be performed to determine if the Guadalupe River can, in physical reality, provide the quantities of water desired.

THREATS TO AGRICULTURE:

No impact foreseen.

THREATS TO NATURAL RESOURCES:

No impact foreseen.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

This strategy will increase the reliability of water during peak demand periods and, thus, will benefit the public and businesses in the City of Kerrville.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

As noted, the source of the water is the City's existing permits and/or purchase of Guadalupe River water from GBRA. Also see "Impact on Other Water Resources".

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

As noted, the source of the water is the City's existing permits and/or purchase of Guadalupe River water from GBRA. Also see "Impact on Other Water Resources"

OTHER FACTORS:

The drilling of public-supply wells must be in compliance with TCEQ regulations, county ordinances, and Headwaters Groundwater Conservation District rules.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No social or economic impacts are anticipated.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

No impact is anticipated.

4.5.4 Strategy J-5

WATER USER NAME:

Water User Name: City of Kerrville

County: Kerr County

River Basin: Guadalupe

Source: Conservation

STRATEGY NAME:

System water audit and water loss

STRATEGY DESCRIPTION:

System water audits and water loss programs are effective methods of accounting for all water usage by a utility within its service area. The structured approach of a water audit allows a utility to reliably track water uses and provide the information to address unnecessary water and revenue losses. The resulting information from a water audit will be valuable in setting performance indicators and in setting goals and priorities for cost-effectively reducing water losses. By adopting this best management practice, a utility will be implementing a more frequent implementation of water auditing and loss reduction techniques than required by HB 3338.

A more detailed description of this best management practice is available in TWDB Report 362, Water Conservation Best Management Practices Guide, and in the TWDB Water Loss Manual.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): To be implemented during this period.

Long Term (from the year 2030 to the year 2060): To be continued indefinitely.

QUANTITY OF WATER:

In conjunction with Strategy J-6 (public information) a total of 1 percent reduction in demand is anticipated. This would result in a water savings of 44 acre-feet in 2010 and increasing to 53 acre-feet by 2060.

RELIABILITY OF WATER:

The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public's willingness to do their part.

COST:

Assuming that the City currently has the tools and facilities to implement the plan, there is no capital outlay. Expected annual operating (labor) cost is approximately $20,000. Cost per acre-foot saved ranges from $454 in 2010 to $377 in 2060.

ENVIRONMENTAL ISSUES:

There are no negative environmental issues related to this strategy. The implementation of this BMP will help reduce the need for developing additional supplies in the future that could have adverse impacts on the environment.

IMPACT ON OTHER WATER RESOURCES:

Implementation of this BMP reduces reliance on other water resources.

THREATS TO AGRICULTURE:

No impact foreseen.

THREATS TO NATURAL RESOURCES:

No impact foreseen.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No negative social and economic impacts are anticipated from this strategy.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

No impact foreseen.

4.5.5 Strategy J-6

WATER USER NAME:

Water User Name: City of Kerrville

County: Kerr County

River Basin: Guadalupe

Source: Conservation

STRATEGY NAME:

Public information

STRATEGY DESCRIPTION:

Public information programs, even though they may not be directly related to any equipment or operational change, can result in both short- and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling cause can be presented with sufficient frequency to be recognized and absorbed by the customers. There are many resources that can be consulted to provide insight into implementing effective information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner.

The goal is education of customers about the overall picture of water resources in the community and how conservation is important for meeting the goals of managing and sustaining existing water supplies and avoiding or delaying building new facilities. An equally important part of the program is to provide data and information on specific actions and measures the customers should take to implement these community goals. Showing customers that the results of those actions have made a difference encourages greater participation in conservation efforts.

A more detailed description of this best management practice is available in TWDB Report 362, Water Conservation Best Management Practices Guide.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): To be implemented during this period.

Long Term (from the year 2030 to the year 2060): To be continued indefinitely.

QUANTITY OF WATER:

In conjunction with Strategy J-5 (system water audit and water loss) a total of 1 percent reduction in demand is anticipated, which would result in a water savings of 44 acre-feet in 2010 and increasing to 53 acre-feet by 2060.

RELIABILITY OF WATER:

The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public's willingness to do their part.

COST:

Assuming that the City currently has the tools and facilities to implement the plan, there is no capital outlay. Expected annual operating (labor) cost is undetermined and is expected to be incorporated into the City's current comprehensive water management plan operations. No additional cost is assigned to this strategy. A comprehensive program is estimated to range in cost from $0.50 to $3.00 per customer per year depending on the size of the utility.

ENVIRONMENTAL ISSUES:

There are no negative environmental issues related to this strategy. The implementation of this BMP will help reduce the need for developing additional supplies in the future that could have adverse impacts on the environment.

IMPACT ON OTHER WATER RESOURCES:

Implementation of this BMP reduces reliance on other water resources.

THREATS TO AGRICULTURE:

No impact foreseen.

THREATS TO NATURAL RESOURCES:

No impact foreseen.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No negative social and economic impacts are anticipated from this strategy.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

No impact foreseen.

4.5.6 Strategy J-7

WATER USER NAME:

Water User Name: County Other (UGRA)

County: Kerr County

River Basin: Guadalupe

Source: Conjunctive use of groundwater and Guadalupe River

STRATEGY NAME:

Purchase water from UGRA

STRATEGY DESCRIPTION:

Kerr County Other entities with a water deficit will be able to augment their supplies through a purchase of water from UGRA. UGRA will fulfill its objective to be the regional provider of water to entities in Kerr County outside of the City of Kerrville's service area that are experiencing water shortages or looking to conjunctive use systems to secure future supplies.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): To be implemented during this period.

Long Term (from the year 2030 to the year 2060): Phased in as needed.

QUANTITY OF WATER:

No quantity has been specified thus far. The objective in obtaining more water from the Guadalupe River is to have more reliability from the Guadalupe River flows and more latitude in the ability to divert during certain months of the year, thus allowing UGRA to more fully utilize a future ASR facility. Surface water supplies will be firmed up with groundwater.

RELIABILITY OF WATER:

Surface water will be augmented with groundwater and an ASR system. The reliability is excellent.

COST OF WATER:

The cost to purchase water from UGRA is currently unknown. Estimated cost per acre-foot is $1,000.

ENVIRONMENTAL ISSUES:

The existing water permits of UGRA contain Special Conditions that restrict diversions only when flows of the Guadalupe are above a minimum level. These restrictions help protect instream flows and the aquatic environment, in addition to serving as key water supply indicators. Any water purchase contract will likely have to contain the same or similar stream flow restrictions because TCEQ and TPWD are interested in maintaining minimum flows regardless of where the water is purchased.

IMPACT ON OTHER WATER RESOURCES:

The conjunctive use of groundwater and surface water will partially relieve the current stress imposed on the local aquifer system.

THREATS TO AGRICULTURE:

No impact foreseen.

THREATS TO NATURAL RESOURCES:

No impact foreseen.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No negative social and economic impacts are anticipated from this strategy.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

All water purchase contracts must be approved by TCEQ, just as new or amended water rights must be approved by TCEQ. This means that - although TCEQ staff will not conduct a full hydrologic study for a contract - the agency will likely investigate any implications of the proposed contract on the Special Conditions outlined within the City's existing water permit. See "Environmental Issues" above. Bookkeeping within the TCEQ master water rights database would simply show the City's new diversions as a contract keyed to the water right of whichever entity provides the water.

4.5.7 Strategy J-8

WATER USER NAME:

Water User Name: Town of Camp Wood

County: Real

River Basin: Nueces

Source: Edwards-Trinity (Plateau) Aquifer

STRATEGY NAME:

Public-supply wells

STRATEGY DESCRIPTION:

Construction of two public-supply water wells.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): Phased in as needed.

Long Term (from the year 2030 to the year 2060): No additional supply anticipated.

QUANTITY OF WATER:

Two wells capable of producing 50 to 70 gpm each will meet the anticipated need for 172 ac-ft/yr.

RELIABILITY OF WATER:

Sufficient groundwater is available from the Edwards-Trinity (Plateau) aquifer without causing excessive water-level declines. Temporary water shortages may occur during drought periods, which may require the lowering of pumps or deepening of wells.

COST:

An estimate for the cost of constructing one public-supply well is about $103,000. The well would likely be completed with 6-inch steel pipe to a depth up to 800 feet. The price includes engineering, well pump, motor controls, column pipe and installation. Two wells would double the price to about $206,000. It is assumed that the wells would be drilled adjacent to the existing distribution system, therefore no additional pipeline is considered for this estimate.

ENVIRONMENTAL ISSUES:

In addition to livestock, local and migratory wildlife often depend on livestock watering facilities. Maintaining water in these facilities is a crucial aspect of wildlife habitat.

IMPACT OF STRATEGY ON OTHER WATER RESOURCES:

Its is recommended that wells be placed a sufficient distance downstream of Old Faithful Springs such that the Springs will not be impacted by a potential lowering of water levels in the aquifer source that sustains the Springs.

THREATS TO AGRICULTURE:

Declining water levels could potentially impact shallow livestock wells in the near vicinity of a new well field.

THREATS TO NATURAL RESOURCES:

No negative impact to natural resources is anticipated.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No negative social and economic impacts are anticipated from this strategy.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

No impact is anticipated.

4.5.8 Strategy J-9

WATER USER NAME:

Water User Name: Town of Camp Wood

County: Real County

River Basin: Nueces

Source: Conservation

STRATEGY NAME:

System water audit and water loss

STRATEGY DESCRIPTION:

System water audits and water loss programs are effective methods of accounting for all water usage by a utility within its service area. The structured approach of a water audit allows a utility to reliably track water uses and provide the information to address unnecessary water and revenue losses. The resulting information from a water audit will be valuable in setting performance indicators and in setting goals and priorities for cost-effectively reducing water losses. By adopting this best management practice, a utility will be implementing a more frequent implementation of water auditing and loss reduction techniques than required by HB 3338.

A more detailed description of this best management practice is available in TWDB Report 362, Water Conservation Best Management Practices Guide, and in the TWDB Water Loss Manual. Due to its small size, it may not be necessary for this utility to follow every step in these manuals.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): To be implemented during this period.

Long Term (from the year 2030 to the year 2060): To be continued indefinitely.

QUANTITY OF WATER:

In conjunction with Strategy J-10 (public information) a total of 1 percent reduction in demand is anticipated. This would result in a water savings of approximately 2 acre-feet per year.

RELIABILITY OF WATER:

The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public's willingness to do their part.

COST:

Camp Wood would likely have to hire out this service at a cost of approximately $1,000 per year. Cost per acre-foot saved is approximately $500 per year.

ENVIRONMENTAL ISSUES:

There are no negative environmental issues related to this strategy. The implementation of this BMP will help reduce the need for developing additional supplies in the future that could have adverse impacts on the environment.

IMPACT ON OTHER WATER RESOURCES:

Implementation of this BMP reduces reliance on other water resources.

THREATS TO AGRICULTURE:

No impact foreseen.

THREATS TO NATURAL RESOURCES:

No impact foreseen.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No negative social and economic impacts are anticipated from this strategy.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

No impact foreseen.

4.5.9 Strategy J-10

WATER USER NAME:

Water User Name: Town of Camp Wood

County: Real County

River Basin: Nueces

Source: Conservation

STRATEGY NAME:

Public information

STRATEGY DESCRIPTION:

Public information programs, even though they may not be directly related to any equipment or operational change, can result in both short- and long-term water savings. Behavioral changes by customers will only occur if a reasonable yet compelling cause can be presented with sufficient frequency to be recognized and absorbed by the customers. There are many resources that can be consulted to provide insight into implementing effective information programs. Like any marketing or public information program, to be effective, water conservation public information should be planned out and implemented in a consistent and continual manner.

The goal is education of customers about the overall picture of water resources in the community and how conservation is important for meeting the goals of managing and sustaining existing water supplies and avoiding or delaying building new facilities. An equally important part of the program is to provide data and information on specific actions and measures the customers should take to implement these community goals. Showing customers that the results of those actions have made a difference encourages greater participation in conservation efforts.

A more detailed description of this best management practice is available in <u>TWDB Report 362, Water Conservation Best Management Practices Guide</u>.

TIME INTENDED TO IMPLEMENT:

Short Term (prior to the year 2030): To be implemented during this period.

Long Term (from the year 2030 to the year 2060): To be continued indefinitely.

QUANTITY OF WATER:

In conjunction with Strategy J-9 (system water audit and water loss) a total of 1 percent reduction in demand is anticipated. This would result in a water savings of 2 acre-feet annually.

RELIABILITY OF WATER:

The reliability of this water savings is contingent on the aggressive implementation of this BMP and the public's willingness to do their part.

COST:

Expected annual operating (labor) cost is undetermined and is expected to be incorporated into the Utility's current water management operations. No additional cost is assigned to this strategy. A comprehensive program is estimated to range in cost from $0.50 to $3.00 per customer per year depending on the size of the utility.

ENVIRONMENTAL ISSUES:

There are no negative environmental issues related to this strategy. The implementation of this BMP will help reduce the need for developing additional supplies in the future that could have adverse impacts on the environment.

IMPACT ON OTHER WATER RESOURCES:

Implementation of this BMP reduces reliance on other water resources.

THREATS TO AGRICULTURE:

No impact foreseen.

THREATS TO NATURAL RESOURCES:

No impact foreseen.

INTERBASIN TRANSFER:

None.

SOCIAL AND ECONOMIC IMPACTS:

No negative social and economic impacts are anticipated from this strategy.

IMPACT ON WATER RIGHTS, CONTRACTS, AND OPTION AGREEMENTS:

No impact foreseen.

4.6 IRRIGATION WATER MANAGEMENT STRATEGIES

Under drought-of-record conditions, the TCEQ river models (WAMs) indicate that only one-third of the permitted irrigation water rights in the Plateau Region can be met. This represents a decreased supply of approximately 21,500 acre-feet. As a result, projected irrigation shortages occur in Bandera and Kerr Counties. The quantity of water needed to meet the full demands cannot be realistically achieved by simply switching to groundwater sources. Farmers in these areas have generally approached this situation by reducing acreage irrigated, changing types of crops planted, or possibly not planting crops until surface water becomes available during the following season.

In some cases, farmers may benefit from Best Management Practices (BMPs) for agricultural water users, which are a mixture of site-specific management, educational, and physical procedures that have proven to be effective and are cost-effective for conserving water. The Texas Water Development Board (TWDB), through the Water Conservation Implementation Task Force, has published a report titled Water Conservation Best Management Practices Guide (TWDB Report 362) which in part contains numerous BMPs for agricultural water users http://www.twdb.state.tx.us/assistance/conservation/TaskForceDocs/WCITFBMPGuide.pdf. The Plateau Water Planning Group suggests that river authorities, river masters, agricultural agencies, and groundwater conservation districts encourage irrigators to implement BMPs. The following BMPs have been selected for their suitability to the irrigation practices occurring in the Plateau Region. General irrigation BMP water savings and cost estimates are provided in Table 4-6. Water savings and cost estimates as they relate to sprinkler systems in Bandera and Kerr Counties are discussed in Section 4.6.5

Agricultural Irrigation Water Use Management

- Irrigation Scheduling
- Volumetric Measurement of Irrigation Water Use
- Crop Residue Management and Conservation Tillage
- On-Farm Irrigation Audit

<u>On-Farm Water Delivery Systems</u>

- Low Pressure Center Pivot Sprinkler Irrigation Systems

TABLE 4- 6. SUMMARY OF IRRIGATION STRATEGIES

Source: TWDB Report 362 - Water Conservation Best Management Practices Guide for Agriculture

Strategy ID	Irrigation Strategy Name	Water Savings	Cost Consideration
J-11&16	Irrigation scheduling	Estimated savings of 0.3 to 0.5 acre-ft/acre	Primarily labor cost
J-12&17	Volumetric measurement of water use (flow gages)	Does not directly conserve water	$600 to $1,000 per gage
J-13&18	Crop residue management and conservation tillage	Estimated savings of 0.75 to 1.0 acre-ft/acre	Primarily labor cost
J-14&19	On farm irrigation audit	Does not directly conserve water	Primarily labor cost
J-15, 20 & 21	Low pressure center pivot sprinkler systems	70% to 95% application efficiency	$300 to $500 per acre

4.6.1 Irrigation Scheduling (Strategy J-11 & 16)

Irrigation scheduling is the act of scheduling the time and amount of water applied to a crop based on the amount of water present in the crop root zone, the amount of water consumed by the crop since the last irrigation, and other management considerations such as salt leaching requirements, deficit irrigation, and crop yield relationships. Irrigation scheduling is a water management strategy that reduces the chance of under or over watering an irrigated crop. Some common irrigation scheduling methods are:

1) Direct measurement of soil moisture content, soil water potential, or crop stress including: soil sampling, tensiometers, gypsum blocks, infrared photography of crop canopy, time domain reflectrometry, plant leaf water potential, and other methods.
2) Soil Water Balance Equations: Irrigation methods based on soil water balance equations. These equations range from simple accounting methods to complex computer models that require input of climatic measurements such as temperature, humidity, solar radiation, and wind speed.

The amount of water saved by implementing advanced irrigation scheduling is difficult to quantify, likely varies from year to year, and is strongly influenced by climatic variation, cropping practices, irrigation water quality, and total amount of water used to irrigate. The cost for implementing advanced irrigation scheduling methods depends on the method of scheduling used and the number of fields scheduled, the type of scheduling program, and the cost for technical assistance.

4.6.2 Volumetric Measurement of Irrigation Water Use (Strategy J-12 & 17)

The volumetric measurement of irrigation water use provides information needed to assess the performance of an irrigation system and better manage an irrigated crop. There are numerous types of volume measurement methods that can be used to either directly measure the amount of water used or to estimate the amounts from secondary information. The following lists direct and indirect methods:

1) Direct measurement methods usually require either the installation of a flow meter or the periodic manual measurements of flow. Common direct measurement systems for closed conduits (pipelines) are:
   - Propeller meters
   - Orifice, venturi or differential pressure meters
   - Magnetic flux meters (both insertion and flange mount)
   - Ultrasonic (travel time method)

   Common methods for direct measurement of flow in open channels are:
   - Various Types of Weirs and Flumes
   - Stage Discharge Rating Tables
   - Area/Point Velocity Measurements
   - Ultrasonic (Doppler and travel time methods)

2) Indirect measurement methods estimate the volume of water used for irrigation from the amount of energy used, irrigation equipment operating or design information, irrigation water pressure, or other information. Indirect measurements require the correlation of energy use, water pressure, system design specifications, or other parameters to the amount of water used during the irrigation or to the flow rate of the irrigation system. Several common indirect measurements for irrigation systems are:
   - Measurement of energy used by a pump supplying water
   - Measurement of end-pressure in a sprinkler irrigation system
   - Change in the elevation of water stored in a water supply reservoir
   - Measurement of time of irrigation and size of irrigation delivery system

This BMP is used in coordination with other BMPs and in itself does not directly conserve water. However, the information gained helps better inform the user of costs associated with water use and will assist the user in implementing voluntary conservation measures.

4.6.3 Crop Residue Management and Conservation Tillage (Strategy J-13 & 18)

Residue management and conservation tillage allow for the management of the amount, orientation and distribution of crop and other plant residue on the soil surface year-round on crops grown where the entire field surface is tilled prior to planting. Conservation tillage can include no till, strip till, mulch tillage, and ridge till and generally improves the ability of the soil to hold moisture, reduces the amount of water that runs off the field, and reduces evaporation of water from the soil surface.

The amount of water saved by conservation tillage will vary by climate and irrigation method. Increased spring soil moisture content resulting from conservation tillage may allow a farmer to conserve one or more irrigation applications per year (typically 0.25 to 0.50 acre-feet per acre). Reduction in soil moisture loss during the irrigation season may save an additional 0.5 acre-foot per acre. The cost of conservation tillage depends on the type of field operation used to manage crop residues. Some conservation tillage programs are less expensive than conventional tillage.

4.6.4 On-Farm Irrigation Audit (Strategy J-14 & 19)

Water audits are an effective method of accounting for all water usage for on-farm irrigation and to identify opportunities to improve water use efficiency. Benefits from implementation may also include energy savings and reduced chemical costs. On-farm irrigation audits include measurement of water entering the farm or withdrawn from an aquifer, the inventory and calculation of on-farm water uses, calculation of water-related costs, and identification of potential water efficiency measures.

The conservation program may consist of one or more projects in different areas of the agricultural operation. The audit will consist of gathering information on the following: field size(s) and shape, obstructions, topography, flood vulnerability, water table, and access for operation and maintenance; type of pump equipment and energy source and pumping efficiency, if any; type of irrigation equipment, age and general state of repair; records of previous and current crops and water use; human assets, available technical ability and language skills of laborers; and time and skill level of management personnel.

On-farm irrigation audits do not directly save any water but helps identify other agricultural water conservation BMPs that may be implemented by the agricultural water user to save water. The cost of a farm audit varies from minimal to significant with the extent of the audit and if the audit is done internally, by a consultant, or using assistance from a governmental entity. The Texas State Soil and Water Conservation Board prepares Water Quality Management Plans which often address water conservation measures for agricultural land, and the NRCS can assist agricultural water user in implementing conservation plans.

4.6.5 Low Pressure Center Pivot Sprinkler Irrigation Systems (Strategy J-15 & 20 & 21)

The four types of Center Pivot Sprinkler Irrigation Systems that are commonly considered to be low-pressure systems and BMPs are:

1) Low Energy Precision Application ("LEPA")

2) Low Pressure In-Canopy ("LPIC")

3) Low Elevation Spray Application ("LESA")

4) Medium Elevation Spray Application ("MESA")

All four systems are low-pressure sprinkler systems (with typical pressures at the outer end of the center pivot ranging from 10 to 25 psig) and use fixed sprinkler applicators or nozzles or drop tubes or a combination of both to apply water. Center Pivots equipped with high or medium pressure (greater than 25 psig) impact sprinkler heads have lower water application efficiencies than low-pressure systems. Care should be taken to match water application rates to soil intake rates to minimize water runoff. Each of these LPCP systems can be combined with cultural practices necessary to prevent runoff during irrigation or moderate rainfall events. LEPA systems combine the LPCP system BMP with the Furrow Dikes BMP and the practice of farming with the row direction perpendicular to the direction of travel of the center pivot (i.e. farming in a circle).

The amount of water saved from converting a conventional center pivot sprinkler irrigation system to a BMP center pivot sprinkler irrigation system (i.e. LPCP system) can be estimated using the following equation:

$$\text{Water Saved (acre-feet per year)} = A1 \times (1 - E1/E2)$$

Where A1 is the annual amount of water pumped or delivered to the inlet of the non-BMP center pivot sprinkler system, E1 is the application efficiency of the non-BMP center pivot sprinkler system, and E2 is the application efficiency of the BMP center pivot sprinkler system. E1 and E2 can be directly measured or obtained from estimated values in available tables.

The amount of water saved is also affected by: environmental conditions during irrigation, the amount of runoff that occurs during irrigation (soil slopes, soil texture, cropping practices), and the time of irrigation (i.e. pre-plant irrigation versus irrigation once the crop canopy is established). The cost for purchase and installation of center pivot systems is typically $300 to $500 per acre. The cost per acre-foot can be estimated by dividing the estimated quantity of water conserved (acre-feet per acre) by the cost per acre of the system ($ per acre-foot). Estimated water savings and capital cost for the installation of sprinkler systems to meet irrigation demand shortages in Bandera and Kerr Counties is shown in the Table 4-7.

TABLE 4- 7 ESTIMATED IRRIGATION AND WATER CONSERVATION COST

County	Basin	Total Acres Irrigated in Year 2010	Average Application Rate (ac-ft/ac)	Irrigated Acres without Sprinklers[1]	Sprinkler Conser-vation Potential per Acre[2] (ac-ft)	Estimated Conser-vation in Year 2000 (ac-ft/yr)	Capital Cost to Install Sprinklers[3]	Annual Cost Amortized over 25 Years @ 6%
Bandera	San Antonio	163	1.9	4	0.61	3	$1,600	$124
	Nueces	81	1.9	2	0.61	1	$800	$62
Kerr	Guadalupe	1,047	1.7	3	0.61	2	$1,200	$93

[1] Source: TWDB Report 347.
[2] Average water savings per acre as calculated by the High Plains Underground Water Conservation District No.1.
[3] Estimated at $400 per acre.

4.7 BRUSH MANAGEMENT AND LAND STEWARDSHIP

Selective Brush Management, as a tool to improve watershed yields and water quality, is a strategy of great interest in the Plateau Region, as well as in surrounding planning regions. Funding and direction is needed to expedite multi-disciplinary research to develop methodologies of defining watersheds of greatest potential for increasing water yields. Teams of geologists, hydrologists, ecologists, wildlife biologists, economists and rangeland scientists working with GIS and various types of aerial photography would have the highest probability of developing tools to identify and quantify the best yielding watersheds for treatment. These studies would estimate the cost-benefit ratios of this Best

Management Practice (BMP) including cost of initial brush management; ecological benefits; grazing benefits; reseeding costs, if necessary; and other range management BMPs as needed to restore brush-infested rangelands while preserving or enhancing wildlife and esthetic values. The end product would quantify both the short-term and long-term costs and benefits per acre-foot of water to such a regional program. Downstream and aquifer users in urban areas would possibly be major beneficiaries and as such should be part of the final equation and possibly part of the funding mechanism. Studies should be of a realistic, large-scale size in order to more accurately correlate with full-scale watershed treatments.

Currently, Texas Parks & Wildlife Department (TPWD) has a program specifically directed at utilizing BMPs for landowners involving brush management in areas possibly containing endangered species. As has been proven on the Kerr Wildlife Management Area (TPWD) with long-term studies, selective brush management coupled with good rangeland management can benefit endangered species and ranchers as well. It is highly likely that watershed values will fit into the same package to provide a win-win situation for all. The voluntary partnership of landowners and TPWD is important to this program, just as it was under the NRCS' Great Plains Program. However, as major parts of targeted watersheds must be treated in order to provide the desired hydrological benefits, it is likely that a high percentage of watershed landowners must opt-in to the program before it could be accepted by the State for treatment and management contracts.

The PWPG further endorses the overall concept of good voluntary land stewardship. Land stewardship recognizes that the relationship between the land's condition and the quality and quantity of water available to all Texans is inextricably linked. In fact, good land stewardship encompasses a myriad of activities far beyond brush control.

4.8 DESALINATION POTENTIAL

The Trinity aquifer in eastern Bandera and Kerr Counties is identified in Chapter 3 Section 3.2.10 as being the most likely brackish groundwater source that might be desalinated to produce drinking water of acceptable quality. However, low productivity from this aquifer source makes desalination a marginal option at this time. Thus no desalination strategies are recommended in this current plan. However, the option should remain as a consideration under appropriate circumstances.

4.9 EXPORT OF GROUNDWATER

The PWPG considered the issue of groundwater export. No projects entailing groundwater export from the Plateau Region to markets outside the Region have reached a contractual stage to warrant bringing them before the Group for consideration. However, there are two projects in Kinney County that are currently being marketed. Although these two projects are not included in this plan as inter-regional management strategies, the PWPG did begin the process of considering potential aquifer impacts.

The TWDB provided funding to the PWPG to evaluate the potential effect that pumping might have on springs and subsequent base flow to rivers and streams. The study included a survey and characterization of 73 springs in Kinney and Val Verde Counties. Several pumping scenarios were run using the TWDB Edwards-Trinity (Plateau) aquifer groundwater availability model (GAM). The aquifer simulation model was run by increasing pumping withdrawals at set intervals until reasonably acceptable levels of impact to surface water drains (non-specified springs) were observed. For regional planning purposes, this exercise resulted in a maximum pumping level from the Edwards-Trinity (Plateau) aquifer in Kinney County of 22,432 ac-ft per year. However, it is important to recognize that this amount of pumping is assumed to be evenly spaced over the extent of the aquifer. Concentrating pumping in smaller areas could increase the impact potential on springs in the immediate vicinity. Also, these model runs assumed average rainfall/recharge conditions. Less then normal recharge would intensify the pumping impact. A report of the findings from this study, titled *Springs of Kinney and Val Verde Counties* (Ashworth and Stein, 2005), was prepared for the PWPG (see Chapter 3 - Appendix 3F).

4.10 EMERGENCY TRANSFER CONSIDERATIONS

The Texas Legislature has established a statute (Texas Water Code 11.139) by which non-municipal surface-water rights may temporarily be interrupted to make water available for public-supply needs during times of emergencies. The intent of the statute is to reduce the health and safety impact to communities that have run short of water because of unexpected circumstances. The statute was specifically enacted as an emergency process to bring relief to several communities that had been affected by drought conditions that had severely diminished their water-supply sources. The PWPG considered the potential for emergency transfer of surface water for communities in the region and chose not to recommend this strategy for this planning period.

APPENDIX 4A

SOCIOECONOMIC IMPACTS OF

UNMET WATER NEEDS

Socioeconomic Impacts of Unmet Water Needs in the Plateau Water Planning Area

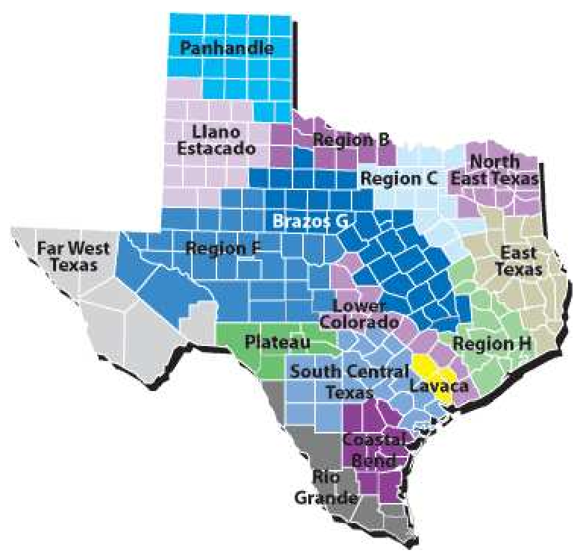
Prepared by:

Stuart Norvell and Kevin Kluge of The Texas Water Development Board's Office of Water Resources Planning

Prepared in support of the:

Plateau Regional Water Planning Group and the 2006 Texas State Water Plan

May 2005



Tables

Executive Summary

Background

Water shortages due to severe drought combined with infrastructure limitations would likely curtail or eliminate economic activity in business and industries heavily reliant on water. For example, without water farmers cannot irrigate; refineries cannot produce gasoline and paper mills cannot make paper. Unreliable water supplies would not only have an immediate and real impact on business and industry, but they might also bias corporate decision makers against plant expansion or plant location in Texas. From a societal perspective, water supply reliability is critical as well. Shortages would disrupt activity in homes, schools and government and could adversely affect public health and safety. For all of the above reasons, it is important to analyze and understand how restricted water supplies during drought could affect communities throughout the state.

Section 357.7(4) of the rules for implementing Texas Senate Bill 1 requires regional water planning groups to evaluate the social and economic impacts of projected water shortages (i.e., "unmet water needs") as part of the planning process. The rules contain provisions that direct the Texas Water Development Board (TWDB) to provide technical assistance to complete socioeconomic impact assessments. In response to requests from regional planning groups, staff of the TWDB's Office of Water Resources Planning designed and conducted analyses to evaluate socioeconomic impacts of unmet water needs.

Overview of Methodology

Two components make up the overall approach to this study: 1) an economic impact module and 2) a social impact module. Economic analysis addresses potential impacts of unmet water needs including effects on residential water consumers and losses to regional economies stemming from reductions in economic output for agricultural, industrial and commercial water uses. Impacts to agriculture, industry and commercial enterprises were estimated using regional "input-output" models commonly used by researchers to estimate how reductions in business activity might affect a given economy. Estimated impacts are *independent* and distinct "what if" scenarios for a given point in time (i.e., 2010, 2020, 2030, 2040, 2050 and 2060). Reported figures are scenarios that illustrate what could happen in a given year if: 1) water supply infrastructure and/or water management strategies do not change through time, 2) the drought of record recurs. Details regarding the methodology and assumptions for individual water use categories (i.e., municipal consumers including residential and commercial water users, manufacturing, steam-electric, mining, and agriculture) are in the main body of the report.

The social component focuses on demographic effects including changes in population and school enrollment. Methods are based on population projection models developed by the TWDB for regional and state water planning. With the assistance of the Texas State Data Center, TWDB staff modified these models and applied them for use here. Basically, the social impact module incorporates results from the economic impact module and assesses how changes in a region's economy due to water shortages could affect patterns of migration in a region.

Summary of Results

Table E-1 and Figure E-1 summarize estimated economic impacts. Variables shown include:[1]

- **sales** - economic output measured by sales revenue;
- **jobs -** number of full and part-time jobs required by a given industry including self-employment;
- **regional income -** total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income and interest payments for the region; and
- **business taxes -** sales, excise, fees, licenses and other taxes paid during normal operation of an industry (does not include any type of income tax).

If drought of record conditions return and water supplies are not developed, study results indicate that the Region J Water Planning Area would suffer significant losses. If such conditions occurred 2010 lost income to residents in the region could total $6 million with associated job losses as high 50. State and local governments could lose $0.14 million in tax receipts. If such conditions occurred in 2060, income losses could run $9.35 million, and job losses could be as high 70. Nearly $0.18 million worth of state and local taxes could be lost. Reported figures are probably conservative because they are based on estimated costs for a single year; however, in much of Texas, the drought of record lasted several years. For example, in 2030 models indicate that shortages would cost residents and businesses in the region $8.09 million in lost income. Thus, if shortages lasted for three years total losses related to unmet needs could easily approach $24.2 million.

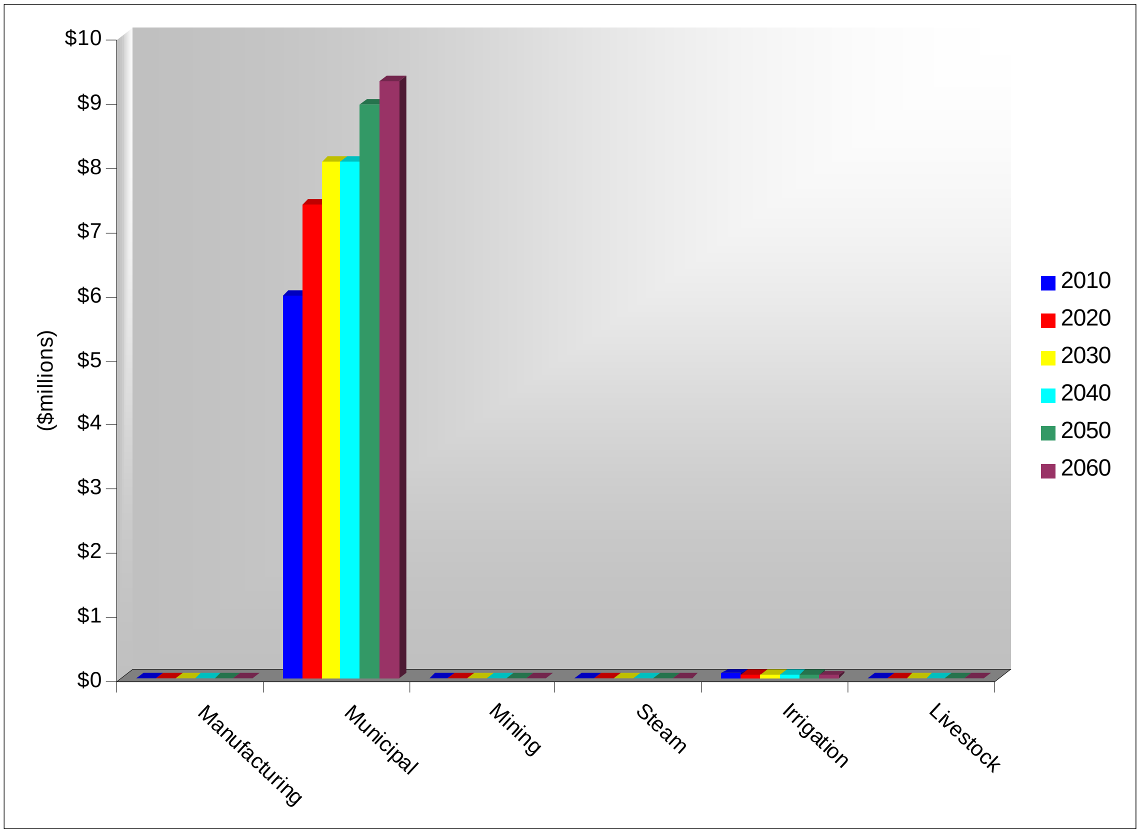
Table E-1: Annual Economic Impacts of Unmet Water Needs
(years, 2010, 2020, 2030, 2040, 2050 and 2060, constant year 2000 dollars)

Year	Sales ($millions)	Income* ($millions)	Jobs	State and Local Taxes ($millions)
2010	$4.18	$6.01	50	$0.14
2020	$5.07	$7.44	59	$0.16
2030	$5.43	$8.09	63	$0.16
2040	$5.36	$8.10	63	$0.16
2050	$6.07	$8.98	70	$0.17
2060	$6.28	$9.35	71	$0.18

* Lost income includes costs associated with unmet domestic water needs. Source: Texas Water Development Board, Office of Water Resources Planning

[1] Total sales are not a good measure of economic prosperity because they include sales to other industries for further processing. For example, a farmer sells rice to a rice mill, which the rice mill processes and sells it to another consumer. Both transactions are counted in an input-output model. Thus, total sales "double count." Regional income plus business taxes are more suitable because they are a better measure of net economic returns.

Figure E-1: Distribution of Lost Income by Water Use Category
(years, 2010, 2020, 2030, 2040, 2050 and 2060, constant year 2000 dollars)



Source: Analysis of the Texas Water Development Boards, Office of Water Resource Planning

Table E-2 shows potential losses in population and school enrollment. Changes in population stem directly from the number of lost jobs estimated as part of the economic impact module. In other words, many – but not all – people would likely relocate due to a job loss and some have families with school age children. Section 1.3 in the main body of the report discusses methodology in detail.

Table E-2: Estimated Regional Social Impacts of Unmet Water Needs
(years, 2010, 2020, 2030, 2040, 2050 and 2060)

Year	Population Losses	Declines in School Enrollment
2010	85	25
2020	100	28
2030	110	30
2040	110	30
2050	120	35
2060	125	35

Source: Based on models developed by the Texas Water Development Board, Office of Water Resources Planning and the Texas State Data Center.

Introduction

Texas is one the nation's fastest growing states. From 1950 to 2000, population in the state grew from about 8 million to nearly 21 million. By the year 2050, the total number of people living in Texas is expected to reach 40 million. Rapid growth combined with Texas' susceptibility to severe drought makes water supply a crucial issue. If water infrastructure and water management strategies are not improved, Texas could face serious social, economic and environmental consequences - not only in our large metropolitan cities, but also on our farms and rural areas.

Water shortages due to severe drought combined with infrastructure limitations would likely curtail or eliminate economic activity in business and industries heavily reliant on water. For example, without water farmers cannot irrigate; refineries cannot produce gasoline and paper mills cannot make paper. Unreliable water supplies would not only have an immediate and real impact on business and industry, but they might also bias corporate decision makers against plant expansion or plant location in Texas. From a societal perspective, water supply reliability is critical as well. Shortages would disrupt activity in homes, schools and government and could adversely affect public health and safety. For all of the above reasons, it is important to analyze and understand how restricted water supplies during drought could affect communities throughout the state.

Section 357.7(4) of the rules for implementing Texas Senate Bill 1 requires regional water planning groups to evaluate the social and economic impacts of unmet water needs as part of the planning process. The rules contain provisions that direct the Texas Water Development Board (TWDB) to provide technical assistance to complete socioeconomic impact analyses. In response to requests from regional planning groups, TWDB staff designed and conducted required studies. The following document prepared by the TWDB's Office of Water Resources Planning summarizes analysis and results for the Plateau Water Planning Area (Region J). Section 1 provides an overview of concepts and methodologies used in the study. Sections 2 and 3 provide detailed information and analyses for each water use category employed in the planning process (i.e., irrigation, livestock, municipal, manufacturing, mining and steam-electric).

1. Overview of Terms and Methodology

Section 1 provides a general overview of how economic and social impacts were measured. In addition, it summarizes important clarifications, assumptions and limitations of the study.

1.1 Measuring Economic Impacts

Economic analysis as it relates to water resources planning generally falls into two broad areas. Supply side analysis focuses on costs and alternatives of developing new water supplies or implementing programs that provide additional water from current supplies. Demand side analysis concentrates on impacts and benefits of providing water to people, businesses and the environment. Analysis in this report focuses strictly on demand side impacts. Specifically, it addresses the potential economic impacts of unmet water needs including: 1) losses to regional economies stemming from reductions in economic output, and 2) costs to residential water consumers associated with implementing emergency water procurement and conservation programs.

1.1.1 Impacts to Agriculture, Business and Industry

As mentioned earlier, severe water shortages would likely affect the ability of business and industry to operate resulting in lost output, which would adversely affect the regional economy. A variety tools are available to estimate such impacts, but by far, the most widely used today are input-output models (IO models) combined with social accounting matrices (SAMs). Referred to as IO/SAM models, these tools formed the basis for estimating economic impacts for agriculture (irrigation and livestock water uses) and industry (manufacturing, mining, steam-electric and commercial business activity for municipal water uses).

Basically, an IO/SAM model is an accounting framework that traces spending and consumption between different economic sectors including businesses, households, government and "foreign" economies in the form of exports and imports. As an example, Table 1 shows a highly aggregated segment of an IO/SAM model that focuses on key agricultural sectors in a local economy. The table contains transactions data for three agricultural sectors (cattle ranchers, dairies and alfalfa farms). Rows in Table 1 reflect sales from each sector to other local industries and institutions including households, government and consumers outside of the region in the form of exports. Columns in the table show purchases by each sector in the same fashion. For instance, the dairy industry buys $11.62 million worth of goods and services needed to produce milk. Local alfalfa farmers provide $2.11 million worth of hay and local households provide about $1.03 million worth of labor. Dairies import $4.17 million worth of inputs and pay $2.61 million in taxes and profits. Total economic activity in the region amounts to about $807.45 million. The entire table is like an accounting balance sheet where total sales equal total purchases.

Table 1: Example of a County-level Transaction and Social Accounting Matrix for Agricultural Sectors ($millions)

Sectors	Cattle	Dairy	Alfalfa	All other Industries	Taxes, govt. & profits	Households	Exports	Total
Cattle	$3.10	$0.01	$0.00	$0.03	$0.02	$0.06	$10.76	$13.98
Dairy	$0.07	$0.13	$0.00	$0.25	$0.01	$0.00	$11.14	$11.60
Alfalfa	$0.00	$2.11	$0.00	$0.01	$0.02	$0.01	$10.38	$12.53
Other industries	$2.20	$1.56	$2.90	$50.02	$70.64	$66.03	$48.48	$241.83
Taxes, govt. & profits	$2.37	$2.61	$5.10	$77.42	$0.23	$49.43	$83.29	$220.45
Households	$0.82	$1.03	$1.38	$50.94	$45.36	$7.13	$14.64	$121.30
Imports	$5.41	$4.17	$3.16	$63.32	$104.17	$5.53	$0.00	$185.76
Total	$13.97	$11.62	$12.54	$241.99	$220.45	$128.19	$178.69	$807.45

* Columns contain purchases and rows represent sales. Source: Adapted from Harris, T.R., Narayanan, R., Englin, J.E., MacDiarmid, T.R., Stoddard, S.W. and Reid, M.E. "*Economic Linkages of Churchill County.*" University of Nevada Reno. May 1993.

To understand how an IO/SAM model works, first visualize that $1 of additional sales of milk is injected into the dairy industry in Table 1. For every $1 the dairies receive in revenue, they spend 18 cents on alfalfa to feed their cows; nine cents is paid to households who provide farm labor, and another 13 cents goes to the category "other industries" to buy items such as machinery, fuel, transportation, accounting services etc. Nearly 22 cents is paid out in the form of profits (i.e., returns to dairy owners) and taxes/fees to local, state and federal government. The value of the initial $1 of revenue in the dairy sector is referred to as a first-round or **direct effect.**

As the name implies, first-round or direct effects are only part of the story. In the example above, alfalfa farmers must make 18 cents worth of hay to supply the increased demand for their product. To do so, they purchase their own inputs, and thus, they spend part of the original 18 cents that they received from the dairies on firms that support their own operations. For example, 12 cents is spent on fertilizers and other chemicals needed to grow alfalfa. The fertilizer industry in turn would take these 12 cents and spend them on inputs in its production process and so on. The sum of all re-spending is referred to as the **indirect effect** of an initial increase in output in the dairy sector.

While direct and indirect impacts capture how industries respond to a change, **induced impacts** measure the behavior of the labor force. As demand for production increases, employees in base industries and supporting industries will have to work more; or alternatively, businesses will have to hire more people. As employment increases, household spending rises. Thus, seemingly unrelated businesses such as video stores, supermarkets and car dealers also feel the effects of an initial change.

Collectively, indirect and induced effects are referred to as **secondary impacts**. In their entirety, all of the above changes (direct and secondary) are referred to as **total economic impacts**. By nature, total impacts are greater than initial changes because of secondary effects. The magnitude of the increase is what is popularly termed a multiplier effect. Input-output models generate numerical multipliers that estimate indirect and induced effects.

In an IO/SAM model impacts stem from changes in output measured by sales revenue that in turn come from changes in consumer demand. In the case of water shortages, one is not assuming a change in demand, but rather a supply shock – in this case severe drought. Demand for a product such as corn has not necessarily changed during a drought. However, farmers in question lack a crucial input (i.e., irrigation water) for which there is no *short-term* substitute. Without irrigation, she cannot grow irrigated crops. As a result, her cash flows decline or cease all together depending upon the severity of the situation. As cash flows dwindle, the farmer's income falls, and she has to reduce expenditures on farm inputs such as labor. Lower revenues not only affect her operation and her employees directly, but they also indirectly affect businesses who sell her inputs such as fuel, chemicals, seeds, consultant services, fertilizer etc.

The methodology used to estimate regional economic impacts consists of three steps: 1) develop IO/SAM models for each county in the region and for the region as whole, 2) estimate direct impacts to economic sectors resulting from water shortages, and 3) calculate total economic impacts (i.e., direct plus secondary effects).

Step 1*: Generate IO/SAM Models and Develop Economic Baseline*

IO/SAM models were estimated using propriety software known as IMPLAN PRO™ (Impact for Planning Analysis). IMPLAN is a modeling system originally developed by the U.S. Forestry Service in the late 1970s. Today, the Minnesota IMPLAN Group (MIG Inc.) owns the copyright and distributes data and software. It is probably the most widely used economic impact model in existence. IMPLAN comes with databases containing the most recently available economic data from a variety of sources.[1] Using IMPLAN software and data, transaction tables conceptually similar to the

[1] The basic IMPLAN database consists of national level technology matrices based on the Benchmark Input-Output Accounts generated the U.S. Bureau of Economic Analysis and estimates of final demand, final payments, industry output and employment for various economic sectors. IMPLAN's regional data (i.e. states, a counties or groups of counties within a state) are divided into two basic categories: 1) data on an industry basis including value-added, output and employment and 2) data on a commodity basis including final demands and institutional sales. State-level data are balanced to the national totals using a matrix ratio allocation system and county data are balanced to state totals. In other words, much of the data in IMPLAN is based on a national average for all industries.

one discussed previously (see Table 1 on page 9) were estimated for each county in the region and for the region as a whole. Each transaction table contains 528 economic sectors and allows one to estimate a variety of economic statistics including:

- **total sales -** total production measured by sales revenues;
- **intermediate sales -** sales to other businesses and industry within a given region;
- **final sales –** sales to end users in a region and exports out of a region;
- **employment -** number of full and part-time jobs (annual average) required by a given industry including self-employment;
- **regional income -** total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income and interest payments; and
- **business taxes -** sales, excise, fees, licenses and other taxes paid during normal operation of an industry (does not include income taxes).

TWDB analysts developed an economic baseline containing each of the above variables using year 2000 data. Since the planning horizon extends through 2060, economic variables in the baseline were allowed to change in accordance with projected changes in demographic and economic activity. Growth rates for municipal water use sectors (i.e., commercial, residential and institutional) are based on TWDB population forecasts. Projections for manufacturing, agriculture, and mining and steam-electric activity are based on the same underlying economic forecasts used to estimate future water use for each category. Monetary impacts in future years are reported in year 2000 dollars.

It is important to stress that employment, income and business taxes are the most useful variables when comparing the relative contribution of an economic sector to a regional economy. Total sales as reported in IO/SAM models are less desirable and can be misleading because they include sales to other industries in the region for use in the production of other goods. For example, if a mill buys grain from local farmers and uses it to produce feed, sales of both the processed feed and raw corn are counted as "output" in an IO model. Thus, total sales double-count or overstate the true economic value of goods and services produced in an economy. They are not consistent with commonly used measures of output such as Gross National Product (GNP), which counts only final sales.

Another important distinction relates to terminology. Throughout this report, the term *sector* refers to economic subdivisions used in the IMPLAN database and resultant input-output models (528 individual sectors based on Standard Industrial Classification Codes). In contrast, the phrase *water use category* refers to water user groups employed in state and regional water planning including irrigation, livestock, mining, municipal, manufacturing and steam electric. All sectors in the IMPLAN database were assigned to a specific water use category (see Attachment A of this report).

Step 2: *Estimate Direct Economic Impacts of Water Shortages*

As mentioned above, direct impacts accrue to immediate businesses and industries that rely on water. Without water industrial processes could suffer. However, output responses would likely vary depending upon the severity of a shortage. A small shortage relative to total water use may have a nominal effect, but as shortages became more critical, effects on productive capacity would increase.

For example, farmers facing small shortages might fallow marginally productive acreage to save water for more valuable crops. Livestock producers might employ emergency culling strategies, or they may consider hauling water by truck to fill stock tanks. In the case of manufacturing, a good example occurred in the summer of 1999 when Toyota Motor Manufacturing experienced water shortages at a facility near Georgetown, Kentucky. As water levels in the Kentucky River fell to historic lows due to drought, plant managers sought ways to curtail water use such as reducing rinse operations to a bare minimum and recycling water by funneling it from paint shops to boilers. They even considered trucking in water at a cost of 10 times what they were paying. Fortunately, rains at the end of the summer restored river levels, and Toyota managed to implement cutbacks without affecting production. But it was a close call. If rains had not replenished the river, shortages could have severely reduced output.[1]

Note that the efforts described above are not planned programmatic or long-term operational changes. They are emergency measures that individuals might pursue to alleviate what they consider a temporary condition. Thus, they are not characteristic of long-term management strategies designed to ensure more dependable water supplies such as capital investments in conservation technology or development of new water supplies.

To account for uncertainty regarding the relative magnitude of impacts to farm and business operations, the following analysis employs the concept of elasticity. Elasticity is a number that shows how a change in one variable will affect another. In this case, it measures the relationship between a percentage reduction in water availability and a percentage reduction in output. For example, an elasticity of 1.0 indicates that a 1.0 percent reduction in water availability would result in a 1.0 percent reduction in economic output. An elasticity of 0.50 would indicate that for every 1.0 percent of unavailable water, output is reduced by 0.50 percent and so on. Output elasticities used in this study are:[2]

- if unmet water needs are 0 to 5 percent of total water demand, no corresponding reduction in output is assumed;

- if water shortages are 5 to 30 percent of total water demand, for every 1.0 one percent of unmet need, there is a corresponding 0.25 percent reduction in output;

- if water shortages are 30 to 50 percent of total water demand, for every 1.0 one percent of unmet need, there is a corresponding 0.50 percent reduction in output; and

- if water shortages are greater than 50 percent of total water demand, for every 1.0 one percent of unmet need, there is a corresponding 1.0 percent (i.e., a proportional reduction).

[1] See, Royal, W. "*High And Dry - Industrial Centers Face Water Shortages*." in Industry Week, Sept, 2000.

[2] Elasticities are based on one of the few empirical studies that analyze potential relationships between economic output and water shortages in the United States. The study, conducted in California, showed that a significant number of industries would suffer reduced output during water shortages. Using a survey based approach researchers posed two scenarios to different industries. In the first scenario, they asked how a 15 percent cutback in water supply lasting one year would affect operations. In the second scenario, they asked how a 30 percent reduction lasting one year would affect plant operations. In the case of a 15 percent shortage, reported output elasticities ranged from 0.00 to 0.76 with an average value of 0.25. For a 30 percent shortage, elasticities ranged from 0.00 to 1.39 with average of 0.47. For further information, see, California Urban Water Agencies, "*Cost of Industrial Water Shortages*." Prepared by Spectrum Economics, Inc. November, 1991.

Once output responses to water shortages were estimated, direct impacts to total sales, employment, regional income and business taxes were derived using regional level economic multipliers estimating using IO/SAM models. When calculating direct effects for the municipal, steam electric, manufacturing and livestock water use categories, sales to final demand were applied to avoid double counting impacts. The formula for a given IMPLAN sector is:

$$D_{i,t} = Q_{i,t} *_{,} S_{i,t} * E_Q * RFD_i * DM_{i(Q, L, I, T)}$$

where:

$D_{i,t}$ = direct economic impact to sector *i* in period *t*

$Q_{i,t}$ = total sales for sector *i* in period *t* in an affected county

$RFD_{i,}$ = ratio of final demand to total sales for sector *i* for a given region

$S_{i,t}$ = water shortage as percentage of total water use in period *t*

E_Q = elasticity of output and water use

$DM_{i(L, I, T)}$ = direct output multiplier coefficients for labor (L), income (I) and taxes (T) for sector *i*.

Direct impacts to irrigation and mining are based upon the same formula; however, total sales as opposed to final sales were used. To avoid double counting, secondary impacts in sectors other than irrigation and mining (e.g., manufacturing) were reduced by an amount equal to or less than direct losses to irrigation and mining. In addition, in some instances closely linked sectors were moved from one water use category to another. For example, although meat packers and rice mills are technically manufacturers, in some regions they were reclassified as either livestock or irrigation. All direct effects were estimated at the county level and then summed to arrive at a regional figure. See Section 2 of this report for additional discussion regarding methodology and caveats used when estimating direct impacts for each water use category.

Step 3: *Estimate Secondary and Total Economic Impacts of Water Shortages*

As noted earlier, the effects of reduced output would extend well beyond sectors directly affected. Secondary impacts were derived using the same formula used to estimate direct impacts; however, regional level *indirect* and *induced* multiplier coefficients were applied and only final sales were multiplied.

1.1.2 Impacts Associated with Domestic Water Uses

IO/SAM models are not well suited for measuring impacts of shortages for domestic uses, which make up the majority of the municipal category.[1] To estimate impacts associated with domestic uses, municipal water demand and thus needs were subdivided into two categories – residential and commercial. Residential water is considered “domestic” and includes water that people use in their homes for things such as cooking, bathing, drinking and removing household waste and for outdoor purposes including lawn watering, car-washing and swimming pools. Shortages to residential uses were valued using a tiered approach. In other words, the more severe the shortage, the more costly it

[1] A notable exception is the potential impacts to the nursery and landscaping industry that could arise due to reductions in outdoor residential uses and impacts to “water intensive” commercial businesses (see Section 2.3.3).

becomes. For instance, a 2 acre-foot shortage for a group of households that use 10 acre-feet per year would not be as severe as a shortage that amounted to 8 acre-feet. In the case of a 2 acre-foot shortage, households would probably have to eliminate some or all outdoor water use, which could have implicit and explicit economic costs including losses to the horticultural and landscaping industry. In the case of an 8 acre-foot shortage, people would have to forgo all outdoor water use and most indoor water consumption. Economic costs would be much higher in this case because people could probably not live with such a reduction, and would be forced to find emergency alternatives. The alternative assumed in this study is a very uneconomical and worst-case scenario (i.e., hauling water in from other communities by truck or rail). Section 2.3.3 of this report discusses methodology for municipal uses in greater detail.

1.2 Measuring Social Impacts

As the name implies, the effects of water shortages can be social or economic. Distinctions between the two are both semantic and analytical in nature – more so analytic in the sense that social impacts are much harder to measure in quantitative terms. Nevertheless, social effects associated with drought and water shortages usually have close ties to economic impacts. For example, they might include:

- demographic effects such as changes in population,
- disruptions in institutional settings including activity in schools and government,
- conflicts between water users such as farmers and urban consumers,
- health-related low-flow problems (e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations),
- mental and physical stress (e.g., anxiety, depression, domestic violence),
- public safety issues from forest and range fires and reduced fire fighting capability,
- increased disease caused by wildlife concentrations,
- loss of aesthetic and property values, and
- reduced recreational opportunities.[1]

Social impacts measured in this study focus strictly on demographic effects including changes in population and school enrollment. Methods are based on models used by the TWDB for state water planning and by the U.S. Census Bureau for national level population projections. With the assistance of the Texas State Data Center (TSDC), TWDB staff modified population projection models used for state water planning and applied them here. Basically, the social impact model incorporates results from the economic component of the study and assesses how changes in labor demand due to unmet water needs could affect migration patterns in a region. Before discussing particulars of the approach model, some background information regarding population projection models is useful in understanding the overall approach.

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[1] Based on information from the website of the National Drought Mitigation Center at the University of Nebraska Lincoln. Available online at: http://www.drought.unl.edu/risk/impacts.htm. See also, Vanclay, F. "*Social Impact Assessment*." in Petts, J. (ed) International Handbook of Environmental Impact Assessment. 1999.

1.2.1 Overview of Demographic Projection Models

More often than not, population projections are reported as a single number that represents the size of an overall population. While useful in many cases, a single number says nothing about the composition of projected populations, which is critical to public officials who must make decisions regarding future spending on public services. For example, will a population in the future have more elderly people relative to today, or will it have more children? More children might mean that more schools are needed. Conversely, a population with a greater percentage of elderly people may need additional healthcare facilities. When projecting future populations, cohort-survival models break down a population into groups (i.e., cohorts) based on factors such as age, sex and race. Once a population is separated into cohorts, one can estimate the magnitude and composition of future population changes.

Changes in a population's size and makeup in survival cohort models are driven by three factors:

1. *Births:* Obviously, more babies mean more people. However, only certain groups in a population are physically capable of bearing children– typically women between the ages of 13 and 49. The U.S. Census Bureau and the TSDC continually updates fertility rates for different cohorts. For each race/ethnicity category, birth rates decline and then stabilize in the future.

2. *Deaths:* When people die, populations shrink. Unlike giving birth, however, everyone is capable of dying and mortality rates are applied to all cohorts in a given population. Hence their name, cohort-survival models use survival rates as opposed to mortality rates. A survival rate is simply the probability that a given person with certain attributes (i.e., race, age and sex) will survive over a given period of time.

3. *Migration*: Migration is the movement of people in or out of a region. Migration rates used to project future changes in a region are usually based on historic population data. When analyzing historic data, losses or increases that are not attributed to births or deaths are assumed to be the result of migration. Migration can be further broken down into changes resulting from economic and non-economic factors. Economic migrants include workers and their families that relocate because of job losses (or gains), while non-economic migrants move due to lifestyles choices (e.g., retirees fleeing winter cold in the nation's heartland and moving to Texas).

In summary, knowledge of a population's composition in terms of age, sex and race combined with information regarding birth and survival rates, and migratory patterns, allows a great deal of flexibility and realism when estimating future populations. For example, an analyst can isolate population changes due to deaths and births from changes due to people moving in and out of a region. Or perhaps, one could analyze how potential changes in medical technology would affect population by reducing death rates among certain cohorts. Lastly, one could assess how changes in *economic conditions* might affect a regional population

1.2.2 Methodology for Social Impacts

Two components make up the model. The first component projects populations for a given year based on the following six steps:

1) *Separate "special" populations from the "general" population of a region:* The general population of a region includes the portion subject to rates of survival, fertility, economic migration and non-economic migration. In other words, they live, die, have children and can move in and out of a region freely. "Special populations," on the other hand, include college students, prisoners and military personnel. Special populations are treated differently than the general population. For example, fertility rates are not applied to prisoners because in general inmates at correctional facilities do not have children, and they are incapable of freely migrating or out of a region. Projections for special populations were compiled by the TSDC using data from the Higher Education Coordinating Board, the Texas Department of Criminal Justice and the U.S. Department of Defense. Starting from the 2000 Census, general and special populations were broken down into the following cohorts:

- age cohorts ranging from age zero to 75 and older,
- race/ethnicity cohorts, including Anglo, Black, Hispanic and "other," and
- gender cohorts (male and female).

2) *Apply survival and fertility rates to the general population* : Survival and fertility rates were compiled by the TSDC with data from the Texas Department of Health (TDH). Natural decreases (i.e., deaths) are estimated by applying survival rates to each cohort and then subtracting estimated deaths from the total population. Birth rates were then applied to females in each age and race cohort in general and special populations (college and military only) to arrive at a total figure for new births.

3) *Estimate economic migration based on labor supply and demand*: TSDC year 2000 labor supply estimates include all non-disabled and non-incarcerated civilians between the ages of 16 and 65. Thus, prisoners are not included. Labor supply for years beyond 2001 was calculated by converting year 2000 data to rates according to cohort and applying these rates to future years. Projected labor demand was estimated based on historical employment rates. Differences between total labor supply and labor demand determines the amount of in or out migration in a region. If supply is greater than demand, there is an out-migration of labor. Conversely, if demand is greater than supply, there is an in-migration of labor. The number of migrants does not necessarily reflect total population changes because some migrants have families. To estimate how many people might accompany workers, a migrant worker profile was developed based on the U.S. Census Bureau's Public Use Microdata Samples (PUMs) data. Migrant profiles estimate the number of additional family members, by age and gender that accompany migrating workers. Together, workers and their families constitute economic migration for a given year.

4) *Estimate non-economic migration*: As noted previously, migration patterns of individuals age 65 and older are generally independent of economic conditions. Retirees usually do not work, and when they relocate, it is primarily because of lifestyle preferences. Migratory patterns for people age 65 or older are based on historical PUMs data from the U.S. Census.

5) *Calculate ending population for a given year*: The total year-ending population is estimated by adding together: 1) surviving population from the previous year, 2) new births, 3) net economic migration, 4) net non-economic migration and 5) special populations. This figure serves as the baseline population for the next year and the process repeats itself.

The second component of the social impact model is identical to the first and includes the five steps listed above for each year where water shortages are reported (i.e., 2010, 2020, 2030, 2040, 2050 and 2060). The only difference is that labor demand changes in years with shortages. Shifts in labor demand stem from employment impacts estimated as part of the economic analysis component of this study with some slight modifications. IMPLAN employment data is based on the number of full and part-time jobs as opposed to the number of people working. To remedy discrepancies, employment impacts from IMPLAN were adjusted to reflect the number of people employed by using simple ratios (i.e., labor supply divided by number of jobs) at the county level. Declines in labor demand as measured using adjusted IMPLAN data are assumed to affect net economic migration in a given regional water planning area. Employment losses are adjusted to reflect the notion that some people would not relocate but would seek employment in the region and/or public assistance and wait for conditions to improve. Changes in school enrollment are simply the proportion of lost population between the ages of 5 and 17.

1.3 Clarifications, Assumptions and Limitations of Analysis

As with any attempt to measure and quantify human activities at a societal level, assumptions are necessary and every model has limitations. Assumptions are needed to maintain a level of generality and simplicity such that models can be applied on several geographic levels and across different economic sectors. In terms of the general approach used here several clarifications and cautions are warranted:

1) While useful for planning purposes, this study is not a benefit-cost analysis (BCA). BCA is a tool widely used to evaluate the economic feasibility of specific policies or projects as opposed to estimating economic impacts of unmet water needs. Nevertheless, one could include some impacts measured in this study as part of a BCA if done so properly.

2) Since this is not a BCA, future impacts are not weighted differently. In other words, estimates are not "discounted." If used as a measure of benefits in a BCA, one must consider the uncertainty of estimated monetary impacts.

3) All monetary figures are reported in constant year 2000 dollars.

4) Shortages reported by regional planning groups are the starting point for socioeconomic analyses. No adjustments or assumptions regarding the magnitude or distributions of unmet needs among different water use categories are incorporated in the analysis.

5) Estimated impacts are point estimates for years in which needs are reported (i.e., 2010, 2020, 2030, 2040, 2050 and 2060).They are independent and distinct "what if" scenarios for each particular year and water shortages are assumed to be temporary events resulting from severe drought conditions combined with infrastructure limitations. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals and resultant impacts are measured. Given, that reported figures are not cumulative in nature, it is inappropriate to sum impacts over the entire planning horizon. Doing so, would imply that the analysis predicts that drought of record conditions will occur every ten years in the future, which is not the case. Similarly, authors of this report recognize that in many communities needs are driven by population growth, and in the future total population will exceed the amount of water available due to infrastructure limitations, *regardless of whether or not there is a drought*. This implies that infrastructure limitations would constrain economic growth. However, since needs as defined by planning rules are based upon water supply and demand under the assumption of drought of record conditions, it improper to conduct economic analysis that focuses on growth related impacts over the planning horizon. Figures generated from such an analysis would presume a 50-year drought of record, which is unrealistic. Estimating lost economic activity related to constraints on population and commercial growth due to lack of water would require developing water supply and demand forecasts under "normal" or "most likely" future climatic conditions. *It is critical to stress that this is a modeling assumption necessary to maintain consistency with planning criteria, which states that water availability be evaluated assuming drought of record conditions. Analysis in this report does not predict that the drought of record will recur, nor does it predict or imply that growth will or should occur as projected.*

6) IO multipliers measure the strength of backward linkages to supporting industries (i.e., those who sell inputs to an affected sector). However, multipliers say nothing about forward linkages consisting of businesses that purchase goods from an affected sector for further processing. For example, ranchers in many areas sell most of their animals to local meat packers who process animals into a form that consumers ultimately see in grocery stores and restaurants. Multipliers do not capture forward linkages to meat packers, and since meat packers sell livestock purchased from ranchers as "final sales," multipliers for the ranching sector do fully account for all losses to a region's economy. Thus, as mentioned previously, in some cases closely linked sectors were moved from on water use category to another.

7) Cautions regarding interpretations of direct and secondary impacts are warranted. IO/SAM multipliers are based on "fixed-proportion production functions," which basically means that input use - including labor - moves in lockstep fashion with changes in levels of output. In a scenario where output (i.e., sales) declines, losses in the immediate sector or supporting sectors could be much less than predicted by an IO/SAM model for several reasons. For one, businesses will likely expect to continue operating so they might maintain spending on inputs for future use; or they may be under contractual obligations to purchase inputs for an extended period regardless of external conditions. Also, employers may not lay-off workers given that experienced labor is sometimes scarce and skilled personnel may not be readily available when water shortages subside. Lastly people who lose jobs might find other employment in the region. As a result, direct losses for employment and secondary losses in sales and employment should be considered an *upper bound*. Similarly, since population projections are based on reduced employment in the region, they should be considered an upper bound as well.

8) IO models are static in nature. Models and resultant multipliers are based upon the structure of the U.S. and regional economies in the year 2000. In contrast, unmet water needs are projected to occur well into the future (i.e., 2010 through 2060). Thus, the analysis assumes that the general structure of the economy remains the same over the planning horizon.

9) With respect to municipal needs, an important assumption is that people would eliminate all outdoor water use before indoor water uses were affected, and people would implement emergency indoor water conservation measures before commercial businesses had to curtail operations, and households had to seek alternative sources of water. Section 2.3.3 discusses this in greater detail.

10) Impacts are annual estimates. If one were to assume that conditions persisted for more than one year, figures should be adjusted to reflect the extended duration. The drought of record in Texas for many communities lasted several years.

2. Economic Impact Analysis

Part 2 of this report summarizes economic analysis for each water use category. Section 2.1 presents the year 2000 economic baseline for Region J. Section 2.2 presents results for agricultural water uses including livestock and irrigated crop production, while Section 2.3 reviews impacts to municipal and industrial water uses including manufacturing, mining, steam-electric and municipal demands.[1]

2.1 Economic Baseline

Table 2 summarizes baseline economic variables for Region J. In year 2000, the region produced $4,000 million in output that generated $2,281 million worth of income for residents in the region. Economic activity supported an estimated 56,347 full and part-time jobs. Business and industry also contributed slightly more $177 million to state and local government. Sections 2.2.and 2.3 discuss contributions of individual water use categories in greater detail.

Table 2: Year 2000 Economic Baseline for Region J (monetary impacts are reported in $millions)

	Sales Activity			Jobs	Regional Income	Business Taxes
	Total	Intermediate	Final			
Irrigation	$1.45	$0.16	$1.29	62	$1.13	$0.11
% of Total Activity for Region J	<1%	<1%	<1%	<1%	<1%	<1%
Livestock	$47.27	$11.69	$35.58	2,635	$34.00	$1.94
% of Total Activity for Region J	1%	1%	1%	5%	1%	1%
Manufacturing	$386.44	$47.70	$338.75	2,617	$130.08	$3.64
% of Total Activity for Region J	10%	4%	12%	5%	6%	2%
Mining	$153.33	$34.53	$118.80	539	$62.82	$7.23
% of Total Activity for Region J	4%	3%	4%	1%	3%	4%
Municipal	$3,359.08	$1,160.70	$2,198.39	50,370	$2,015.19	$157.28
% of Total Activity for Region J	84%	92%	80%	89%	88%	89%
Steam Electric	$54.13	$9.35	$44.78	124	$38.71	$6.93
% of Total Activity for Region J	1%	1%	2%	<1%	2%	4%
Total	$4,001.71	$1,264.12	$2,737.58	56,347	$2,281.93	$177.14
% of Total Activity for Region J	100%	100%	100%	100%	100%	100%

Source: Based input-output models generated using IMPLAN Pro software from MIG Inc.

[1] Attachment B of this report contains tables showing the distribution of impacts at the county level and city level (municipal uses only).

2.2 Agriculture

In 2000, farmers using irrigation in Region J produced about $1.5 million dollars worth of crops that generated $1.1 million in regional income. Livestock constitutes a larger share with $47.7 million in output and $34.0 million in regional income. Collectively, irrigated farming and the livestock industry accounted for about two percent of regional income and about six percent of jobs.

2.2.1 Irrigation

The first step in estimating impacts to irrigation required calculating gross sales for IMPLAN crop sectors.[1] Once gross sales were known, other statistics such as employment and income were derived using IMPLAN direct multiplier coefficients. Gross sales for a given crop are based on two data sources:

1) county-level data collected and maintained by the TWDB and the USDA Natural Resources Conservation Service (NRCS) including the number of irrigated acres by crop type and water application per acre, and

2) regional-level information published by the Texas Agricultural Statistics Service (TASS) including prices received for crops (marketing year averages), crop yields and crop acreages.

Crop categories used by the TWDB differ from those used in IMPLAN datasets. To maintain consistency, sales and other statistics are reported using IMPLAN crop classifications, which are more aggregated than TWDB groupings. Table 3 shows the TWDB crops included in corresponding IMPLAN sectors. Table 4 summarizes acreage and estimated annual water use for each crop classification (year 2000), and Table 5 displays year 2000 baseline economic variables for irrigation. Feed grains are the largest sector in terms output value.

Table 3: Crop Classifications Used in TWDB Water Use Survey and Corresponding IMPLAN Crop Sectors Applied in Socioeconomic Impact Analysis

IMPLAN Sector	TWDB Sector
Cotton	Cotton
Feed Grains	Corn, sorghum and “forage crops”
Food Grains	Wheat and "other grains"
Hay and Pasture	Alfalfa and “other hay and pasture”
Oil Crops	Peanuts, soybeans and “other oil crops”
Tree Nuts	Pecans
Vegetables *	Deep-rooted vegetables, shallow-rooted vegetables and potatoes

* includes melons.

[1] Default IMPLAN data do not distinguish irrigated production from dry-land production.

Table 4. Summary of Irrigated Crop Acreage and Water Demand for Region J (Year 2000)				
Sector	Acres (1000s)	Distribution of Acres	Water Use (1000s of AF)	Distribution of Water Use
Feed Grains	3.3	36%	8.7	43%
Food Grains	2.7	28%	4.1	20%
Hay and Pasture	1.5	17%	2.9	14%
Cotton	1.0	11%	2.6	13%
Oil Crops	0.5	6%	1.0	5%
Tree Nuts and other crops	0.3	3%	0.9	4%
Total	9.4	100%	20.2	100%

Source: Water demand figures are taken from the Texas Water Development Board 2006 Water Plan Projections data for year 2000. Statistics for irrigated crop acreage are based upon annual survey data collected by the TWDB and the National Resources Conservation Service (USDA).

Table 5: Year 2000 Baseline for Irrigated Crop Production in Region J (monetary figures reported in $millions)

Sector	Sales Activity			Jobs	Regional Income	Business Taxes
	Total	Intermediate	Final			
Feed Grains	$0.62	$0.05	$0.57	19	$0.53	$0.06
Oil Crops	$0.34	$0.08	$0.25	16	$0.23	$0.02
Cotton	$0.18	$0.00	$0.18	2	$0.08	$0.01
Hay and Pasture	$0.15	$0.01	$0.14	20	$0.13	$0.01
Tree Nuts	$0.10	$0.00	$0.10	3	$0.09	$0.00
Food Grains	$0.07	$0.01	$0.07	2	$0.06	$0.01
Total	$1.45	$0.16	$1.29	62	$1.13	$0.11

Source: Based on data from the Texas Water Development Board, the Texas Agricultural Statistics Service and the Minnesota IMPLAN Group, Inc.

Table 6: Data Used to Estimate Direct Economic Impacts to Irrigated Crop Production in Region J.			
Crop sector	Gross sales revenue per irrigated acre	Gross sales revenue per dry-land acre (drought conditions)	Data Sources for yield, prices and planted acreage used to estimate gross sales per acre
Cotton	$290	$50	Gross sales (irrigated) five-year (1995-2000) average for cotton based on data from TASS Edwards Plateau Regional District. Dry-land 1998 yields and prices for same district.
Food Grains	$105	$40	Gross sales (irrigated) five-year (1995-2000) average for wheat based on data from TASS Edwards Plateau Regional District. Dry-land 1998 yields and prices for same district.
Hay and Pasture	$100	$50	Based on TAMU crop enterprise budget data for – average of coastal Bermuda hay and coastal pasture. Dry-land value on same data source but assumes a yield reduction of 0.50 percent.
Feed Grains	$180	$20	Gross sales (irrigated) are an average five year (1995-2000) value for corn and grain sorghum weighted by acreage. Dry-land value based on same data using only 1998 yields and prices.
Oil Crops	$690	$0	Based on five year averages (1995-2000) TASS data for peanuts in the TASS Edwards Plateau District.
Tree Nuts	$515	$0	Based on statewide TASS data, five year averages (1995-2000).
*Values are rounded. TASS = Texas Agricultural Statistics Service. TAMU = Texas A&M University.			

An important consideration when estimating impacts to irrigation was determining which crops are affected by water shortages. Several options are available. One approach is the so-called rationing model, which assumes that farmers respond to water supply cutbacks by fallowing the lowest value crops in the region first and the highest valued crops last until the amount of water saved equals the shortage.[1] For example, if farmer A grows vegetables (higher value) and farmer B grows wheat (lower value) and they both face a proportionate cutback in irrigation water, then farmer B will sell water to farmer A. Farmer B will fallow her irrigated acreage before farmer A fallows anything. Of course, this assumes that farmers can and do transfer enough water to allow this to happen. A different approach involves constructing farm-level profit maximization models that conform to widely-accepted economic theory that farmers make decisions based on marginal net returns. Such models have good predictive capability, but data requirements and complexity are high. Given that a detailed analysis for each region would require a *substantial* amount of farm-level data and analysis, the following investigation assumes that projected shortages are distributed equally across predominant

[1] The rationing model was initially proposed by researchers at the University of California at Berkeley, and was then modified for use in a study conducted by the U.S. Environmental Protection Agency that evaluated how proposed water supply cutbacks recommended to protect water quality in the Bay/Delta complex in California would affect farmers in the Central Valley. See, Zilberman, D., Howitt, R. and Sunding, D. "*Economic Impacts of Water Quality Regulations in the San Francisco Bay and Delta*." Western Consortium for Public Health. May 1993.

crops in the region. "Predominant" in this case are crops that comprise at least one percent of total acreage in the region (see Table 4).

The following steps outline the overall method used to estimate direct impacts to irrigated agriculture:

1. *Distribute shortages across predominant crop types in the region*. Again, unmet water needs were distributed equally across crop sectors that constitute one percent or more of irrigated acreage in 2000.

2. *Estimate associated reductions in output for affected crop sectors*. Output reductions are based on elasticities discussed in Section 1.2.1 and on estimated values per acre for different crops. Values per acre stem from the same data used to estimate output for the year 2000 baseline. Given that 2000 may have been an unusually poor or productive year for some crops and not necessarily representative of normal conditions, statistics regarding yield, price and acreage for crop sectors were averaged over a five-year period (1995-2000) if sufficient data were available.

3. *Offset reductions in output by revenues from dry-land production.* If TASS acreage data indicate that farmers grow a dry-land version of a given crop in the region (e.g., cotton or corn), estimated losses from irrigated acreage are offset by assumed revenues from dry-land harvests. Basically, the analysis assumes that farmers who use irrigation would have some output even if irrigation water were not available. Given that water shortages are expected to occur under drought conditions, values per acre for dry-land crops are based on 1998 and/or 1996 yields and prices. Both 1996 and 1998 were particularly bad drought years for much of Texas. Table 6 summarizes data used to estimate the value of lost output.

The Region J 2006 Water Plan indicates that under drought of record conditions, shortages to irrigation would occur in Bandera and Kerr counties. Table 7 summarizes estimated impacts. Attachment B of this report shows impacts by county, and Attachment C shows impacts by major river basin.

Table 7: Annual Economic Impacts of Unmet Water Needs for Irrigation
(years 2010, 2020, 2030, 2040, 2050 and 2060, constant year 2000 dollars)

Year	Sales ($millions)	Regional Income ($millions)	Jobs	Business Taxes ($millions)
2010	$0.07	$0.06	4	$0.005
2020	$0.07	$0.05	3	$0.004
2030	$0.06	$0.05	3	$0.004
2040	$0.05	$0.04	3	$0.004
2050	$0.05	$0.04	2	$0.003
2060	$0.04	$0.03	2	$0.002

Source: Based on economic impact models developed by the Texas Water Development Board, Office of Water Planning.

2.2.2 Livestock

No shortages for livestock were reported for Region J.

2.3 Municipal and Industrial

Municipal and industrial (M&I) water uses make up the majority (about 98 percent) of direct economic activity in Region J. In 2000, M&I users generated $3,952 million in sales and nearly $2,246 million worth of income for residents in the region. M&I generated most of the tax revenues in Region J.

2.3.1 Manufacturing

No shortages for manufacturing water were reported for Region J.

2.3.2 Mining

No shortages for mining water were reported for Region J.

2.3.3 Municipal

Table 8 summarizes economic activity for municipal uses. In 2000, businesses and institutions that make up the municipal category produced $3,359 million worth of goods and services. In return, they received $2,015 million in wages, salaries and profits. Municipal uses also generate the bulk of business taxes generated in the region – nearly $157 million (93 percent). Top commercial sectors in terms of income and output include wholesale trade, real estate, banking and medical services.

Table 8: Year 2000 Direct Economic Activity Associated with Municipal Uses in Region J

Sector	Sales Activity			Jobs	Regional Income	Business Taxes
	Total	Intermediate	Final			
Real Estate	$254.76	$75.06	$179.69	1,382	$151.08	$30.14
Banking	$111.14	$33.99	$77.15	691	$71.80	$1.80
Medical and Health Services	$102.33	$2.03	$100.29	2,714	$46.30	$1.45
Wholesale Trade	$98.78	$40.64	$58.13	1,187	$54.02	$14.05
All other municipal sectors	$2,792.07	$1,008.98	$1,783.13	44,396	$1,691.99	$109.84
Total	$3,359.08	$1,160.70	$2,198.39	50,370	$2,015.19	$157.28

Source: Generated using data from MIG, Inc., and models developed by the TWDB using IMPLAN software.

Estimating direct economics impacts for the municipal category is complicated for a number of reasons. For one, municipal uses comprise a range of different consumers including commercial businesses, institutions (e.g., schools and government) and households. However, reported shortages do not specify how needs are distributed among different consumers. In other words, how much of a municipal need is commercial and how much is residential? The amount of commercial water use as a percentage of total municipal demand was estimated based on "GED" coefficients (gallons per employee per day) published in secondary sources (see Attachment A). For example, if year 2000 baseline data for a given economic sector (e.g., amusement and recreation services) shows employment at 30 jobs and the GED coefficient is 200, then average daily water use by that sector is (30 x 200 = 6,000 gallons) and thus annual use is 6.7 acre-feet. Water not attributed to commercial use is considered domestic, which includes single and multi-family residential consumption, institutional uses and all use designated as "county-other." The estimated proportion of water used for commercial purposes ranges from about 5 to 35 percent of total municipal demand at the county level. Less populated rural counties occupy the lower end of the spectrum, while larger metropolitan counties are at the higher end.

As mentioned earlier, a key study assumption is that people would eliminate outdoor water use before indoor water consumption was affected; and they would implement *voluntary* emergency indoor water conservation measures before people had to curtail business operations or seek emergency sources of water. This is logical because most water utilities have drought contingency plans. Plans usually specify curtailment or elimination of outdoor water use during periods of drought. In Texas, state law requires retail and wholesale water providers to prepare and submit plans to the Texas Commission on Environmental Quality (TCEQ). Plans must specify demand management measures for use during drought including curtailment of "non-essential water uses."[1] Thus, when assessing municipal needs there are several important considerations: 1) how much of a need would people reduce via eliminating outdoor uses and implementing emergency indoor conservation measures; and 2) what are the economic implications of such measures?

Determining how much water is used for outdoor purposes is key to answering these questions. The proportion used here is based on several secondary sources. The first is a major study sponsored by the American Water Works Association, which surveyed cities in states including Colorado, Oregon, Washington, California, Florida and Arizona. On average across all cities surveyed 58 percent of residential water use was for outdoor activities. In cities with climates comparable to large metropolitan areas of Texas, the average was 40 percent.[2]Earlier findings of the U.S. Water Resources Council showed a national average of 33 percent. Similarly, the United States Environmental Protection Agency (USEPA) estimated that landscape watering accounts for 32 percent of total residential and commercial water use on annual basis.[3] A study conducted for the California Urban Water Agencies (CUWA) calculated values ranging from 25 to 35 percent.[4] Unfortunately, there does not appear to be any comprehensive research that has estimated non-agricultural outdoor water use in Texas. As an approximation, an average annual value of 30 percent based on the above references was selected to serve as a rough estimate in this study. With respect to emergency indoor conservation measures, this analysis assumes that citizens in affected communities would reduce needs by an additional 20 percent. Thus, 50 percent of total needs could

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[1] Non-essential uses include, but are not limited to, landscape irrigation and water for swimming pools or fountains. For further information see the Texas Environmental Quality Code §288.20.

[2] See, Mayer, P.W., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W., Dziegielewski, D., Nelson, J.O. "*Residential End Uses of Water*." Research sponsored by the American Water Works Association and completed by Aquacraft, Inc. and Planning and Management Consultants, Ltd. (PMCL@CDM).

[3] U.S. Environmental Protection Agency. *"Cleaner Water through Conservation*." USEPA Report no. 841-B-95-002. April, 1995.

[4] Planning and Management Consultants, Ltd. "*Evaluating Urban Water Conservation Programs: A Procedures Manual*." Prepared for the California Urban Water Agencies. February 1992.

be eliminated before households and businesses had to implement emergency water procurement activities.

Eliminating outdoor watering would have a range of economic implications. For one, such a restriction would likely have adverse impacts on the landscaping and horticultural industry. If people are unable to water their lawns, they will likely purchase less lawn and garden materials such as plants and fertilizers. On the other hand, during a bad drought people may decide to invest in drought tolerant landscaping, or they might install more efficient landscape plumbing and other water saving devices. But in general, the horticultural industry would probably suffer considerable losses if outdoor water uses were restricted or eliminated. For example, many communities in Colorado, which is in the midst of a prolonged drought, have severely restricted lawn irrigation. In response, the turf industry in Colorado has laid off at least 50 percent of its 2,000 employees.[1] To capture impacts to the horticultural industry, regional sales net of exports for the greenhouse and nursery sectors and the landscaping services sector were reduced by proportion equal to reductions in outdoor water use. Note that these losses would not necessarily appear as losses to the regional or state economies because people would likely spend the money that they would have spent on landscaping on other goods in the economy. Thus, the net effect to state or regional accounts could be neutral.

Other considerations include the "welfare" losses to consumers who had to forgo outdoor and indoor water uses to reduce needs. In other words, the water that people would have to give up has an economic value. Estimating the economic value of this forgone water for each planning area would be a very time consuming and costly task, and thus secondary sources served as a proxy. Previous research funded by the TWDB, explored consumer "willingness to pay" for avoiding restrictions on water use.[2] Surveys revealed that residential water consumers in Texas would be willing to pay – on average across all income levels - $36 to avoid a 30 percent reduction in water availability lasting for at least 28 days. Assuming the average person in Texas uses 140 gallons per day and the typical household in the state has 2.7 persons (based on U.S. Census data), total monthly water use is 13,205 gallons per household. Therefore, the value of restoring 30 percent of average monthly water use during shortages to residential consumers is roughly one cent per gallon or $2,930 per acre-foot. This figure serves as a proxy to measure consumer welfare losses that would result from restricted outdoor uses and emergency indoor restrictions.

The above data help address the impacts of incurring water needs that are 50 percent or less of projected use. Any amount greater than 50 percent would result in municipal water consumers having to seek alternative sources. Costs to residential and non-water intensive commercial operations (i.e., those that use water only for sanitary purposes) are based on the most likely alternative source of water in the absence of water management strategies. In this case, the most likely alternative is assumed to be "hauled-in" water from other communities at annual cost of $6,530 per acre-foot for small rural communities and approximately and $10,995 per acre-foot for metropolitan areas.[3]

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[1] Based on assessments of the Rocky Mountain Sod Growers. See, "*Drought Drying Up Business for Landscapers*." Associated Press. September, 17 2002.

[2] See, Griffin, R.C., and Mjelde, W.M. "*Valuing and Managing Water Supply Reliability*. Final Research Report for the Texas Water Development Board: Contract no. 95-483-140." December 1997.

[3] For rural communities, figure assumes an average truck hauling distance of 50 miles at a cost of 8.4 cents per ton-mile (an acre foot of water weighs about 1,350 tons) with no rail shipment. For communities in metropolitan areas, figure assumes a 50 mile truck haul, and a rail haul of 300 miles at a cost of 1.2 cents per ton-mile. Cents per ton-mile are based on figures in: Forkenbrock, D.J., "*Comparison of External Costs of Rail and Truck Freight Transportation*." Transportation Research. Vol. 35 (2001).

This is not an unreasonable assumption. It happened during the 1950s drought and more recently in Texas and elsewhere. For example, in 2000 at the heels of three consecutive drought years Electra - a small town in North Texas - was down to its last 45 days worth of reservoir water when rain replenished the lake, and the city was able to refurbish old wells to provide supplemental groundwater. At the time, residents were forced to limit water use to 1,000 gallons per person per month - less than half of what most people use - and many were having water hauled delivered to their homes by private contractors.[1] In 2003 citizens of Ballinger, Texas, were also faced with a dwindling water supply due to prolonged drought. After three years of drought, Lake Ballinger, which supplies water to more than 4,300 residents in Ballinger and to 600 residents in nearby Rowena, was almost dry. Each day, people lined up to get water from a well in nearby City Park. Trucks hauling trailers outfitted with large plastic and metal tanks hauled water to and from City Park to Ballinger.[2] In Australia, four cities have run out of water as a result of drought, and residents have been trucking in water since November 2002. One town has five trucks carting about one acre-foot eight times daily from a source 20 miles away. They had to build new roads and infrastructure to accommodate the trucks. Residents are currently restricted to indoor water use only.[3]

Direct impacts to commercial sectors were estimated in a fashion similar to other business sectors. Output was reduced among "water intensive" commercial sectors according to the severity of projected shortages. Water intensive is defined as non-medical related sectors that are heavily dependent upon water to provide their services. These include:

- car-washes,
- laundry and cleaning facilities,
- sports and recreation clubs and facilities including race tracks,
- amusement and recreation services,
- hotels and lodging places, and
- eating and drinking establishments.

For non-water intensive sectors, it is assumed that businesses would haul water by truck and/or rail.

An example will illustrate the breakdown of municipal water needs and the overall approach to estimating impacts of municipal needs. Assume City B has an unmet need of 50 acre feet in 2020 and projected demands of 200 acre-feet. In this case, residents of City B could eliminate needs via restricting all outdoor water use. City A, on the other hand, has an unmet need of 150 acre-feet in 2020 with a projected demand of 200 acre-feet. Thus, total shortages are 75 percent of total demand. Emergency outdoor and indoor conservation measures would eliminate 50 percent of projected needs; however, 50 acre-feet would still remain. This remaining portion would result in costs to residential and commercial water users. Water intensive businesses such as car washes, restaurants, motels, race tracks would have to curtail operations (i.e., output would decline), and residents and non-water intensive businesses would have to have water hauled-in assuming it was available.

The last element of municipal water shortages considered focused on lost water utility revenues. Estimating these was straightforward. Analyst used annual data from the "*Water and Wastewater Rate Survey*" published annually by the Texas Municipal League to calculate an average value per acre-foot for water and sewer. For water revenues, averages rates multiplied by total water needs served as a proxy. For lost wastewater, total unmet needs were adjusted for return flow factor of 0.60 and multiplied by average sewer rates for the region. Needs reported as "county-other" were excluded under the presumption that these consist primarily of self-supplied water uses. In addition,

[1] Zewe, C. "*Tap Threatens to Run Dry in Texas Town*." July 11, 2000. CNN Cable News Network.

[2] Associated Press, "*Ballinger Scrambles to Finish Pipeline before Lake Dries Up*." May 19, 2003.

[3] Healey, N. (2003) *Water on Wheels*, Water: Journal of the Australian Water Association, June 2003.

15 percent of water demand and needs are considered non-billed or "unaccountable" water that comprises things such leakages and water for municipal government functions (e.g., fire departments). Lost tax receipts are based on current rates for the "miscellaneous gross receipts tax, "which the state collects from utilities located in most incorporated cities or towns in Texas.

The Region J 2006 Water Plan indicates that under drought of record conditions, shortages to municipal water uses would occur in Kerr and Real counties. Tables 9 through 12 summarize estimated impacts to domestic uses, commercial businesses, water utilities and the horticultural industry. Attachment B of this report shows impacts by county, and Attachment C shows impacts by major river basin.

Table 9: Annual Economic Impacts of Unmet Water Needs for Commercial Businesses
(years 2010, 2020, 2030, 2040, 2050 and 2060, constant year 2000 dollars)

Year	Sales ($millions)	Regional Income ($millions)	Jobs	Business Taxes ($millions)
2010	$1.36	$0.73	27	$0.09
2020	$1.36	$0.73	27	$0.09
2030	$1.36	$0.73	27	$0.09
2040	$1.36	$0.73	27	$0.09
2050	$1.36	$0.73	27	$0.09
2060	$1.36	$0.73	27	$0.09

* Estimates are based on *projected* economic activity in the region. Source: Source: Texas Water Development Board, Office of Water Resources Planning.

Table 10: Annual Economic Impacts of Unmet Water Needs for the Horticultural Industry
(years 2010, 2020, 2030, 2040, 2050 and 2060, constant year 2000 dollars)

Year	Sales ($millions)	Regional Income ($millions)	Jobs	Business Taxes ($millions)
2010	$0.76	$0.60	19	$0.01
2020	$1.15	$0.90	29	$0.02
2030	$1.31	$1.03	33	$0.02
2040	$1.25	$0.98	31	$0.02
2050	$1.64	$1.29	41	$0.03
2060	$1.70	$1.34	43	$0.03

Source: Generated by the Texas Water Development Board, Office of Water Resources Planning.

Table 11: Annual Impacts Associated with Unmet Domestic Water Needs (years 2010, 2020, 2030, 2040, 2050 and 2060, constant year 2000 dollars)	
Year	$millions
2010	$4.63
2020	$5.75
2030	$6.28
2040	$6.35
2050	$6.92
2060	$7.25
Source: Generated by Texas Water Development Board, Office of Water Resources Planning.	

Table 12: Impacts to Water Utilities (years 2010, 2020, 2030, 2040, 2050 and 2060, constant year 2000 dollars)		
Year	Revenues ($millions)	Utility Taxes ($millions)
2010	$1.99	$0.04
2020	$2.51	$0.04
2030	$2.70	$0.05
2040	$2.71	$0.05
2050	$3.03	$0.05
2060	$3.19	$0.06
Source: Texas Water Development Board, Office of Water Resources Planning.		

2.3.4 Steam Electric

No shortages for manufacturing water uses were reported.

3. Regional Social Impacts

As discussed previously in Section 1.2, estimated social impacts focus changes including population loss and subsequent related in school enrollment. As shown in Table 13, water shortages in 2010 could result in a population loss of 85 people with a corresponding reduction in school enrollment of 25. Models indicate that shortages in 2060 could cause population in the region to fall by 125 people and school enrollment by 35 students.

Table13: Estimated Regional Social Impacts of Unmet Water Needs (years, 2010, 2020, 2030, 2040, 2050 and 2060)		
Year	Population Losses	Declines in School Enrollment
2010	85	25
2020	100	28
2030	110	30
2040	110	30
2050	120	35
2060	125	35
Source: Generated by the Texas Water Development Board, Office of Water Planning.		

Attachment A: Baseline Regional Economic Data

Tables A-1 through A-6 contain data from several sources that form a basis of analyses in this report. Economic statistics were extracted and processed via databases purchased from MIG, Inc. using IMPLAN Pro™ software. Values for gallons per employee (i.e. GED coefficients) for the municipal water use category are based on several secondary sources.[1] County-level data sets along with multipliers are not included given their large sizes (i.e., 528 sectors per county each with 12 different multiplier coefficients). Fields in Tables A-1 through A-6 contain the following variables:

- *GED -* average gallons of water use per employee per day (municipal use only);
- *total sales -* total industry production measured in millions of dollars (equal to shipments plus net additions to inventories);
- *intermediate sales -* sales to other industries in the region measured in millions of dollars;
- *final sales -* all sales to end-users including sales to households in the region and exports out of the region;
- *jobs -* number of full and part-time jobs (annual average) required by a given industry;
- *regional income* - total payroll costs (wages and salaries plus benefits), proprietor income, corporate income, rental income and interest payments;
- *business taxes –* sales taxes, excise taxes, fees, licenses and other taxes paid during normal business operations (includes all payments to federal, state and local government except income taxes).

[1] Sources for GED coefficients include: Gleick, P.H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G. Cushing, K.K., and Mann, A. "*Waste Not, Want Not*. *The Potential for Urban Water Conservation in California*." Pacific Institute. November 2003. U.S. Bureau of the Census. 1982 Census of Manufacturers: Water Use in Manufacturing. USGPO, Washington D.C. See also: "*U.S. Army Engineer Institute for Water Resources, IWR Report 88-R-6.*," Fort Belvoir, VA. See also, Joseph, E. S., 1982, "*Municipal and Industrial Water Demands of the Western United States*." Journal of the Water Resources Planning and Management Division, Proceedings of the American Society of Civil Engineers, v. 108, no. WR2, p. 204-216. See also, Baumann, D. D., Boland, J. J., and Sims, J. H., 1981, "*Evaluation of Water Conservation for Municipal and Industrial Water Supply*." U.S. Army Corps of Engineers, Institute for Water Resources, Contract no. 82-C1.

Table A-1: Economic Data for Irrigated Agriculture in Region J (Year 2000)

Sector	Total Sales	Intermediate Sales	Final Sales	Jobs	Regional Income	Business Taxes
Cotton	$0.18	$0.00	$0.18	2	$0.08	$0.01
Food Grains	$0.07	$0.01	$0.07	2	$0.06	$0.01
Feed Grains	$0.62	$0.05	$0.57	19	$0.53	$0.06
Hay and Pasture	$0.15	$0.01	$0.14	20	$0.13	$0.01
Tree Nuts	$0.10	$0.00	$0.10	3	$0.09	$0.00
Oil Crops	$0.34	$0.08	$0.25	16	$0.23	$0.02
Total	$1.45	$0.16	$1.29	62	$1.13	$0.11

Data do not include dry-land production.

Table A-2: Economic Data for Livestock Sectors, Region J (Year 2000)

Sector	Total Sales	Intermediate Sales	Final Sales	Jobs	Regional Income	Business Taxes
Range Fed Cattle	$15.65	$2.27	$13.38	658	$12.54	$0.81
Sheep, Lambs and Goats	$6.95	$0.55	$6.41	885	$3.81	$0.22
Cattle Feedlots	$6.46	$4.62	$1.84	19	$5.65	$0.45
Poultry and Eggs	$6.18	$0.53	$5.64	105	$3.40	$0.06
Miscellaneous Livestock	$5.48	$0.12	$5.37	693	$3.96	$0.10
Ranch Fed Cattle	$3.68	$3.25	$0.43	195	$2.95	$0.21
Other Meat Animal Products	$1.75	$0.12	$1.63	55	$0.66	$0.06
Dairy Farm Products	$0.88	$0.00	$0.88	12	$0.86	$0.01
Hogs, Pigs and Swine	$0.23	$0.23	$0.00	12	$0.17	$0.02
Total	$47.27	$11.69	$35.58	2,635	$34.00	$1.94

Table A-3: Economic Data for Municipal Sectors, Region J (Year 2000)

Sector	GED	Total Sales	Intermediate Sales	Final Sales	Jobs	Regional Income	Business Taxes
Accounting, Auditing and Bookkeeping	120	$31.94	$19.67	$12.26	546	25	$0.29
Advertising	117	$14.22	$11.44	$2.78	161	6	$0.12
Agricultural, Forestry, Fishery Services	-	$9.84	$0.89	$8.95	579	5	$0.23
Air Transportation	171	$41.90	$5.26	$36.64	421	21	$3.06
Amusement and Recreation Services,	427	$6.67	$0.00	$6.67	255	4	$0.37
Apparel & Accessory Stores	68	$14.09	$0.87	$13.22	402	8	$2.25
Arrangement Of Passenger	130	$6.43	$3.09	$3.34	44	4	$0.19
Automobile Parking and Car Wash	681	$3.12	$0.32	$2.79	81	2	$0.14
Automobile Repair and Services	55	$53.35	$5.72	$47.64	674	27	$2.44
Automotive Dealers & Service Stations	49	$62.27	$11.96	$50.31	829	$37.14	$9.63
Banking	59	$111.14	$33.99	$77.15	691	$71.80	$1.80
Beauty and Barber Shops	216	$10.14	$1.19	$8.95	420	6	$0.12
Bowling Alleys and Pool Halls	86	$0.80	$0.00	$0.80	46	0	$0.07
Building Materials & Gardening	35	$16.29	$2.08	$14.21	363	12	$2.68
Business Associations	160	$6.76	$1.59	$5.17	149	5	$0.00
Child Day Care Services	120	$6.92	$0.00	$6.92	183	2	$0.06
Colleges, Universities, Schools	75	$15.79	$0.13	$15.66	559	10	$0.00
Commodity Credit Corporation	-	$0.00	$0.00	$0.00	0	0	$0.00
Communications, Except Radio and TV	47	$93.03	$31.59	$61.44	383	$46.49	$4.95
Computer and Data Processing Services	40	$8.99	$6.77	$2.22	157	7	$0.14
Credit Agencies	156	$31.08	$20.16	$10.92	924	16	$1.04
Detective and Protective Services	84	$10.57	$3.99	$6.57	154	8	$0.15
Doctors and Dentists	203	$80.74	$0.00	$80.74	927	$52.59	$1.01
Domestic Services	-	$7.02	$7.02	$0.00	891	7	$0.00
Eating & Drinking	157	$94.42	$4.65	$89.77	2712	$42.94	$5.99
Electrical Repair Service	37	$7.18	$1.59	$5.59	109	2	$0.21
Elementary and Secondary Schools	169	$0.05	$0.00	$0.05	2	0	$0.00
Engineering, Architectural Services	87	$21.55	$18.79	$2.75	239	9	$0.14
Equipment Rental and Leasing	29	$16.24	$7.76	$8.47	144	7	$0.47
Federal Government - Military	-	$188.62	$188.62	$0.00	1678	$188.62	$0.00

Table A-3: Economic Data for Municipal Sectors, Region J (Year 2000)

Federal Government - Non-Militarv	-	$191.80	$191.80	$0.00	3423	$191.80	$0.00
Food Stores	98	$58.84	$1.59	$57.25	1648	$44.11	$9.40
Funeral Service and Crematories	111	$6.63	$0.00	$6.63	173	4	$0.19
Furniture & Home Furnishings Stores	42	$8.85	$0.90	$7.95	221	6	$1.39
Gas Production and Distribution	51	$22.67	$8.93	$13.74	21	6	$1.64
General Merchandise Stores	47	$38.84	$1.44	$37.39	1154	24	$6.20
Greenhouse and Nursery Products	-	$8.68	$1.65	$7.03	249	8	$0.11
Hospitals	76	$66.32	$0.08	$66.24	999	$41.33	$0.23
Hotels and Lodging Places	230	$57.62	$9.91	$47.71	1199	$30.54	$3.93
Insurance Agents and Brokers	89	$17.39	$3.31	$14.08	448	13	$0.19
Insurance Carriers	136	$14.64	$1.25	$13.39	111	8	$0.80
Labor and Civic Organizations	122	$9.28	$0.04	$9.24	706	7	$0.00
Landscape and Horticultural Services	-	$8.39	$6.65	$1.74	302	5	$0.21
Laundry, Cleaning and Shoe Repair	517	$11.99	$2.10	$9.88	527	9	$0.31
Legal Services	76	$17.69	$6.34	$11.35	232	14	$0.16
Local, Interurban Passenger Transit	68	$3.86	$0.40	$3.46	96	2	$0.08
Maintenance and Repair Oil and Gas	25	$9.33	$9.00	$0.32	62	5	$0.37
Maintenance and Repair Other Facilities	25	$59.41	$27.97	$31.44	1205	$39.32	$0.26
Maintenance and Repair, Residential	25	$47.74	$13.39	$34.35	382	12	$0.16
Management and Consulting Services	87	$40.44	$28.25	$12.19	545	19	$0.25
Membership Sports and Recreation	427	$10.18	$0.12	$10.06	392	5	$0.35
Miscellaneous Personal Services	129	$4.95	$0.22	$4.73	77	1	$0.09
Miscellaneous Repair Shops	124	$11.89	$3.94	$7.95	190	5	$0.33
Miscellaneous Retail	132	$51.64	$3.94	$47.70	1479	32	$7.89
Motion Pictures	113	$10.73	$5.49	$5.24	142	3	$0.12
Motor Freight Transport and	85	$74.52	$38.39	$36.14	743	$28.71	$0.90
New Government Facilities	63	$79.66	$0.00	$79.66	575	$26.67	$0.42
New Highways and Streets	45	$19.48	$0.00	$19.48	196	7	$0.11
New Industrial and Commercial	63	$77.42	$0.00	$77.42	721	$23.66	$0.49
New Mineral Extraction Facilities	63	$44.94	$0.55	$44.39	851	26	$2.08
New Residential Structures	35	$152.89	$0.00	$152.89	1028	$23.99	$0.82
New Utility Structures	63	$33.11	$0.00	$33.11	352	12	$0.16
Nursing and Protective Care	197	$26.51	$0.00	$26.51	764	19	$0.66
Other Business Services	84	$23.68	$22.14	$1.55	210	11	$0.39
Other Educational Services	116	$8.22	$1.60	$6.62	149	4	$0.27
Other Federal Government Enterprises	-	$7.74	$1.39	$6.35	58	1	$0.00
Other Medical and Health Services	168	$102.33	$2.03	$100.29	2714	$46.30	$1.45
Other Nonprofit Organizations	122	$18.30	$0.24	$18.05	785	9	$0.11
Other State and Local Govt Enterprises	-	$31.75	$6.83	$24.92	181	10	$0.00
Owner-occupied Dwellings	89	$226.26	$0.00	$226.26	0	$142.05	$29.34
Personnel Supply Services	484	$2.80	$2.39	$0.41	141	3	$0.05
Photofinishing, Commercial	112	$2.57	$1.69	$0.88	28	1	$0.05
Portrait and Photographic Studios	184	$0.29	$0.01	$0.28	8	0	$0.01
Racing and Track Operation	391	$4.57	$0.62	$3.95	38	2	$0.91
Radio and TV Broadcasting	64	$8.50	$6.43	$2.07	64	2	$0.09
Railroads and Related Services	68	$13.41	$3.22	$10.19	119	4	$0.19
Real Estate	89	$254.76	$75.06	$179.69	1382	$151.08	$30.14
Religious Organizations	328	$12.24	$0.00	$12.24	101	1	$0.00
Research, Development & Testing	123	$1.54	$1.09	$0.44	29	1	$0.01
Residential Care	111	$12.22	$0.00	$12.22	425	8	$0.11
Sanitary Services and Steam Supply	51	$7.22	$5.10	$2.12	28	3	$1.32
Security and Commodity Brokers	59	$17.03	$10.50	$6.53	107	5	$0.48
Services To Buildings	67	$17.04	$10.40	$6.63	400	8	$0.33
Social Services, N.E.C.	42	$5.96	$0.33	$5.63	120	2	$0.01
State & Local Government - Education	-	$122.77	$122.77	$0.00	4157	$122.77	$0.00
State & Local Government - Non-	-	$95.29	$95.29	$0.00	2257	$95.29	$0.00
State and Local Electric Utilities	-	$0.46	$0.08	$0.38	1	0	$0.00
Theatrical Producers, Bands Etc.	36	$3.75	$2.13	$1.62	60	1	$0.10
Transportation Services	40	$4.89	$2.55	$2.34	51	4	$0.04
U.S. Postal Service	-	$12.71	$8.10	$4.61	163	9	$0.00
Water Supply and Sewerage Systems	51	$4.46	$0.88	$3.58	26	2	$0.30
Wholesale Trade	43	$98.78	$40.64	$58.13	1187	$54.02	$14.05
Total	na	$3,359.08	$1,160.70	$2,198.39	50,370	$2,015.19	$157.28

NEC = not elsewhere classified. “na” = not available.

Table A-4: Economic Data for Manufacturing Sectors, Region J (Year 2000)

Sector	Total Sales	Intermediate Sales	Final Sales	Jobs	Regional Income	Business Taxes
Aircraft	$100.73	$4.89	$95.84	415	$18.91	$0.75
Apparel Made From Purchased Materials	$1.81	$0.02	$1.79	15	$0.59	$0.01
Architectural Metal Work	$3.02	$0.07	$2.95	33	$1.62	$0.03
Automotive and Apparel Trimmings	$1.03	$0.22	$0.81	8	$0.13	$0.00
Automotive Stampings	$3.36	$0.24	$3.13	17	$1.17	$0.04
Blinds, Shades, and Drapery Hardware	$0.43	$0.00	$0.43	5	$0.19	$0.00
Boat Building and Repairing	$1.59	$0.00	$1.58	16	$0.39	$0.01
Bookbinding & Related	$0.22	$0.01	$0.21	4	$0.11	$0.00
Brass, Bronze, and Copper Foundries	$0.13	$0.01	$0.12	6	$0.06	$0.00
Bread, Cake, and Related Products	$0.24	$0.06	$0.18	1	$0.12	$0.00
Commercial Fishing	$10.87	$0.18	$10.69	383	$9.87	$0.34
Commercial Printing	$10.69	$4.58	$6.11	107	$2.82	$0.08
Concrete Products, N.E.C	$1.52	$0.01	$1.52	15	$0.43	$0.02
Costume Jewelery	$2.79	$0.05	$2.74	31	$1.83	$0.03
Die-cut Paper and Board	$0.39	$0.01	$0.39	3	$0.11	$0.00
Dog, Cat, and Other Pet Food	$0.71	$0.00	$0.70	2	$0.08	$0.00
Drugs	$11.20	$3.31	$7.89	66	$5.65	$0.12
Electrical Industrial Apparatus, N.E.C.	$4.13	$0.30	$3.83	17	$0.43	$0.02
Electronic Components, N.E.C.	$0.45	$0.33	$0.12	2	$0.08	$0.00
Fabricated Plate Work (Boiler Shops)	$4.48	$0.09	$4.38	47	$2.47	$0.04
Fabricated Rubber Products, N.E.C.	$2.30	$0.03	$2.27	17	$0.57	$0.01
Fabricated Structural Metal	$1.42	$0.03	$1.39	11	$0.39	$0.01
Fabricated Textile Products, N.E.C.	$28.51	$1.94	$26.57	153	$11.78	$0.26
Farm Machinery and Equipment	$1.36	$0.36	$1.00	8	$0.32	$0.01
Fasteners, Buttons, Needles, Pins	$0.71	$0.01	$0.70	13	$0.60	$0.01
Forest Products	$0.44	$0.02	$0.42	16	$0.41	$0.02
Glass and Glass Products, Exc Containers	$0.71	$0.45	$0.26	6	$0.32	$0.01
Gum and Wood Chemicals	$13.86	$2.45	$11.40	40	$5.98	$0.13
Hand and Edge Tools, N.E.C.	$4.77	$0.45	$4.31	44	$2.80	$0.05
Hardware, N.E.C.	$2.39	$0.29	$2.10	11	$1.16	$0.03
Hardwood Dimension and Flooring Mills	$0.34	$0.32	$0.02	5	$0.15	$0.00
Household Cooking Equipment	$0.71	$0.01	$0.71	4	$0.17	$0.01
Industrial Furnaces and Ovens	$0.48	$0.02	$0.47	4	$0.12	$0.00
Industrial Machines N.E.C.	$1.41	$0.03	$1.38	15	$0.51	$0.01
Instruments To Measure Electricity	$1.77	$0.09	$1.68	8	$0.77	$0.02
Jewelry, Precious Metal	$51.42	$0.73	$50.69	239	$27.03	$0.68
Leather Tanning and Finishing	$0.49	$0.25	$0.24	2	$0.07	$0.00
Lighting Fixtures and Equipment	$0.29	$0.01	$0.29	2	$0.10	$0.00
Luggage	$1.22	$0.07	$1.15	14	$0.44	$0.01
Manufacturing Industries, N.E.C.	$3.33	$0.12	$3.21	40	$1.15	$0.03
Marking Devices	$0.58	$0.03	$0.54	6	$0.47	$0.00
Meat Packing Plants	$16.24	$0.95	$15.28	44	$1.04	$0.07
Mechanical Measuring Devices	$1.44	$0.55	$0.89	8	$0.76	$0.02
Millwork	$0.90	$0.87	$0.04	10	$0.28	$0.01
Miscellaneous Plastics Products	$12.45	$0.27	$12.19	82	$2.49	$0.06
Miscellaneous Publishing	$0.65	$0.38	$0.27	6	$0.27	$0.01
Newspapers	$9.75	$5.69	$4.06	131	$4.21	$0.10
Periodicals	$0.97	$0.46	$0.51	7	$0.25	$0.01
Plastics Materials and Resins	$10.90	$4.54	$6.37	18	$1.80	$0.07
Potato Chips & Similar Snacks	$3.58	$0.06	$3.52	16	$0.66	$0.02
Poultry Processing	$0.32	$0.02	$0.30	2	$0.08	$0.00
Printed Circuit Boards	$4.64	$3.42	$1.22	55	$2.86	$0.04
Ready-mixed Concrete	$7.70	$0.05	$7.65	57	$2.12	$0.09
Sawmills and Planing Mills, General	$0.66	$0.59	$0.07	4	$0.15	$0.01
Sheet Metal Work	$1.49	$0.03	$1.46	12	$0.56	$0.01
Signs and Advertising Displays	$2.39	$0.82	$1.57	32	$0.91	$0.02
Silverware and Plated Ware	$1.81	$0.04	$1.77	18	$0.87	$0.03
Surgical and Medical Instrument	$1.65	$0.80	$0.85	7	$0.71	$0.02
Surgical Appliances and Supplies	$19.94	$2.50	$17.44	115	$3.78	$0.15
Transformers	$0.31	$0.02	$0.30	3	$0.12	$0.00
Wines, Brandy, and Brandy Spirits	$0.22	$0.00	$0.22	1	$0.03	$0.02
Womens Handbags and Purses	$0.12	$0.00	$0.12	3	$0.01	$0.00
Wood Household Furniture	$1.77	$0.03	$1.74	21	$0.60	$0.01
Wood Kitchen Cabinets	$6.14	$2.73	$3.41	86	$2.53	$0.05
Wood Pallets and Skids	$0.55	$0.16	$0.38	9	$0.17	$0.00
Wood Partitions and Fixtures	$0.48	$0.33	$0.15	6	$0.10	$0.00
Wood Products, N.E.C	$1.05	$0.28	$0.76	11	$0.36	$0.01
Total	$386.44	$47.70	$338.75	2,617	$130.08	$3.64

NEC = not elsewhere classified. “na” = not available.

Table A-5: Economic Data for Mining Sectors, Region J (Year 2000)

Sector	Total Sales	Intermediate Sales	Final Sales	Jobs	Regional Income	Business Taxes
Natural Gas & Crude Petroleum	$138.82	$32.40	$106.41	469	$56.77	$6.67
Natural Gas Liquids	8.69	2.03	7	7	2	0.38
Sand and Gravel	5.22	0.09	5	56	3	0.16
Dimension Stone	0.60	0.01	1	7	0	0.02
Total	$153.33	$34.53	$118.80	539	$62.82	$7.23

na = "not available"

Table A-6: Economic Data for the Steam Electric Sector, Region J (Year 2000)

Sector	Total Sales	Intermediate Sales	Final Sales	Jobs	Regional Income	Business Taxes
Electric Services	$54.13	$9.35	$44.78	124	$38.71	$6.93

na = "not available"

Attachment B: Distribution of Economic Impacts by County and Water User Group

Tables B-1 through B-2 show economic impacts by county and water user group; however, caution is warranted. Figures shown for specific counties are *direct* impacts only. For the most part, figures reported in the main text for all water use categories uses include *direct and secondary* impacts. Secondary effects were estimated using regional level multipliers that treat each regional water planning area as an aggregate and autonomous economy. Multipliers do not specify where secondary impacts will occur at a sub-regional level (i.e., in which counties or cities). All economic impacts that would accrue to a region as a whole due to secondary economic effects are reported in Tables B-1 through B-2 as "secondary regional level impacts."

For example, assume that in a given county (or city) water shortages caused significant reductions in output for a manufacturing plant. Reduced output resulted in lay-offs and lost income for workers and owners of the plant. This is a *direct* impact. Direct impacts were estimated at a county level; and thus one can say with certainty that direct impacts occurred in that county. However, secondary impacts accrue to businesses and households throughout the region where the business operates, and it is impossible using input-output models to determine where these businesses are located spatially.

The same logic applies to changes in population and school enrollment. Since employment losses and subsequent out-migration from a region were estimated using *direct* and *secondary* multipliers, it is impossible to say with any degree of certainty how many people a given county would lose regardless of whether the economic impact was direct or secondary. For example, assume the manufacturing plant referred to above is in County A. If the firm eliminated 50 jobs, one could state with certainty that water shortages in County A resulted in a loss of 50 jobs in that county. However, one could not unequivocally say whether 100 percent of the population loss due to lay-offs at the manufacturing would accrue to County A because many affected workers might commute from adjacent counties. This is particularly true in large metropolitan areas that overlay one or counties. Thus, population and school enrollment impacts cannot be reported at a county level.

Irrigation

Table B-1: Distribution of Economic Impacts by County and Water User Groups: (Irrigation)						
Lost Sales, $millions)						
County	2010	2020	2030	2040	2050	2060
Bandera						
Direct	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
Secondary Regional Level Impacts	$0.003	$0.003	$0.003	$0.003	$0.003	$0.003
Kerr						
Direct	$0.041	$0.037	$0.033	$0.029	$0.024	$0.020
Secondary Regional Level Impacts	$0.024	$0.022	$0.019	$0.017	$0.014	$0.011
Total	$0.073	$0.066	$0.060	$0.053	$0.046	$0.038
Lost Income ($millions)						
County	2010	2020	2030	2040	2050	2060
Bandera						
Direct	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
Secondary Regional Level Impacts	$0.002	$0.002	$0.002	$0.002	$0.002	$0.002
Kerr						
Direct	$0.036	$0.033	$0.029	$0.025	$0.021	$0.017
Secondary Regional Level Impacts	$0.015	$0.014	$0.012	$0.011	$0.009	$0.007
Total	$0.058	$0.052	$0.047	$0.042	$0.036	$0.030
Lost Jobs						
	2010	2020	2030	2040	2050	2060
Bandera						
Direct	0	0	0	0	0	0
Secondary Regional Level Impacts	0	0	0	0	0	0
Kerr						
Direct	3	3	2	2	2	1
Secondary Regional Level Impacts	0	0	0	0	0	0
Total	4	3	3	3	2	2
Lost Business Taxes ($millions)						
Bandera	2010	2020	2030	2040	2050	2060
Direct	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Secondary Regional Level Impacts	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Kerr						
Direct	$0.003	$0.003	$0.003	$0.002	$0.002	$0.002
Secondary Regional Level Impacts	$0.001	$0.001	$0.001	$0.001	$0.001	$0.001
Total	$0.005	$0.004	$0.004	$0.004	$0.003	$0.002
Source: Texas Water Development Board, Office of Water Resources Planning						

Municipal

Impacts to the horticultural industry were estimated at the regional level only and are not included in tables below.

Table B-2: Distribution of Economic Impacts by County and Water User Groups: (Commercial Businesses)						
Lost Output (Total Sales, $millions)						
County	2010	2020	2030	2040	2050	2060
Real						
Direct	$0.77	$0.77	$0.77	$0.77	$0.77	$0.77
Secondary Regional Level Impacts	$0.59	$0.59	$0.59	$0.59	$0.59	$0.59
Total	$1.36	$1.36	$1.36	$1.36	$1.36	$1.36
Lost Income ($millions)						
County	2010	2020	2030	2040	2050	2060
Real						
Direct	18	18	18	18	18	18
Secondary Regional Level Impacts	8	8	8	8	8	8
Total	27	27	27	27	27	27
Lost Jobs (numbers may not sum to figures in text due to rounding)						
County	2010	2020	2030	2040	2050	2060
Real						
Direct	$0.39	$0.39	$0.39	$0.39	$0.39	$0.39
Secondary Regional Level Impacts	$0.34	$0.34	$0.34	$0.34	$0.34	$0.34
Total	$0.73	$0.73	$0.73	$0.73	$0.73	$0.73
Lost Business Taxes ($millions)						
County	2010	2020	2030	2040	2050	2060
Real						
Direct	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
Secondary Regional Level Impacts	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04
Total	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09
Source: Texas Water Development Board, Office of Water Resources Planning						

Table B-3: Impacts Associated with Unmet Needs for Domestic Water Uses (Municipal)						
County	2010	2020	2030	2040	2050	2060
Kerr	$0.74	$0.74	$0.72	$0.69	$0.70	$0.72
Real	$3.88	$5.01	$5.57	$5.65	$6.22	$6.53
Total	$4.63	$5.75	$6.28	$6.35	$6.92	$7.25
Source: Texas Water Development Board, Office of Water Resources Planning						

Table B-4: Lost Water Utility Revenues (Municipal)						
County	2010	2020	2030	2040	2050	2060
Kerr	$0.23	$0.23	$0.22	$0.21	$0.22	$0.22
Real	$1.76	$2.28	$2.48	$2.49	$2.81	$2.96
Total	$1.99	$2.51	$2.70	$2.71	$3.03	$3.19
Source: Texas Water Development Board, Office of Water Resources Planning						

Table B-5: Lost Water Utility Taxes (Municipal)						
County	2010	2020	2030	2040	2050	2060
Kerr	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Real	$0.03	$0.04	$0.04	$0.04	$0.05	$0.05
Total	$0.04	$0.04	$0.05	$0.05	$0.05	$0.06
Source: Texas Water Development Board, Office of Water Resources Planning						

Attachment C: Allocation of Economic Impacts by River Basin

Tables C-1 and C-2 distribute regional economic and social impacts by major river basin. Impacts were allocated based on distribution of water shortages among counties. For instance, if 50 percent of water shortages in River Basin A and 50 percent occur in River Basin then impacts were split equally among the two basins.

Irrigation

Table C1: Distribution of Impacts among Major River Basins (Irrigation)						
Lost Sales ($millions)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	$0.01	$0.02	$0.02	$0.02	$0.02	$0.01
Guadalupe	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Nueces	$0.06	$0.05	$0.04	$0.04	$0.03	$0.02
Rio Grande	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
San Antonio	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$0.07	$0.07	$0.06	$0.05	$0.05	$0.04
Lost Income ($millions)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Guadalupe	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Nueces	$0.05	$0.04	$0.04	$0.03	$0.02	$0.02
Rio Grande	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
San Antonio	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$0.06	$0.05	$0.05	$0.04	$0.04	$0.03
Job Losses (numbers may not sum to figures in text due to rounding)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	1	1	1	1	1	1
Guadalupe	0	0	0	0	0	0
Nueces	3	3	2	2	2	1
Rio Grande	0	0	0	0	0	0
San Antonio	0	0	0	0	0	0
Total	4	3	3	3	2	2
Lost Business Taxes ($millions)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	$0.001	$0.001	$0.001	$0.001	$0.001	$0.001
Guadalupe	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Nueces	$0.004	$0.003	$0.003	$0.003	$0.002	$0.002
Rio Grande	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
San Antonio	$0.000	$0.000	$0.000	$0.000	$0.000	$0.000
Total	$0.005	$0.004	$0.004	$0.004	$0.003	$0.002
Source: Texas Water Development Board, Office of Water Resources Planning						

Municipal

Table C-2: Distribution of Impacts among Major River Basins (Municipal)

Lost Sales ($millions)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Guadalupe	$3.93	$4.63	$4.82	$4.63	$4.50	$2.26
Nueces	$0.18	$0.37	$0.55	$0.68	$0.71	$0.27
Rio Grande	$0.00	$0.00	$0.00	$0.00	$0.81	$3.71
San Antonio	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$4.11	$5.01	$5.37	$5.31	$6.02	$6.24
Lost Income ($millions)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Guadalupe	$5.70	$6.84	$7.22	$7.03	$6.68	$3.38
Nueces	$0.26	$0.55	$0.82	$1.03	$1.05	$0.41
Rio Grande	$0.00	$0.00	$0.00	$0.00	$1.21	$5.54
San Antonio	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$5.96	$7.39	$8.05	$8.06	$8.94	$9.32
Job Losses (numbers may not sum to figures in text due to rounding)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	0	0	0	0	0	0
Guadalupe	44	51	54	51	51	25
Nueces	2	4	6	7	8	3
Rio Grande	0	0	0	0	9	41
San Antonio	0	0	0	0	0	0
Total	46	56	60	58	68	70
Lost Business Taxes ($millions)						
Basin	2010	2020	2030	2040	2050	2060
Colorado	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Guadalupe	$0.13	$0.14	$0.14	$0.14	$0.13	$0.06
Nueces	$0.01	$0.01	$0.02	$0.02	$0.02	$0.01
Rio Grande	$0.00	$0.00	$0.00	$0.00	$0.02	$0.10
San Antonio	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	$0.14	$0.15	$0.16	$0.16	$0.17	$0.18

Source: Texas Water Development Board, Office of Water Resources Planning

APPENDIX 4B

WATER SUPPLY CAPACITY AND

WATER DEMAND COMPARISON

BY RIVER BASIN

APPENDIX 4B. WATER SUPPLY CAPACITY AND WATER DEMAND COMPARISON BY RIVER BASIN DURING DROUGHT-OF-RECORD CONDITIONS

(Acre-Feet/Year) (Shaded areas designate shortages)

Bandera County

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Bandera	San Antonio	S	1,210	1,210	1,210	1,210	1,210	1,210
		D	259	284	312	332	351	371
			951	**926**	**898**	**878**	**859**	**839**
County Other	Guadalupe	S	31	31	31	31	31	31
		D	1	2	2	3	3	3
			30	**29**	**29**	**28**	**28**	**28**
	San Antonio	S	10,673	10,673	10,673	10,673	10,673	10,673
		D	2,425	3,381	4,330	4,817	4,932	5,232
			8,248	**7,292**	**6,343**	**5,856**	**5,741**	**5,441**
	Nueces	S	806	806	806	806	806	806
		D	183	255	327	386	439	491
			623	**551**	**479**	**420**	**367**	**315**
Mining	San Antonio	S	24	24	24	24	24	24
		D	24	24	24	24	24	24
			0	**0**	**0**	**0**	**0**	**0**
Irrigation	Guadalupe	S	3	3	3	3	3	3
		D	0	0	0	0	0	0
			3	**3**	**3**	**3**	**3**	**3**
	San Antonio	S	207	207	207	207	207	207
		D	283	283	283	283	283	283
			-76	**-76**	**-76**	**-76**	**-76**	**-76**
	Nueces	S	143	143	143	143	143	143
		D	181	181	181	181	181	181
			-38	**-38**	**-38**	**-38**	**-38**	**-38**
Livestock	Guadalupe	S	6	6	6	6	6	6
		D	6	6	6	6	6	6
			0	**0**	**0**	**0**	**0**	**0**
	San Antonio	S	262	262	262	262	262	262
		D	218	218	218	218	218	218
			44	**44**	**44**	**44**	**44**	**44**
	Nueces	S	95	95	95	95	95	95
		D	91	91	91	91	91	91
			4	**4**	**4**	**4**	**4**	**4**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060

Edwards County

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Rocksprings	Colorado	S	322	322	322	322	322	322
		D	174	179	172	164	160	154
			148	**143**	**150**	**158**	**162**	**168**
	Nueces	S	180	180	180	180	180	180
		D	98	100	96	92	90	86
			82	**80**	**84**	**88**	**90**	**94**
County Other	Colorado	S	121	121	121	121	121	121
		D	35	36	34	33	32	31
			86	**85**	**87**	**88**	**89**	**90**
	Nueces	S	411	411	411	411	411	411
		D	118	121	116	111	108	104
			293	**290**	**295**	**300**	**303**	**307**
	Rio Grande	S	72	72	72	72	72	72
		D	20	20	19	19	18	17
			52	**52**	**53**	**53**	**54**	**55**
Mining	Colorado	S	6	6	6	6	6	6
		D	5	5	5	5	5	5
			1	**1**	**1**	**1**	**1**	**1**
Irrigation	Colorado	S	96	96	96	96	96	96
		D	43	41	39	38	36	34
			53	**55**	**57**	**58**	**60**	**62**
	Nueces	S	197	197	197	197	197	197
		D	87	84	81	77	74	71
			110	**113**	**116**	**120**	**123**	**126**
	Rio Grande	S	53	53	53	53	53	53
		D	23	22	21	20	19	18
			30	**31**	**32**	**33**	**34**	**35**
Livestock	Colorado	S	225	225	225	225	225	225
		D	175	175	175	175	175	175
			50	**50**	**50**	**50**	**50**	**50**
	Nueces	S	230	230	230	230	230	230
		D	230	230	230	230	230	230
			0	**0**	**0**	**0**	**0**	**0**
	Rio Grande	S	164	164	164	164	164	164
		D	157	157	157	157	157	157
			7	**7**	**7**	**7**	**7**	**7**

Kerr County

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Kerrville	Guadalupe	S	3,040	3,040	3,040	3,040	3,040	3,040
		D	4,362	4,746	4,918	4,937	5,152	5,262
			-1,322	**-1,706**	**-1,878**	**-1,897**	**-2,112**	**-2,222**
Ingram	Guadalupe	S	585	585	585	585	585	585
		D	220	238	242	229	212	200
			365	**347**	**343**	**356**	**373**	**385**
Kerrville South WC	Guadalupe	S	420	420	420	420	420	420
		D	405	437	448	424	393	371
			15	**-17**	**-28**	**-4**	**27**	**49**
County Other	Colorado	S	251	251	251	251	251	251
		D	58	62	63	60	56	52
			193	**189**	**188**	**191**	**195**	**199**
	Guadalupe	S	12,182	12,182	12,182	12,182	12,182	12,182
		D	2,246	2,429	2,469	2,494	2,632	2,716
			9,936	**9,753**	**9,713**	**9,688**	**9,550**	**9,466**
	San Antonio	S	125	125	125	125	125	125
		D	18	19	19	18	17	16
			107	**106**	**106**	**107**	**108**	**109**
Manufacturing	Guadalupe	S	51	51	51	51	51	51
		D	30	33	36	39	41	44
			21	**18**	**15**	**12**	**10**	**7**
Mining	Colorado	S	13	13	13	13	13	13
		D	13	12	12	12	12	12
			0	**1**	**1**	**1**	**1**	**1**
	Guadalupe	S	252	252	252	252	252	252
		D	154	153	152	151	150	149
			98	**99**	**100**	**101**	**102**	**103**
Irrigation	Guadalupe	S	1,364	1,364	1,364	1,364	1,364	1,364
		D	1,821	1,761	1,706	1,652	1,599	1,548
			-457	**-397**	**-342**	**-288**	**-235**	**-184**
Livestock	Colorado	S	125	125	125	125	125	125
		D	125	125	125	125	125	125
			0	**0**	**0**	**0**	**0**	**0**
	Guadalupe	S	355	355	355	355	355	355
		D	324	324	324	324	324	324
			31	**31**	**31**	**31**	**31**	**31**
	San Antonio	S	34	34	34	34	34	34
		D	34	34	34	34	34	34
			0	**0**	**0**	**0**	**0**	**0**
	Nueces	S	12	12	12	12	12	12
		D	4	4	4	4	4	4
			8	**8**	**8**	**8**	**8**	**8**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Kinney County								
Brackettville	Rio Grande	S	647	647	647	647	647	647
		D	583	583	582	582	581	582
			64	**64**	**65**	**65**	**66**	**65**
Fort Clark Springs	Rio Grande	S	1,120	1,120	1,120	1,120	1,120	1,120
		D	626	653	678	704	723	727
			494	**467**	**442**	**416**	**397**	**393**
County Other	Nueces	S	48	48	48	48	48	48
		D	35	21	13	8	4	3
			13	**27**	**35**	**40**	**44**	**45**
	Rio Grande	S	88	88	88	88	88	88
		D	32	31	31	31	31	31
			56	**57**	**57**	**57**	**57**	**57**
Irrigation	Nueces	S	4,382	4,382	4,382	4,382	4,382	4,382
		D	338	323	310	296	284	271
			4,044	**4,059**	**4,072**	**4,086**	**4,098**	**4,111**
	Rio Grande	S	25,784	25,784	25,784	25,784	25,784	25,784
		D	13,169	12,605	12,063	11,547	11,053	10,582
			12,615	**13,179**	**13,721**	**14,237**	**14,731**	**15,202**
Livestock	Nueces	S	334	334	334	334	334	334
		D	187	187	187	187	187	187
			147	**147**	**147**	**147**	**147**	**147**
	Rio Grande	S	341	341	341	341	341	341
		D	258	258	258	258	258	258
			83	**83**	**83**	**83**	**83**	**83**
Real County								
Camp Wood	Nueces	S	0	0	0	0	0	0
		D	172	172	166	160	163	167
			-172	**-172**	**-166**	**-160**	**-163**	**-167**
County Other	Colorado	S	34	34	34	34	34	34
		D	11	11	11	10	11	11
			23	**23**	**23**	**24**	**23**	**23**
	Nueces	S	1,488	1,488	1,488	1,488	1,488	1,488
		D	417	416	400	386	394	402
			1,071	**1,072**	**1,088**	**1,102**	**1,094**	**1,086**
Mining	Colorado	S	6	6	6	6	6	6
		D	5	5	5	5	5	5
			1	**1**	**1**	**1**	**1**	**1**
Irrigation	Nueces	S	2,511	2,511	2,511	2,511	2,511	2,511
		D	392	377	361	346	330	314
			2,119	**2,134**	**2,150**	**2,165**	**2,181**	**2,197**
Livestock	Nueces	S	205	205	205	205	205	205
		D	148	148	148	148	148	148
			57	**57**	**57**	**57**	**57**	**57**
	Colorado	S	39	39	39	39	39	39
		D	28	28	28	28	28	28
			11	**11**	**11**	**11**	**11**	**11**

County/ Water Use Category	Source Basin	Supply/ Demand	2010	2020	2030	2040	2050	2060
Val Verde County								
Del Rio	Rio Grande	S	16,577	16,577	16,577	16,577	16,577	16,577
		D	12,898	13,817	14,646	15,314	15,855	16,281
			3,679	**2,760**	**1,931**	**1,263**	**722**	**296**
Laughlin AFB	Rio Grande	S	2,299	2,299	2,299	2,299	2,299	2,299
		D	1,303	1,296	1,289	1,281	1,276	1,276
			996	**1,003**	**1,010**	**1,018**	**1,023**	**1,023**
County Other	Rio Grande	S	6,044	6,044	6,044	6,044	6,044	6,044
		D	2,621	3,274	3,888	4,378	4,766	5,046
			3,423	**2,770**	**2,156**	**1,666**	**1,278**	**998**
Mining	Rio Grande	S	156	156	156	156	156	156
		D	118	111	107	104	101	99
			38	**45**	**49**	**52**	**55**	**57**
Irrigation	Rio Gande	S	6,837	6,837	6,837	6,837	6,837	6,837
		D	3,086	2,968	2,852	2,743	2,636	2,535
			3,751	**3,869**	**3,985**	**4,094**	**4,201**	**4,302**
Livestock	Rio Grande	S	767	767	767	767	767	767
		D	767	767	767	767	767	767
			0	**0**	**0**	**0**	**0**	**0**

CHAPTER 5

WATER QUALITY IMPACTS AND

IMPACTS ON MOVING WATER

FROM AGRICULTURAL AREAS

5.1 INTRODUCTION

Water quality plays an important role in determining the availability of water supplies to meet current and future water needs in the Plateau Region. This chapter describes the general water quality of the surface water and groundwater sources in the Region, discusses specific water quality issues, and considers potential water management strategy impacts on water quality. In consideration of impacts on water quality, the Plateau Water Planning Group identified primary and secondary safe drinking-water standards as being the significant factor that determines the usefulness of the various water resources in the Region (Table 5-1).

A groundwater quality database comprised of water quality analyses from the TWDB groundwater database was established for the four primary aquifers in the Region. Tables 5-2 through 5-5 provide information pertaining to the number of mineral constituent analyses available and the percent of these analyses that depict concentration levels above safe drinking water standards.

While there appears to be a sufficient number of evenly distributed sample locations (Figure 5-1) for making regional quality assumptions, many of the sample dates are relatively old and thus less reliable as current indicators. It is recommended that these older analyses be replaced by re-sampling the same wells or, if not practical, new wells in the same general area. Groundwater conservations districts should take the lead in this task within their respective areas. A water quality survey of sampled wells in the Frio River Alluvium aquifer in Real County, concentrating on nitrates, would be beneficial in assessing impacts of urbanization in the general area of the town of Leakey.

5.2 WATER QUALITY STANDARDS

Screening levels for public drinking water supplies are used for comparisons of water quality data in the Region. Drinking water standards are classified as primary and secondary and are listed in terms of maximum contaminant levels (MCLs) as defined in the Texas Administrative Code (30 TAC, Chapter 290, Subchapter F). U.S. Environmental Protection Agency (EPA) MCLs for certain secondary constituents are more stringent than the State standards.

Primary MCLs are legally enforceable standards that apply to public drinking water supplies in order to protect human health from contaminants in drinking water. Secondary standards are non-enforceable guidelines based on aesthetic effects that these constituents may cause (taste, color, odor, etc.). In addition to primary MCLs and secondary standards, two constituents, lead and copper, have specified action levels. These action levels apply to community and non-transient non-community water systems, and to new water systems when notified by the Texas Commission on Environmental Quality (TCEQ) Executive Director. A summary of the public drinking water supply parameters used to evaluate water quality is provided in Table 5-1. Certain constituents on the State list are not included on the table because there is a significant lack of analyses containing these elements in the public databases that were used.

On October 31, 2001, EPA announced that the new arsenic MCL for drinking water would be 10 parts per billion (ppb) with a compliance date of January 23, 2006. Until recently, the MCL for arsenic allowed under the Safe Drinking Water Act was 50 ppb. Because of this impending new standard, a screening level of 10 ppb is used for the evaluation in this chapter.

TABLE 5- 1. SELECTED PUBLIC DRINKING WATER SUPPLY PARAMETERS

Constituent	Maximum Contaminant Level (mg/L unless otherwise noted)	Type of Standard
Nitrate-N	10	Primary
Fluoride	4	Primary
Barium	2	Primary
Alpha	15 pc/L	Primary
Cadmium	0.005	Primary
Chromium	0.1	Primary
Selenium	0.05	Primary
Arsenic	0.01	Primary
Lead	0.015	Action Level
Copper	1.3	Action Level
TDS	1000	Secondary
Chloride	300	Secondary
Sulfate	300	Secondary
pH	6.5 – 8.5	Secondary
Fluoride	2	Secondary
Iron	0.3	Secondary
Manganese	0.05	Secondary
Copper	1	Secondary

Primary drinking water standard from 30 TAC Chapter 290 Subchapter F, Rule 290.106

Action Level for Copper and Lead from 30 TAC Chapter 290 Subchapter F, Rule 290.117

Secondary drinking water standard from 30 TAC Chapter 290 Subchapter F, Rule 290.118

5.3 GROUNDWATER QUALITY

All groundwater contains minerals carried in solution and their concentration is rarely uniform throughout the extent of an aquifer. The degree and type of mineralization of

groundwater determines its suitability for municipal, industrial, irrigation and other uses. Groundwater resources in the Plateau Region are generally potable, although regionwide between five and ten percent of the groundwater is brackish. Groundwater quality issues in the Region are generally related to naturally high concentrations of total dissolved solids (TDS) or to the occurrence of elevated concentrations of individual dissolved constituents.

High concentrations of TDS are primarily the result of the lack of sufficient recharge and restricted circulation. Together, these retard the flushing action of fresh water moving through the aquifers.

The quality of groundwater in the aquifers was evaluated to help determine the suitability of the groundwater sources for use and potential impacts on recommended water management strategies. Water-quality data was compiled from the TWDB groundwater database and the TCEQ public water-supply well database.

TDS is commonly used to generally define water quality. TDS refers to the sum of the concentrations of all the dissolved ions in water, which are chiefly composed of sodium, calcium, magnesium, potassium, chloride, sulfate, and bicarbonate ions. The TWDB has defined gross aquifer water quality in terms of TDS concentrations expressed in milligrams per liter (mg/l), and has classified water into four broad categories:

- fresh (less than 1,000 mg/l); *(Note: 500 mgl is Secondary Standard)*
- slightly saline (1,000 - 3,000 mg/l);
- moderately saline (3,000 - 10,000 mg/l); and
- saline (10,000 - 35,000 mg/l).

Because of its usefulness as an indicator of general groundwater quality, TDS serves as a primary parameter of interest for this evaluation. Figure 5-1 shows the water quality, in terms of TDS, for groundwater from the four primary aquifers in the Plateau Region area; the Edwards-Trinity (Plateau), the Trinity, the Edwards (BFZ), and the Austin Chalk aquifers. This figure indicates that a majority of groundwater in the Plateau Region is fresh, with limited occurrences of slightly to moderately saline groundwater occurring in the Trinity aquifer in Bandera County, and in the Edwards-Trinity (Plateau) aquifer in Val Verde and Real Counties in particular. It should be noted that wells in much of the extent of the Edwards-Trinity (Plateau) aquifer produce from the shallower Edwards Formation, and there is probably brackish groundwater available from the underlying Trinity portions of this aquifer in much of the Region. However, there is no data from which to base an evaluation of this part of the Trinity Formation due to the lack of wells producing from this lower zone.

Most of the parameters in groundwater samples from the Plateau Region were found below the applicable water quality standard. Three constituents that were found above the applicable standard in a significant number of wells are fluoride, sulfate and iron. More than one-third of the samples from the Trinity aquifer and between ten and fifteen percent of samples from the Edwards-Trinity (Plateau) aquifer have concentrations of these parameters above the secondary standard. Figures 5-2 and 5-3 show the distribution of fluoride and iron in the Plateau Region, respectively. As shown in these figures, a larger percentage of groundwater in Kerr and Bandera Counties, where the Trinity aquifer is heavily used, have concentrations of these two analytes above the drinking water standard. More detail on the presence of these analytes in each aquifer is given in the sections below.

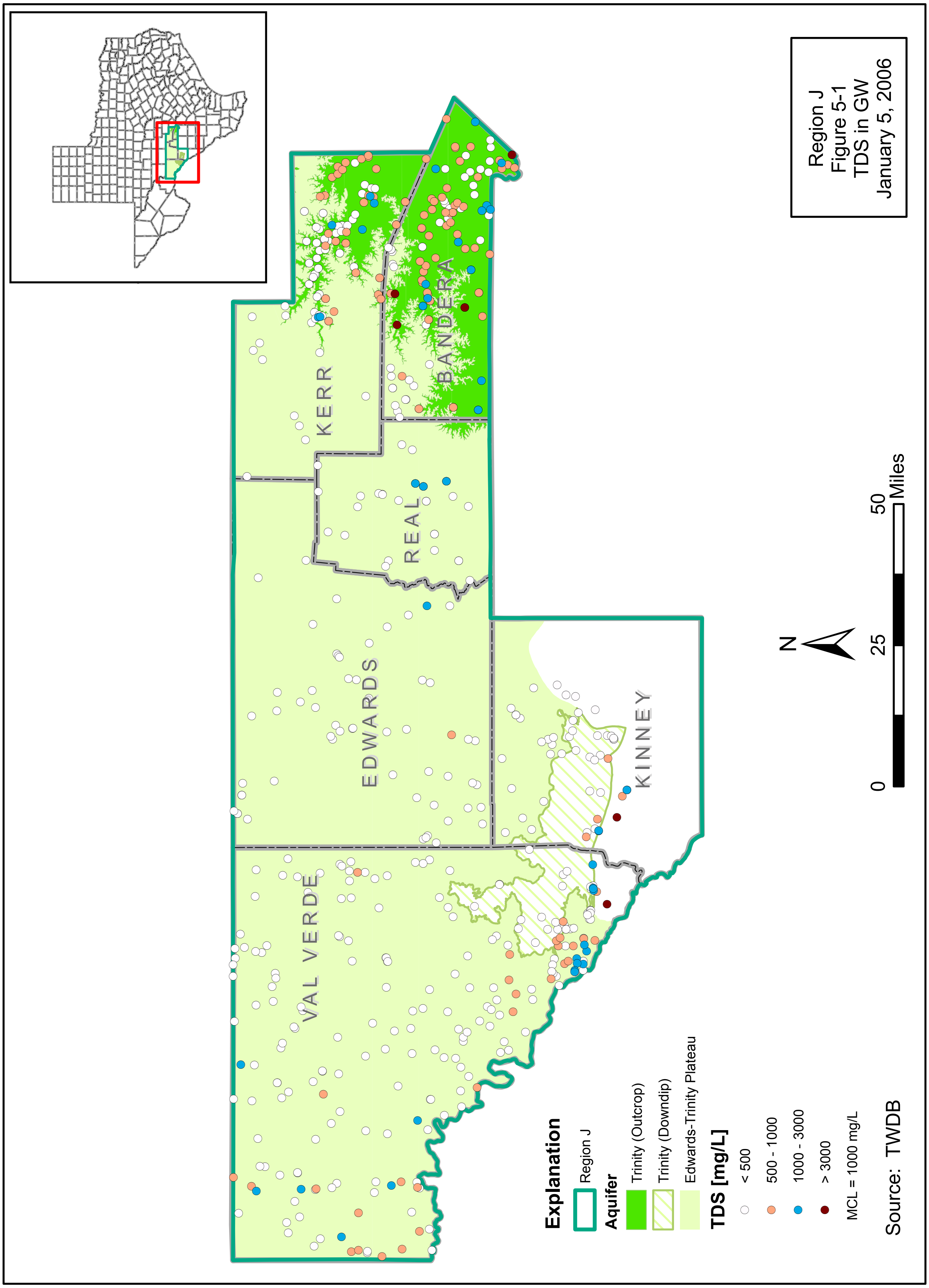


FIGURE 5-1. TOTAL DISSOLVED SOLIDS IN GROUNDWATER IN THE PLATEAU REGION

LBG-GUYTON ASSOCIATES

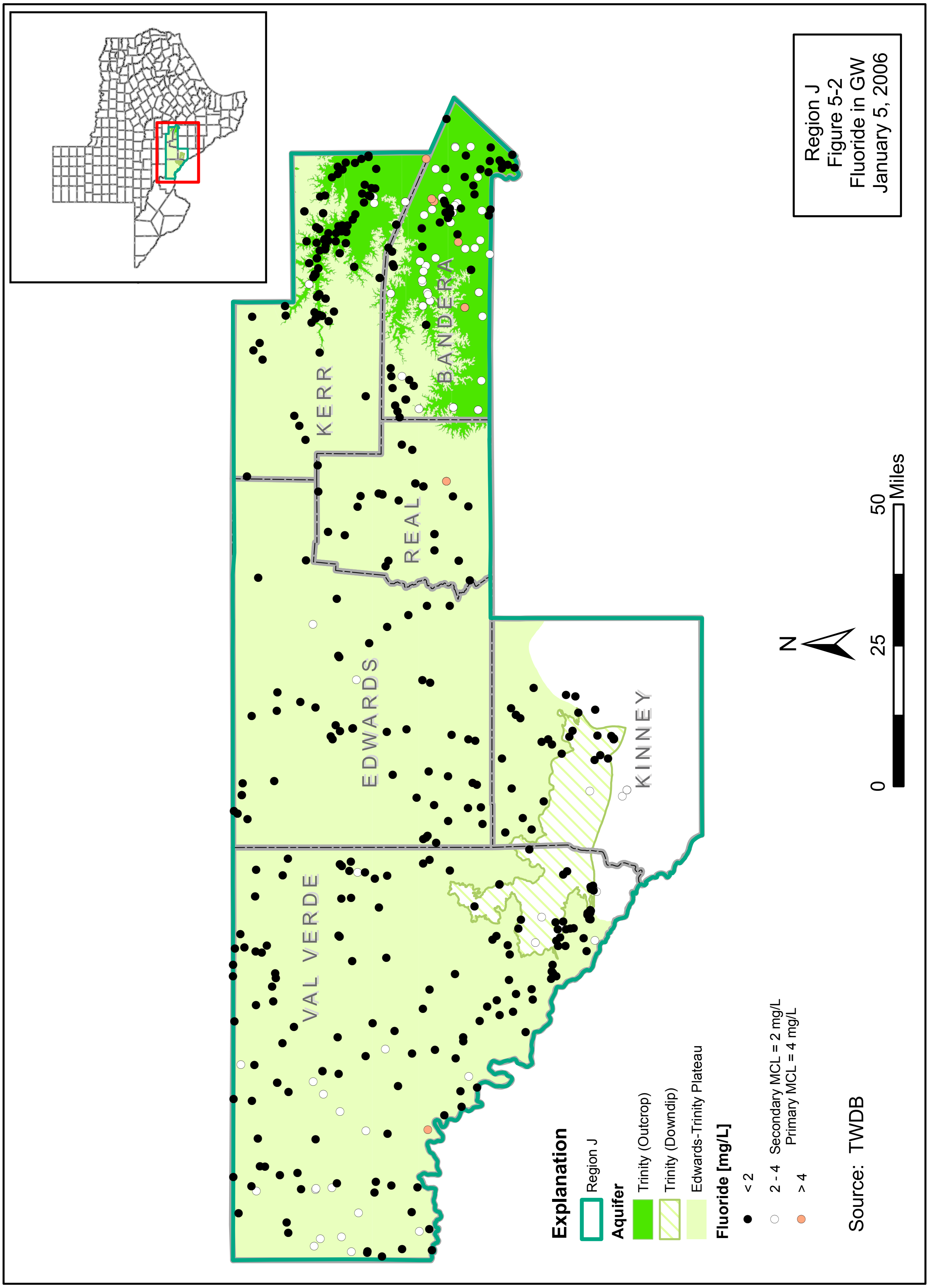


FIGURE 5-2. FLUORIDE IN GROUNDWATER IN THE PLATEAU REGION

LBG-GUYTON ASSOCIATES

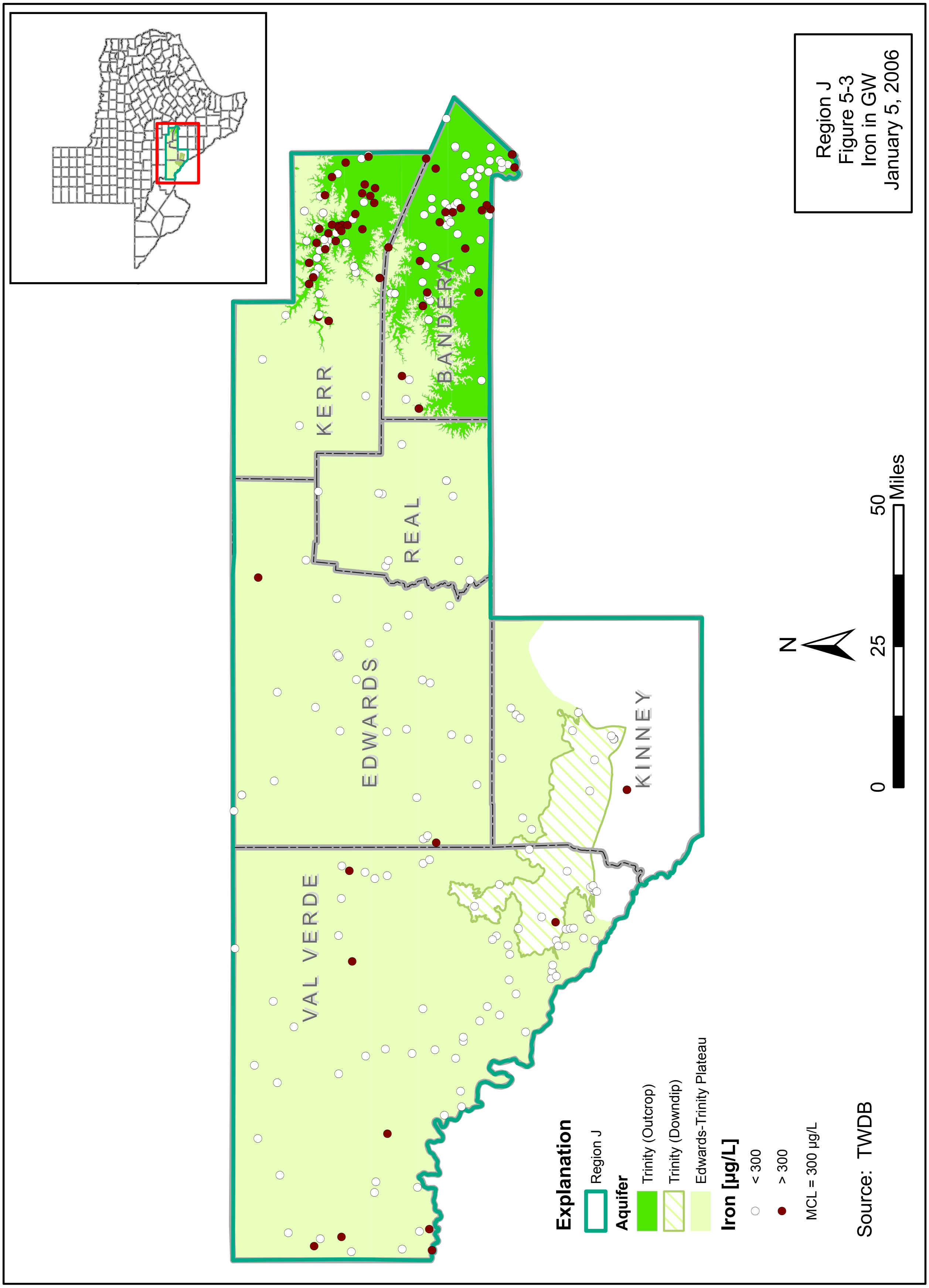


FIGURE 5-3. IRON IN GROUNDWATER IN THE PLATEAU REGION

LBG-GUYTON ASSOCIATES

5.3.1 Edwards-Trinity (Plateau) Aquifer

Usable quality water (containing less than 3,000 mg/l dissolved solids) in the Edwards-Trinity (Plateau) aquifer occurs to depths of up to about 3,000 feet. The water is typically hard and may vary widely in concentrations of dissolved solids consisting mostly of calcium and bicarbonate. The salinity of the groundwater in the Trinity portion of the aquifer tends to increase toward the southwest. Water quality from primarily the Edwards portion of the aquifer is acceptable for most municipal and industrial purposes, however, excess concentrations of certain constituents in many places exceed drinking-water standards for municipal supplies. In most instances, excess levels of constituents are naturally occurring.

Up to 439 results were included in the analysis of groundwater quality in the Edwards-Trinity (Plateau) aquifer. The occurrence of selected drinking water parameters for the Edwards-Trinity (Plateau) compared to screening levels is shown in Table 5-2. As indicated in this table, water in the Edwards-Trinity (Plateau) aquifer contains only a few occurrences of constituents above primary MCLs, including alpha radiation (3.5% of the results), fluoride (1.1%), and nitrate (0.9%). Of the parameters with secondary drinking water standards, all but copper were detected above the screening level in some of the results, including TDS (8.2%), sulfate (9.6%), chloride (1.1%), fluoride (13.1%), iron (13.2%), manganese (1.4%), and pH (1.4%).

TABLE 5- 2. OCCURRENCE AND LEVELS OF SELECTED PUBLIC DRINKING WATER SUPPLY PARAMETERS IN THE EDWARDS-TRINITY (PLATEAU) AQUIFER

	Number of Results	Screening Level (mg/L unless otherwise noted)	Type of Standard	Percent of Results Exceeding Screening Level
Nitrate-N	425	10	Primary	0.9%
Fluoride	343	4	Primary	1.1%
Barium	136	2	Primary	0%
Alpha	85	15 pc/L	Primary	3.5%
Cadmium	102	0.005	Primary	0%
Chromium	108	0.1	Primary	0%
Selenium	113	0.05	Primary	0%
Arsenic	136	0.01	Primary	0%
Lead	132	0.015	Action Level	0%
Copper	137	1.3	Action Level	0%
TDS	439	1000	Secondary	8.2%
Chloride	438	300	Secondary	1.1%
Sulfate	439	300	Secondary	9.6%
pH	368	6.5 – 8.5	Secondary	1.4%
Fluoride	343	2	Secondary	13.1%
Iron	174	0.3	Secondary	13.2%
Manganese	145	0.05	Secondary	1.4%
Copper	137	1	Secondary	0%

5.3.2 Trinity Aquifer

The Upper and Middle Trinity aquifer units are divisible based on differences in water quality. The upper member of the Glen Rose Limestone, which forms the Upper Trinity aquifer unit, contains water with relatively high concentrations of sulfate. TDS often exceeds 1,000 mg/l, as compared to the generally fresher Middle Trinity aquifer. Middle Trinity aquifer water quality is generally acceptable for most municipal and industrial purposes; however, certain constituents, such as sulfate and fluoride, exceed drinking-water standards for municipal supplies in many places. In most instances, excess levels of constituents are naturally occurring.

The water chemistry in the Lower Trinity is generally suitable for most uses in Bandera and Kerr Counties, the only areas where this portion of the aquifer is used. However, the dissolved solids can occasionally be found at concentrations above 1,000 mg/l.

Up to 162 results were included in the analysis of groundwater quality in the Trinity aquifer. The occurrence of selected drinking water parameters compared to screening levels is shown in Table 5-3. As indicated in this table, water in the Trinity aquifer contains only a few occurrences of constituents above primary MCLs, including chromium (1.6% of the results), fluoride (4.9%), and nitrate (0.6%). Of the parameters with secondary drinking water standards, all except chloride and copper were detected above the screening level in some of the results, including TDS (14.2%), sulfate (20.4%), fluoride (34.3%), iron (38.1%), manganese (6.5%), and pH (1.9%).

TABLE 5- 3. OCCURRENCE AND LEVELS OF SELECTED PUBLIC DRINKING WATER SUPPLY PARAMETERS IN THE TRINITY AQUIFER

	Number of Results	Screening Level (mg/L unless otherwise noted)	Type of Standard	Percent of Results Exceeding Screening Level
Nitrate-N	425	10	Primary	0.6%
Fluoride	343	4	Primary	4.9%
Barium	136	2	Primary	0%
Alpha	85	15 pc/L	Primary	0%
Cadmium	102	0.005	Primary	0%
Chromium	108	0.1	Primary	1.6%
Selenium	113	0.05	Primary	0%
Arsenic	136	0.01	Primary	0%
Lead	132	0.015	Action Level	0%
Copper	137	1.3	Action Level	0%
TDS	439	1000	Secondary	14.2%
Chloride	438	300	Secondary	0%
Sulfate	439	300	Secondary	20.4%
pH	368	6.5 – 8.5	Secondary	1.9%
Fluoride	343	2	Secondary	34.3%
Iron	174	0.3	Secondary	38.1%
Manganese	145	0.05	Secondary	6.5%
Copper	137	1	Secondary	0%

5.3.3 Edwards (BFZ) Aquifer

The chemical quality of water in the Edwards (BFZ) aquifer is typically fresh, although hard, with dissolved-solids concentrations averaging less than 500 mg/l. The downdip interface between fresh and slightly-saline water represents the extent of water containing less than 1,000 mg/l. Within a short distance downgradient of this "bad water line" the groundwater becomes increasingly mineralized.

Up to 23 results were included in the analysis of groundwater quality in the Edwards (BFZ) aquifer in Kinney County, the only county in the Region where this aquifer occurs. The occurrence of selected drinking water parameters for the aquifer compared to screening levels is shown in Table 5-4.

As indicated in Table 5-4, the only primary standard constituent that was detected above the screening level in the Edwards (BFZ) aquifer is nitrate, with more than one-quarter of the results being above the screening level. Of the parameters with secondary drinking water standards, only TDS (4.3%), sulfate (8.6%), and fluoride (13%) were detected above the screening level.

TABLE 5- 4. OCCURRENCE AND LEVELS OF SELECTED PUBLIC DRINKING WATER SUPPLY PARAMETERS IN THE EDWARDS (BFZ) AQUIFER

	Number of Results	Screening Level (mg/L unless otherwise noted)	Type of Standard	Percent of Results Exceeding Screening Level
Nitrate-N	23	10	Primary	26.1%
Fluoride	5	4	Primary	0%
Barium	7	2	Primary	0%
Alpha	6	15 pc/L	Primary	0%
Cadmium	6	0.005	Primary	0%
Chromium	6	0.1	Primary	0%
Selenium	6	0.05	Primary	0%
Arsenic	7	0.01	Primary	0%
Lead	7	0.015	Action Level	0%
Copper	6	1.3	Action Level	0%
TDS	23	1000	Secondary	4.3%
Chloride	23	300	Secondary	0%
Sulfate	23	300	Secondary	8.6%
pH	13	6.5 – 8.5	Secondary	0%
Fluoride	5	2	Secondary	13%
Iron	16	0.3	Secondary	0%
Manganese	11	0.05	Secondary	0%
Copper	6	1	Secondary	0%

5.3.4 Austin Chalk Aquifer

Up to 29 results were included in the analysis of groundwater quality in the Austin Chalk aquifer in Kinney County, the only county in the Plateau Region where this aquifer occurs. The occurrence of selected drinking water parameters for the aquifer compared to screening levels is shown in Table 5-5.

As indicated in Table 5-5, the only primary constituent that was detected above the screening level in the Austin Chalk aquifer is nitrate, with more than one-fifth of the results being above the screening level. Of the parameters with secondary drinking water standards, only TDS (4.5%), sulfate (3.4%), and chloride (3.4%) were detected above the screening level.

TABLE 5- 5. OCCURRENCE AND LEVELS OF SELECTED PUBLIC DRINKING WATER SUPPLY PARAMETERS IN THE AUSTIN CHALK AQUIFER

	Number of Results	Screening Level (mg/L unless otherwise noted)	Type of Standard	Percent of Results Exceeding Screening Level
Nitrate-N	29	10	Primary	20.7%
Fluoride	17	4	Primary	0%
Barium	3	2	Primary	0%
Alpha	3	15 pc/L	Primary	0%
Cadmium	3	0.005	Primary	0%
Chromium	3	0.1	Primary	0%
Selenium	3	0.05	Primary	0%
Arsenic	3	0.01	Primary	0%
Lead	3	0.015	Action Level	0%
Copper	3	1.3	Action Level	0%
TDS	22	1000	Secondary	4.5%
Chloride	29	300	Secondary	3.4%
Sulfate	29	300	Secondary	3.4%
pH	6	6.5 – 8.5	Secondary	0%
Fluoride	17	2	Secondary	0%
Iron	3	0.3	Secondary	0%
Manganese	3	0.05	Secondary	0%
Copper	3	1	Secondary	0%

5.4 SURFACE WATER QUALITY

Reservoirs within the Plateau Region - Amistad Reservoir, Medina Lake and Medina Diversion Lake - are some of the clearest (most transparent) water bodies in the State of Texas. Amistad Reservoir is the third clearest water body in Texas. Medina Lake is the fifth clearest, while Medina Diversion Lake is the ninth clearest water body (TNRCC, 1996, Table 41, p. 171). TNRCC (now TCEQ) compared chlorophyll values for 104 Texas reservoirs from the 1994 and 1996 reporting cycles. Of these, reservoirs that showed the most improvement in nutrient status, as evidenced by decreases in algal biomass, included Medina Lake (TNRCC, 1996, p. 177). However, the State also identified the levels of diazanon in Medina Lake as exceeding both the chronic and acute criteria for protection of aquatic life (TNRCC, 1996, Table 52, p. 217). These criteria are defined in terms of toxic substances in ambient water.

The state has also defined criteria in terms of toxic substances found in fish tissue harvested from water bodies. In the Plateau Region, the water-quality segment of concern for toxic substances found in fish tissue is the Rio Grande above Amistad Reservoir; selenium is the toxin identified (TNRCC, 1996, Table 55, p. 222).

The State's Clean Water Program administers federal Clean Water Act directives through TCEQ's Water Quality Inventories. TCEQ is the responsible agency for identifying water-quality problems within the Water Quality Inventory. However, the Inventory does not identify sources of water-quality problems; in most cases, the problems are "non-point source" pollutants. TCEQ, EPA and other agencies have discussed and researched methodologies by which non-point source pollution could be modeled, but thus far modeling efforts have been less than satisfactory. Detailed excerpts from the Water Quality Inventory were included in the Chapter 3 Appendices in the first (2001) Plateau Regional Water Plan; these excerpts address potential water-quality threats to river systems in the Plateau Region, including Medina Lake, citing no known water quality problems (i.e., Plateau rivers are clear of the parameters which the agency monitors).

5.5 CURRENT WATER QUALITY ISSUES

Water-quality problems sometimes pose potential threats to natural resources and the ecological environments therein. Fecal coliform bacteria, in addition to posing a potential public health threat, tend to upset the microbiological balance of a water system. Generally the presence of fecal coliform bacteria also indicates the presence of other pathogens. Watercourses where high levels of nutrients have been identified have the potential to experience algal blooms, which may consume too much of the available dissolved oxygen in the water leaving less oxygen for fish. High levels of dissolved minerals such as sodium in water used to irrigate crops can harm or kill the crops.

In terms of agricultural activity, pesticide and fertilizer application poses a potential threat to underlying groundwater supplies. The propensity for pesticides and fertilizers to leach past the root zone depends on which chemicals are chosen and on the soil's leaching potential. The U.S. Natural Resource Conservation Service has developed a Soil-Pesticide Interaction Screening Procedure, which evaluates the potential for pesticide loss from a field (and thus into groundwater). According to the methodology utilized in the procedure, very little of the Plateau Region has soils in the "High Soil Leaching Class".

Water quality is generally good throughout the Plateau Region; however, a few specific water quality issues should be mentioned, including the impact of urban runoff on surface water and groundwater quality, the impact of vehicular traffic in riverbeds on surface water, and general water quality problems, including the presence of nitrate in the Edwards (BFZ) and Austin Chalk aquifers.

5.5.1 Urban Runoff

Increasing population impacts water quality in many ways, one of which is the increase in urban runoff that comes with the increase in impervious cover in populated areas. Within the Plateau Region, urban runoff can impact both surface water and groundwater in a variety of ways. First is the increase in runoff. Impervious cover concentrates runoff into storm sewers and drains, which then discharges into streams, increasing the flow, which also increases the erosional power of the water. Groundwater can also be impacted due to this increase in runoff, including a decrease in the infiltration of precipitation into the ground due to impervious cover, thus impacting recharge to the aquifers.

In addition to the problem with increase in runoff, urbanization also causes increased pollutant loads, including sediment, oil/grease/toxic chemicals from motor vehicles, pesticides/herbicides/fertilizers from gardens and lawns, viruses/bacteria/ nutrients from human and animal wastes including septic systems, heavy metals from a variety of sources, and higher temperatures of the runoff. All of these can have significant adverse impacts on the water quality in both surface waters and groundwater, as all of the contaminants that are increased in surface waters through runoff from impervious cover can be introduced into groundwater via the infiltration of the runoff. This is especially true in the more karstic aquifers that are present in the Region, which are characteristically rapidly recharged through sinkholes and other conduits into the subsurface.

5.5.2 Vehicular Traffic in River Beds

Of concern to the Plateau Water Planning Group is the impact that vehicular traffic is having on streambeds. Vehicular traffic in river and stream beds disrupts streamflow, damages plants and animals living in these areas, damages channels and erodes banks, and decreases water quality by increasing the turbidity of the water in these rivers and streams. This traffic disturbs the environment both in the streambed and out of it. Disruption in the streambed can result in a reduction in species diversity with some species being unable to adapt to the modified environment and disappearing from the modified environment. These impacts can occur during all seasons, as different species have different requirements for the environment for reproduction cycles. Impacts to the streambed include the erosion of banks and the negative impact to riparian areas along these streams and rivers.

The 78th Texas Legislature (2003) passed Senate Bill 155, which prohibits, with certain exemptions, the use of motorized vehicles in navigable streambeds (except the Canadian River and Prairie Dog Town Fork of the Red River). This law went into effect in January 1, 2004, and is enforceable by any law enforcement agency.

5.5.3 Turbidity in San Felipe Springs

Occasionally after rainstorms, water discharging from San Felipe Springs becomes turbid. This turbidity caused some concern with regulating agencies about the potential for microbial contamination and the reliability of the City of Del Rio's chlorine treatment of the spring water. As a result, a microfiltration plant was constructed to treat all spring water that is supplied to the City. This plant was completed and brought on-line in 2002, and has the capacity to treat 16 million gallons of water per day.

5.5.4 Well Construction

The primary contribution to poor groundwater quality occurs in wells that do not have adequately cemented casing, thus allowing poorer quality water or contaminated to commingle with good quality water within an aquifer. Poorer water quality in the Region is generally the result of two well-completion problems. First, if a well is not properly sealed, poor quality water in part of an aquifer can migrate upward or downward in the well and mix with fresher zones. This is often the case when "gyp" water in the upper Glen Rose formation is not adequately cemented off from better water lower in the aquifer.

A second possible means of contamination is from surface sources of bacteria and high nitrates from grazing animals or leachate from septic systems. Fecal coliform bacteria can pose a potential public health threat and can also indicate the presence of other pathogens. High nitrate levels in consumed water can cause a disease known as methemoglobinemia especially in small children. This problem is generally the result of wells that are not adequately cased and cemented at the land surface of a well.

The best consideration for addressing groundwater quality problems is to have all wells properly completed with adequate amounts of cemented surface casing, especially in areas that have a high density of closely spaced wells. Closely spaced wells increase the potential that a poorly constructed well can impact numerous surrounding wells.

Groundwater conservation districts play a key role in establishing and enforcing well construction policies for the purpose of maintaining desired water quality. These districts generally follow Water Well Drillers standards established by the Texas Department of Licensing and Regulation.

5.5.5 Radioactivity

Above normal levels of radioactivity have been detected in sand sequences of the Glen Rose and Hensell formations in a few areas of their extent. The origin of the radioactivity is the product of eroded granitic rocks from the Llano uplift region to the north.

5.5.6 Salt Water Disposal Wells and Oil Field Operations

The oil and gas drilling industry is not a major activity within the Plateau Region; however, active and abandoned wells do exist in the area. Most of the Region is characterized by karst terrain which is highly susceptible to surface contamination. It is highly advisable for ongoing oilfield activities and future drilling operations to be particularly cognizant of preventing unwarranted releases on the land surface that might percolate downward to the underlying aquifer. Likewise, salt water disposal wells currently in operation in Edwards County must be maintained to prevent leakage into freshwater formations.

5.5.7 Water Quality Impacts on Potential Strategies

Water quality has the potential to significantly impact water management strategies. Based on currently observed water quality characteristics of surface water and groundwater sources, few impacts are expected to occur due to water quality issues. Of the five primary groundwater sources in the Region, most have acceptable water quality, with only a few parameters of potential concern.

The constituent of most concern in groundwater is nitrate, which was found above the primary maximum contaminant level in more than one-quarter of the results from the Edwards (BFZ) aquifer, and about one-fifth of the results from the Austin Chalk aquifer, both of which are only present in Kinney County. Nitrate contamination of groundwater supplies is a fairly common problem in many parts of the State, and is most commonly the result of contamination from septic tanks and/or contamination due to farming activities, in particular resulting from the application of fertilizer or from animal waste. Because farming is relatively uncommon in much of the Region, most of the nitrate contamination is presumed to be due to contamination from septic tanks to shallow wells. Bluntzer (1992) noted that nitrate contamination is very serious in many areas in the Hill Country, including some of the Plateau Region area. Due to the nature of nitrate contamination, it should be evaluated on a site-specific basis.

Another potential contaminant to both surface water and groundwater relates to agricultural activity and the use of pesticides. The propensity for pesticides to leach past the root zone depends on which pesticide is chosen and on the soil's leaching potential. The best preventative for agricultural activities is to minimize usage and not over apply many of the common agricultural chemicals.

Water quality degradation can also pose threats to natural resources and ecological environments. Watercourses where high levels of nutrients have been identified have the potential to experience algal blooms, which may consume too much of the available dissolved oxygen in the water, leaving less oxygen for fish. High levels of dissolved minerals such as sodium in water used to irrigate crops can harm or kill the crops.

5.6 WATER QUALITY IMPACTS OF IMPLEMENTING WATER MANAGEMENT STRATEGIES

The implementation of water management strategies recommended in Chapter 4 of this Plan is not expected to have any impact on native water quality. In particular, primary and secondary safe drinking water standards, which are the key parameters of water quality identified by the Plateau Water Planning Group as important to the use of the water resource, are not compromised by the implementation of the strategies.

5.7 IMPACTS OF MOVING WATER FROM AGRICULTURAL AREAS

Only one recommended strategy involves moving water from a rural location for use in an urban area. The development of a remote well field by the City of Kerrville could potentially result in the lowering of groundwater levels, which could impact shallow livestock wells in the vicinity of the well field. No well field location has been identified at this early stage of consideration. If implemented, the recommendation that the Headwaters Groundwater Conservation District establish management guidelines for the Edwards-Trinity (Plateau) aquifer in western Kerr County (Section 8.4.8 in Chapter 8) could minimize the impact of additional pumping in the area.

CHAPTER 6

WATER CONSERVATION AND DROUGHT CONTINGENCY

6.1 INTRODUCTION

Water conservation and drought contingency planning are two of the most important components of water supply management. Recognizing their impact, setting realistic goals, and aggressively enforcing their implementation may significantly extend the time when new supplies and associated infrastructure are needed. This chapter explores conservation opportunities and provides a road map for integrating both conservation and drought contingency planning into long-range water supply management goals.

6.2 WATER CONSERVATION

Water conservation are those practices, techniques, programs, and technologies that will protect water resources, reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling or reuse of water so that a water supply is made available for future or alternative uses. Water conservation management strategies recommended in Chapter 4 for Kerrville and Camp Wood include water audit and loss audit to reduce distribution losses, and public education to bring awareness of wasteful practices.

The implementation of water conservation programs that are cost effective, meet state mandates, and result in permanent real reductions in water use will be a challenge for the citizens of the Plateau Region. Smaller communities that lack financial and technical resources will be particularly challenged and will look to the State for assistance.

Because portions of the region are particularly susceptible to water-supply shortages during periods of drought conditions, these areas are especially encouraged to develop conservation oriented management plans. Likewise, water-user entities within these areas should become actively involved in the regional water planning activities associated with this plan.

The PWPG considers all groundwater sources recognized in this plan as being critical to the future health and economic welfare of the Plateau Region. Because of the reliance on groundwater to meet current and future water needs, the PWPG recommends that local groundwater conservation districts be formed throughout the entire Region to administer sound, reasonable, and scientifically-based management objectives; and that these districts play a major role in the regional water planning process.

It is generally recognized that brush infestations are the symptom of deeper ecological disturbances such as fire control, drought, grazing mismanagement, wildlife overpopulations and other causes. Selective Brush Management, as a tool to improve watershed yields and water quality, is a conservation management strategy of great interest in the Plateau Region, as well as in surrounding planning regions. The State should draft legislation based upon the best available science and input from all stakeholders to provide a cost-share funding program to landowners in the targeted watersheds for the Selective Brush Management BMP and required other practices.

The PWPG joins with the Rio Grande Region (M) and the Far West Texas Region (E) in encouraging funding for projects aimed at the eradication and long-term suppression of salt cedar and other nuisance phreatophytes in the Rio Grande watershed.

6.2.1 Water Conservation Considerations

6.2.1.1 Water-Saving Plumbing Fixture Program

The Texas Legislature created the Water-Savings Plumbing Fixture Program on Jan. 1, 1992 to promote water conservation. Manufacturers of plumbing fixtures sold in Texas must comply with the Environmental Performance Standards for Plumbing Fixtures, which requires all plumbing fixtures such as showerheads, toilets and faucets sold in Texas to conform with specific water use efficiency standards.

Because more water is used in the bathroom than any other place in the home, water-efficient plumbing fixtures play an integral role in reducing water consumption, wastewater production, and consumers' water bills. It is estimated that switching to water-efficient fixtures can save the average household between $50 and $100 per year on water and sewer bills. Many hotels and office buildings find that water-efficient fixtures can save 20 percent on water and wastewater costs.

6.2.1.2 Water Conservation Best Management Practices

The 78th Texas Legislature under Senate Bill 1094 created the Texas Water Conservation Implementation Task Force and charged the group with reviewing, evaluating, and recommending optimum levels of water use efficiency and conservation for the state. TWDB Report 362, Water Conservation Best Management Practices Guide was prepared in partial fulfillment of this charge. The Guide is organized into three sections, for municipal, industrial, and agricultural water user groups with a total of 55 Best Management Practices (BMPs). Each BMP has several elements that describe the efficiency measures, implementation techniques, schedule of implementation, scope, water savings estimating procedures, cost effectiveness considerations, and references to assist end-users in implementation. This document can be accessed at the following TWDB web site: http://www.twdb.state.tx.us/assistance/conservation/TaskForceDocs/WCITFBMPGuide.pdf.

6.2.1.3 Water Conservation Education

Public education may be one of the most productive actions that can result in the greatest amount of water savings. Most citizens are willing to actively do their part to conserve water once the need is communicated and the means by which to accomplish the most benefit is explained. Numerous state, county, and academic agencies provide educational material and demonstrations. Groundwater conservation districts also provide water conservation activities. The TWDB provides a significant amount of information and services pertaining to water conservation that can be accessed at http://www.twdb.state.tx.us/assistance/conservation/consindex.asp. Likewise, Water Conservation Tips were developed by the TCEQ's Clean Texas 2000. TPWD also offers programs geared toward the appreciation and conservation of the state's outdoor natural resources.

Education of our youth may be one of the best ways to spread the word about water conservation. The TWDB provides an excellent educational program for 4th and 5th grade elementary school levels. Information pertaining to this program can be accessed at http://www.twdb.state.tx.us/assistance/conservation/conservationpublications/majorrivers.asp

6.2.2 Watershed Best Management Practices

6.2.2.1 Brush Management

A potential means of increasing water supply is to reduce the amount of water consumed by shrubs and trees on rangelands. The density and coverage of shrubs has increased dramatically during the past century as former grasslands have now converted to shrublands or closed-canopy woodlands. A total loss of herbaceous vegetation cover will increase water yields in the form of surface runoff; however, this process will accelerate erosion, degrade water quality, and damage aquatic ecosystems. A more desirable way of increasing water yield is to manage vegetation to decrease evapotranspiration, which will generally increase the amount of water that percolates below the root zone into groundwater and eventually back into streams. Researchers* believe it is appropriate to broaden the issue from solely focusing on "brush control for increasing water yield" to "best management practices for watershed health and sustainability".

** Wilcox, B.P., Dugas, W.A., Owens, M.K., Ueckert, D.N., and Hart, C.R., 2005, Shrub Control and Water Yield on Texas Rangelands, Current State of Knowledge: Texas Agricultural Experiment Station Research Report 05-1.*

6.2.2.2 Rainwater Harvesting

The following discussion on Rainwater Harvesting is taken from the Texas Water Development Board's The Texas Manual on Rainwater Harvesting, 3rd Edition. This manual can be accessed from TWDB's website: http://www.twdb.state.tx.us/publications.

Rainwater is valued for its purity and softness. It has a nearly neutral pH, and is free from disinfection by-products, salts, minerals, and other natural man-made contaminants. Plants thrive under irrigation with stored rainwater. Appliances last longer when free from the corrosive or scale effects of hard water. Users with potable systems prefer the superior taste and cleansing properties of rainwater. Rainwater harvesting, in its essence, is the collection, conveyance, and storage of rainwater.

Rainwater harvesting systems can be as simple as a rain barrel for garden irrigation at the end of a downspout, or as complex as a domestic potable system or a multiple end-use system at a large corporate campus.

Advantages and benefits of rainwater harvesting are numerous (Krishna, 2003):

- The water is free; the only cost is for collection and use.
- The end use of harvested water is located close to the source, eliminating the need for complex and costly distribution systems.
- Rainwater provides a water source when groundwater is unacceptable or unavailable, or it can augment limited groundwater supplies.
- The zero hardness of rainwater helps prevent scale on appliances, extending their use; rainwater eliminates the need for a water softener and the salts added during the softening process.
- Rainwater is sodium-free, important for persons on low-sodium diets.
- Rainwater is superior for landscape irrigation.
- Rainwater harvesting reduces flow to stormwater drains and also reduces non-point source pollution.
- Rainwater harvesting helps utilities reduce the summer demand peak and delay expansion of existing water treatment plants.
- Rainwater harvesting reduces consumers' utility bills.

From a financial perspective, the installation and maintenance costs of a rainwater harvesting system for potable water cannot compete with water supplied by a central utility, but is often cost-competitive with installation of a well in rural settings.

The State of Texas also offers financial incentives for rainwater harvesting systems. Senate Bill 2 of the 77th Legislature exempts rainwater harvesting equipment from sales tax, and allows local governments to exempt rainwater harvesting systems from ad valorem (property) taxes.

6.2.2.3 Landscape Maintenance

A significant amount of water is used each year in the maintenance of residential and non-residential landscapes. Landscape irrigation conservation practices are an effective method of accounting for and reducing outdoor water usage while maintaining healthy landscapes and avoiding runoff. Water wise landscape programs should follow the seven principals of xeriscape:

- Planning and design
- Soil analysis and improvement
- Appropriate plant selection
- Practical turf area
- Efficient irrigation
- Use of mulch
- Appropriate maintenance

Additional detail on this subject is available in TWDB Report 362 Water Conservation Best Management Practices Guide.

6.2.3 Model Water Conservation Plan

Water Conservation Plan forms are available from TCEQ in WordPerfect and PDF formats. The forms for the following entity types listed below are available at http://www.tceq.state.tx.us/permitting/water_supply/water_rights/conserve.html. You can receive a print copy of a form by calling 512/239-4691 or by email to wras@tceq.state.tx.us.

Municipal Use - Utility Profile and Water Conservation Plan Requirements for Municipal Water Use by Public water Suppliers (TCEQ-10218)

Wholesale Public Water Suppliers - Profile and Water Conservation Plan Requirements for Wholesale Public Water Suppliers (TCEQ-20162)

Industrial/Mining Use - Industrial/Mining Water Conservation Plan (TCEQ-10213)

Agricultural Uses –
Agriculture Water Conservation Plan-Non-Irrigation (TCEQ-10541)
System Inventory and Water Conservation Plan for Individually-Operated Irrigation System (TCEQ-10238)
System Inventory and Water Conservation Plan for Agricultural Water Suppliers

Providing Water to More Than One User (TCEQ-10244)

6.2.4 Municipal Water Conservation Plans

Texas Water Code §11.1271 requires water conservation plans for all municipal and industrial water users with surface water rights of 1,000 acre-feet per year or more and irrigation water users with surface water rights of 10,000 acre-feet per year or more. Water conservation plan summaries for the cities of Kerrville and Del Rio, which meet these criteria, are provided in the following sections. The Upper Guadalupe River Authority, which also has water rights that meet the criteria, is not currently providing water and therefore has not developed a conservation plan under the above TWC requirement. However, UGRA does have a Water Conservation/Drought Management Plan, which was adopted in 1993. Water conservation plans are also required for all other water users applying for a State water right, and may also be required for entities seeking State funding for water supply projects.

6.2.4.1 City of Kerrville Water Conservation Plan

The City of Kerrville adopted a new Water Management Plan on Jan. 27, 2004. This new Plan included, for the first time, year-round water conservation measures. The most important measures included in the year-round plan are the limitation of irrigation watering to the hours of 6 p.m. to 10:00 a.m. and the ban on water runoff in streets and gutters. The year-round measures also include: banning the waste of water; banning the use of water from fire hydrants and blow-offs other than for their intended purpose and/or maintenance; requirement for customers to repair leaks within 24 hours of receiving notice of the leak; providing educational information to the public on water use and water conservation; adopting and enforcing plumbing codes to ensure the use of water conservation devices in new construction; universal metering; encouraging water conservation landscaping; increased effort in leak detection and repair; continued evaluation of methods of reuse and recycling of wastewater; and water saving measures for the service industry.

6.2.4.2 City of Del Rio Water Conservation Plan

City of Del Rio's Water Conservation Plan was not available at the time of this printing.

6.3 DROUGHT CONTINGENCY

6.3.1 Drought Contingency Planning

Drought is a frequent and inevitable factor in the climate of Texas, and therefore it is vital to plan for the effect that droughts will have on the use, allocation and conservation of water in the state. The climate of the Plateau Region is intermediate to the more humid climates of regions to the northeast and east and drier climates of regions to the northwest and west. The combination of high temperatures, high potential evapotranspiration and intermediate rainfall totals combine to produce a semi-arid climate with drought conditions during all or parts of some years (Bomar, 1995).

Although residents of the Region are generally accustomed to the highly variable climatic conditions typical for the region, the relatively low rainfall and the accompanying high levels of evaporation underscore the necessity of developing plans that respond to potential disruptions in the supply of groundwater and surface water caused by drought conditions.

Because of the range of conditions that affected the more than 4,000 water utilities throughout the State in 1997, the Texas Legislature directed the TCEQ to adopt rules establishing common drought plan requirements for water suppliers. As a result, the TCEQ requires all wholesale public water suppliers, retail public water suppliers serving 3,300 connections or more, and irrigation districts to submit drought contingency plans. For all retail public water suppliers serving less than 3,300 connections, the drought contingency plans must be prepared and adopted no later than May 1, 2005, and shall be available for inspection upon request.

Droughts typically develop slowly over a period of months or even years and can have a major impact on the region. Water shortages may also occur over briefer periods as a result of water production and distribution facility failures. Drought contingency plans provide a structured response that is intended to minimize the damaging effects caused by the water shortage conditions. A common feature of drought contingency plans is a structure that allows increasingly stringent drought response measures to be implemented in successive stages as water supply or water demand worsens. This measured or gradual approach allows for timely and appropriate action as a water shortage develops. The onset and termination of each implementation stage should be defined by specific "triggering" criteria. Triggering criteria are intended to ensure that timely action is taken in response to a developing situation and that the response is appropriate to the level of severity of the situation.

Each water-supply entity is responsible for establishing its own drought or emergency contingency plan that includes appropriate triggering criteria. Water-supply management and drought contingency plans have been prepared by the cities of Bandera, Brackettville, Del Rio, and Kerrville, by the Fort Clark MUD, and by the Headwaters GCD.

6.3.2 Drought Triggers

Drought response triggers should be specific to each water supplier and should be based on an assessment of the water user's vulnerability. In some cases it may be more appropriate to establish triggers based on a supply source volumetric indicator such as a lake surface elevation or an aquifer static water level. Similarly, triggers might be based on supply levels remaining in an elevated or ground storage tank within the water distribution system; this is not a recommended approach, as the warning of supply depletion would be only three to four days. Triggers based on demand levels can also be effective, if the demands are very closely and frequently monitored. Whichever method is employed, trigger criteria should be defined on well-established relationships between the benchmark and historical experience. If historical observations have not been made then common sense must prevail until such time that more specific data can be presented.

6.3.2.1 Surface Water Triggers

Surface water sources are among the first reliable indicators of the onset of hydrologic drought, as defined in Section 1.2.6. Diminished spring discharge and stream flow, for example, can be monitored daily by city, county, and state agencies, and also by landowners. Of particular interest, however, are the levels to which spring discharge and stream flow must be reduced before the onset of drought is declared and appropriate response measures are initiated in the region. Cities that rely exclusively on spring flow for municipal water are particularly vulnerable to drought-induced reductions in discharge, especially if alternative sources of supply have not been developed to make up potential shortfalls created by lower discharge. As an operating definition of hydrologic drought, it is recommended that reductions of spring discharge between 25 percent and 33 percent (compared with average discharge and flow) be considered effective hydrologic drought triggers in the Plateau Region.

The Medina/Diversion lake system operation is administered by the major water right holder on the lake, Bexar-Medina-Atascosa WCID 1. Operations are constrained by a Special Condition of BMAWCID1's water right that specifies that emergency firefighting vehicles should have access to impounded water, and further constrained by a Memorandum of Understanding between BMAWCID1, Bandera County, Bandera County River Authority and Groundwater District, and Bexar Metropolitan Water District dated March 19, 1997. The MOU specifies that BMA will restrict diversions for municipal purposes when the level of Medina Lake is at or below 1,035 feet (which level is to be measured based upon the datum plane for the Medina Dam identified as being located at the 1,084 feet amsl level). The 1,035-ft level can very well be considered a drought trigger, although the term is not explicitly applied within the MOU.

6.3.2.2 Groundwater Triggers

Groundwater triggers that indicate the onset of drought are not as easily identified as factors related to surface-water systems. This is attributable to (1) the rapid response of stream discharge and reservoir storage to short-term changes in climatic conditions within a region and within adjoining areas where surface drainage originates, and (2) the typically slower response of groundwater systems to recharge processes. Although climatic conditions over a period of one or two years might have a significant impact on the availability of surface water, aquifers of the same area might not show comparable levels of response for much longer periods of time, depending on the location and size of recharge areas in a basin, the distribution of precipitation over recharge areas, the amount of recharge, and the extent to which aquifers are developed and exploited by major users of groundwater. It is recognized, however, that karstic formations may produce rapid recharge rates in aquifers such as the Edwards-Trinity (Plateau).

With the exception of the Trinity aquifer of Bandera and Kerr Counties, all other aquifers in the rural counties are unlikely to experience significant water-level declines, based on comparisons between projected water demand, aquifer recharge and storage. In these areas, water levels are expected to remain constant or relatively constant over the 50-year planning period. Observation wells in major recharge areas and in areas adjacent to municipal well fields in the rural counties might provide a sufficient number of points to monitor water levels, provided that water-level measurements are made on a regular basis for long periods of time. Water levels below specified elevations for a pre-determined period of time might be interpreted to be reasonable groundwater indicators of drought conditions in any basin.

Basins that do not receive sufficient recharge to offset natural discharge and pumpage may be depleted of groundwater (e.g., mined). This is especially the case with the Trinity aquifer of Bandera and Kerr Counties. The rate and extent of groundwater mining in any area are related to the timeframe and the extent to which withdrawals exceed recharge. In such basins, water levels may fall over long periods of time, eventually reaching a point at which the cost of lifting water to the surface becomes uneconomical. Thus, water levels in such areas may not be a satisfactory drought trigger. Instead, communities might consider the rate at which water levels decline in response to increased demand as a sufficient indicator of drought.

Because of the above described problems with using water levels as drought-condition indicators, most municipal water-supply entities in the Plateau Region that rely on groundwater generally establish drought-condition triggers based on levels of demand that exceed a percentage of the systems production capacity. Table 6-1 provides a list of groundwater dependent entities, their supply source, their type of trigger, and their associated responses.

Water levels in observation wells in and adjacent to municipal well fields, especially where wells are completed in aquifers that respond relatively quickly to recharge events, may be established as drought triggers for municipalities in the future providing a sufficient number of measurements are made annually to establish a historical record. Water levels below specified elevations for a pre-determined period of time might be interpreted to be reasonable groundwater indicators of drought conditions. Until such historical water-level trends are established, municipalities will likely continue to depend on demand as a percentage of production capacity as their primary drought trigger.

Water-use categories in the Region other than municipal that are dependent on groundwater as their primary or only source of supply must rely on a number of factors to identify drought conditions. In most cases, atmospheric condition (days without measurable rainfall) is the most obvious factor. Various drought indices (Palmer, Standard Precipitation, and Keetch-Byram) are available from State and local sources. Groundwater conservation districts, agricultural agencies, as well as individuals can access these indices for use in determining local drought conditions and appropriate responses.

Table 6-2 provides a selection of wells with a history of measurements and a proposed drought trigger level. Five of the nine wells are equipped with continuously recording devises. In time, all wells on this list should be similarly equipped. Other wells on this list are measured on an annual basis by TWDB staff, which does not allow for observation of seasonal fluctuation or response to recharge events. Wells selected for drought contingency triggers should be re-evaluated for appropriateness during the next planning period, and where possible, should be selected or positioned so that local pumping does not influence the water level.

Groundwater conservation districts are generally responsible for monitoring conditions within their boundaries and making appropriate public notification. Outside of existing districts, the TWDB should assume responsibility of public notification of drought conditions based on their water-level monitoring network. County Commissioners are expected to designate trigger levels and establish responses. In Val Verde County, the City of Del Rio is responsible for designating trigger levels and establishing responses. Appropriate drought responses are also the responsibility of and at the discretion of private well owners.

TABLE 6- 1. SUGGESTED OR MANDATED DROUGHT TRIGGERS FOR GROUNDWATER DEPENDENT ENTITIES

Water-Supply Entity	Water Supply Source	Drought Trigger	Trigger Response
City of Bandera	Trinity	Multi-stage drop in water levels in the Dallas Street Municipal Well.	Multi-stage limitation on water use.
Town of Rocksprings	Edwards-Trinity (Plateau)	Water level drops 20 feet below summertime average.	Multi-stage limitation on water use.
City of Kerrville	Upper Guadalupe River Trinity	Drought triggers based on flows in the Guadalupe River and relationship between supply and demand.	Multi-stage limitation on water use.
Community of Ingram	Trinity	Water level drops 20 feet below summertime average.	Multi-stage limitation on water use.
Town of Brackettville	Edwards (BFZ)	Multi-stage drop in water levels in city well.	Multi-stage limitation on water use.
Fort Clark Municipal Water District	Edwards (BFZ)	Multi-stage drop in water levels in municipal well.	Multi-stage limitation on water use.
Town of Camp Wood	Spring flow from Edwards-Trinity (Plateau)	Spring flow diminishes by 20% of average summertime level.	Multi-stage limitation on water use.
Town of Leakey	Frio River Alluvium	Water level drops 20 feet below summertime average.	Multi-stage limitation on water use.
City of Del Rio	San Felipe Springs Edwards-Trinity (Plateau)	1. Water level in Bedell Street Storage Reservoir is less than a designated depth; 2. Significant decline in spring flow or aquifer water level; 3. Aquifer water level.	Multi-stage limitation on water use.

TABLE 6- 2. SUGGESTED GROUNDWATER LEVEL TRIGGER WELLS IN EACH AQUIFER SOURCE

Aquifer	County	Well ID	Lat. / Long.	Avg. Depth to Water
Trinity	Bandera	Purple Sage Well	29.44651 / 99.01831	215
Trinity	Kerr	56-63-916	30.00741 / 99.09592	295
Edwards-Trinity	Edwards	55-63-803	30.01833 / 100.20778	415
Edwards-Trinity	Kerr	56-53-304	30.22028 / 99.40667	181
Edwards-Trinity	Kinney	Ring Well	29.23243 / 100.28408	40
Edwards-Trinity	Val Verde	Old Y Well	29.26241 / 100.54578	105
Edwards (BFZ)	Kinney	70-38-902	29.41333 / 100.26194	187
Austin Chalk	Kinney	70-45-404	29.31222 / 100.46806	Unknown
Frio River Alluvium	Real	69-18-302	29.72583 / 99.76000	25

* Wells selected for drought triggers should be re-evaluated for appropriateness during each planning period.
** Local groundwater conservation districts will continue to refine this monitoring network.

6.3.3 Model Drought Contingency Plans

The TCEQ has prepared model drought contingency plans for wholesale and retail public water suppliers, water supply corporations, and investor owned utilities that meet the TCEQ's minimum requirements. The forms for the entity types listed below are available at http://www.tceq.state.tx.us/permitting/water_supply/water_rights/contingency.html. You can receive a print copy of the model plan by calling 512/239-4691, or by e-mail to wras@tceq.state.tx.us.

- Handbook for Drought Contingency Planning for Retail Public Water Suppliers.
- Handbook for Drought Contingency Planning for Wholesale Public Water Suppliers.
- Handbook for Drought Contingency Planning for Irrigation Districts.
- Model Drought Contingency Plan for the Investor Owned Utility.
- Model Drought Contingency Plan for the Water Supply Corporation.

The model drought contingency plans for the above categories incorporate the following guidelines:

- Specific, quantified targets for water use reductions
- Drought response stages
- Triggers to begin and end each stage
- Supply management measures
- Demand management measures
- Descriptions of drought indicators
- Notification procedures
- Enforcement procedures
- Procedures for granting exceptions
- Public input to the plan
- Ongoing public education
- Adoption of plan
- Coordination with regional water planning group

6.4 GROUNDWATER CONSERVATION DISTRICTS

The Texas Legislature has established a process for local management of groundwater resources through Groundwater Conservation Districts. The districts are charged with managing groundwater by providing for the conservation, preservation, protection, recharging and prevention of waste of groundwater within their jurisdictions. An elected board governs these districts and establishes rules, programs and activities specifically designed to address local problems and opportunities. Texas Water Code §36.0015 states, in part, "Groundwater Conservation Districts created as provided by this chapter are the state's preferred method of groundwater management." Four districts are currently in operation within the planning region.

6.4.1 Bandera County River Authority and Groundwater District

The Bandera County River Authority and Groundwater District was originally the Bandera County River Authority, created by the Texas legislature in 1971, and the Springhills Water Management District, created by the legislature in 1989. The authority of the Bandera County River Authority was incorporated into the Springhills Water Management District, and in 2003 the TCEQ authorized changing the District's name to Bandera County River Authority and Groundwater District. The District includes all of Bandera County within its jurisdiction. Management goals of the District include:

- Manage groundwater in order to provide the most efficient use of groundwater resources
- Control and prevent the waste of groundwater
- Address conjunctive surface water management issues
- Address drought conditions
- Address conservation
- Address water quality

In order to help meet these management goals, the District is responsible for the following activities:

- Register and permit water wells in the District
- Sample surface water streams throughout the county to determine water quality
- Properly plug abandoned and deteriorating wells
- Develop programs to educate the public on water conservation and inform the public on activities of the District
- Permit and inspect installation of septic systems in the county
- Measuring water levels and collect water samples from selected monitor wells to assess aquifer conditions in the county

- Collect and analyze rainfall data to study rainfall and it's impact on the recharge of the aquifer
- Investigate complaints relating to contaminants and spills from all sources of potential pollution
- Manage groundwater supplies in the District

6.4.2 Headwaters Groundwater Conservation District

The Headwaters Groundwater Conservation District was created by the Texas legislature in 1991 (HB 1463) and includes all of Kerr County within its jurisdiction. The District adopted a management plan in 2003, along with associated rules and regulations, and has established the following management goals:

- Implement management strategies that will provide for the most efficient use of groundwater
- Implement strategies that will control and prevent waste of groundwater
- Implement strategies that will address conjunctive surface water management issues
- Implement strategies that will address natural resources issues which impact the use and availability of groundwater, or which are impacted by the use of groundwater
- Implement strategies that will address drought conditions

To achieve these management goals, some specific management objectives include:

- Implementing a program to improve the understanding of usable groundwater supplies in the District
- Implementing a program to regulate groundwater withdrawals
- Provide for a regular review of the District rules
- Raising public awareness about the most efficient use of groundwater and the prevention of waste through the use of public speakers and water efficient literature handouts

6.4.3 Kinney County Groundwater Conservation District

The Kinney County Groundwater Conservation District was created by the legislature in 2001 (HB 3243), and was confirmed by the voters of Kinney County in 2002. The District includes all of Kinney County within its jurisdiction. The District adopted a management plan in 2003. The District was created to develop, promote, and implement water conservation and management strategies to conserve, preserve, protect groundwater supplies within the District, protect and enhance recharge, prevent waste and pollution, and to promote the efficient use of groundwater within the District. The following goals are included in the District's management plan:

- Provide the most efficient use of groundwater
- Control and prevent waste of groundwater
- Promote the conjunctive use of surface water
- Develop drought management strategies
- Encourage conservation of groundwater supplies

6.4.4 Real-Edwards Conservation and Reclamation District

The Real-Edwards Conservation and Reclamation District was formed by the Texas legislature in 1959 (HB 447) and includes all of Real and Edwards Counties within its jurisdiction. The District was created to provide for the conservation, preservation, protection, recharge and prevention of waste of the underground water reservoirs located under the District. The District strives to bring about conservation, preservation and the efficient, beneficial and wise use of water for the benefit of the citizens and the economy of the District through monitoring and protecting the quantity and quality of the groundwater. The District also strives to maintain groundwater ownership and rights of the landowners.

District activities include regulating groundwater withdrawals by means of spacing and production limits, using the Texas Water Development Board's observation network to monitor changing storage conditions of groundwater supplies within the District, undertaking, as necessary, and cooperating with investigations of the groundwater resources within the District and making the results of investigations available to the public upon adoption by the Board, and potentially requiring reduction of groundwater withdrawals to amounts which will not cause harm to the aquifer. The following goals are included in the District's management plan:

- Control and prevent waste of groundwater
- Addressing natural resource issues that impact the use and availability of groundwater and are impacted by the use of groundwater.
- Providing for the efficient use of groundwater within the District
- Implement strategies that will address drought conditions
- Promote the conservation of groundwater within the District

CHAPTER 7

PLAN CONSISTENCY

7.1 INTRODUCTION

The long-term protection of the Plateau Region's water resources, agricultural resources, and natural resources is an important component of this 2006 update to the Plateau Region Water Plan. Specific guidance is provided to insure that the Plan reaches this goal. 31 TAC 357.14 (C) defines this requirement by the following consistency rules:

a) 31 TAC §358.3 relating to guidelines for state water planning,
b) 31 TAC §357.5 relating to guidelines for the development of Regional Water Plans,
c) 31 TAC §357.7 relating to Regional Water Plan development,
d) 31 TAC §357.8 relating to ecologically unique river and stream segments, and
e) 31 TAC §357.9 relating to unique sites for reservoir construction.

Chapter 7 identifies those considerations that provide for the long-term protection of water resources, agricultural resources, and natural resources that are important to the Plateau Region; and describes how those resources are protected through the regional water planning process.

7.2 PROTECTION OF WATER RESOURCES

Water resources in the Plateau Region as described in Chapter 3 include groundwater in five principal aquifers and surface water occurring in tributaries, mainstream branches, and lakes within five river basins. The numerous springs, which represent a transition point between groundwater and surface water, are also recognized in this plan for their major importance.

The first step in achieving long-term water resources protection is in the process of estimating each source's availability. Surface water estimates are developed through a water availability model process (WAM) and are based on the quantity of water available in each river basin to meet existing water rights during a drought-of-record.

Groundwater availability estimates are set at a conservative level that is estimated to not have significant impacts to spring flows. Where available, groundwater availability models (GAMs) are used as a tool to estimate this impact threshold. Establishing conservative levels of water source availability thus results in less potential of over exploiting the supply.

The next step in establishing the long-term protection of water resources occurs in the water management strategies developed in Chapter 4 to meet potential water supply shortages. Each strategy is evaluated for potential threats to water resources in terms of source depletion, quality degradation, and impact to environmental habitat.

Water conservation strategies are also recommended for each entity with a supply deficit. Conservation reduces the impact on water supplies by reducing the actual water demand for the supply. Table 4-2 in Chapter 4 provides an overview of these impact evaluations.

Chapters 6 and 8 contain information and recommendations pertaining to water conservation and drought management practices. When enacted, the conservation practices will diminish water demand, the drought management practices will extend supplies over the stress period, and the land management practices will potentially increase aquifer recharge and stream base flow conditions.

7.3 PROTECTION OF AGRICULTURAL RESOURCES

Although irrigated agriculture is not as prevalent in the Plateau Region as in other areas of the State, agricultural use does represent 41 percent of total water use in the Region. Only municipal and domestic water consumption combined is greater. Many of the communities in the Region depend on various forms of agricultural industry for a significant portion of their economy. It is thus important to the economic health and way of life in these communities to protect water resources that are dedicated to agriculture.

The Plateau Region Water Plan provides irrigation strategy recommendations in Chapter 4 that address water conservation best management practices. These strategies include appropriate application scheduling, use monitoring, and use of low-pressure delivery systems. If implemented, these practices will result in reduced water application per acre irrigated. Also, non-agricultural strategies provided in Chapter 4 include an analysis of potential impact to agricultural interests.

7.4 PROTECTION OF NATURAL RESOURCES

The Plateau Water Planning Group has adopted a strong stance toward the protection of natural resources. Natural resources are defined in Chapter 1 as including terrestrial and aquatic habitats that support a diverse environmental community as well as provide recreational and economic opportunities. Appendix 8B (Texas Parks and Wildlife Recommended Ecologically Significant River and Stream Segments) provides information on species and aquatic habitat.

The protection of natural resources as impacted by this regional water plan is closely linked with the protection of water resources as discussed in Section 7.2 above. The methodology adopted to asses groundwater source availability estimates is based on not significantly impacting spring flows that contribute to base flows in area rivers (Chapter 3, Section 3.2.7). Thus, the intention to protect surface flows is directly related to those natural resources that are dependent on surface water sources for their existence.

Environmental impacts were evaluated in the consideration of strategies to meet water-supply deficits. Chapter 4 provides an overview of the environmental impact analysis process. Of prime consideration was whether a strategy potentially could diminish the quantity of water currently existing in the natural environment and if a strategy could impact water quality to a level that would be detrimental to animals and plants that naturally inhabit the area under consideration.

Although no specific ecologically unique river and stream segments are recommended in this plan, the PWPG is very explicit in acknowledging the importance of all springs and stream segments for their significance as wildlife habitat. Several recommendations in Chapter 8 are related to the protection of natural resources.

- Section 8.2.2 Conservation Management of State-Owned Lands
- Section 8.3.2 Best Management Land Use Practices
- Section 8.3.4 Alternative Sources of Water
- Section 8.4.8 Management of the Edwards-Trinity Aquifer in Kerr County
- Section 8.5.6 Groundwater / Surface Water Relationship
- Section 8.5.8 Salt Cedar Eradication
- Section 8.6 Policy Issues - Environmental

CHPATER 8

RECOMMENDATIONS

8.1 INTRODUCTION

The regional water planning process offers an opportunity to make recommendations pertaining to the development and management of the groundwater and surface water resources of the State of Texas. This chapter contains specific suggestions and decisions made by the Plateau Water Planning Group (PWPG). Regional water planning is a relatively new process for the State of Texas. Because of the complex nature of this undertaking, many ideas and approaches to the problems of water-resource management are either refined or changed significantly as all participants in the planning process learn more about the Region's water resources and about what is required to produce a plan that will benefit all areas of the Region. The PWPG supports the continuation of the regional planning process and recommends certain modifications intended to strengthen its effectiveness.

The following recommendations by the PWPG are derived from careful consideration of many issues covered during the course of the planning exercise. This includes legislative, state funding and assistance, planning, and needed studies and data. Issues concerning ecologically unique river and stream segments and sites for the construction of reservoirs are covered. The recommendations in the following sections are designed to present new and/or modified approaches to key technical, administrative, institutional, and policy matters that will help to streamline the planning process, and to offer guidance to future planners with regard to specific issues of concern within the Region.

8.2 LEGISLATIVE

Legislative recommendations are those that will require a formal statute passed during a legislative session of the Texas State Legislature.

8.2.1 Require Participation of State Agencies Involved with the Planning Process

Representatives of State agencies involved in the regional planning process could effectively derail a regional plan at the end of the planning period - without attending as much as one meeting. The PWPG recommends that nonvoting members of State agencies be required to attend and provide input at every planning group meeting. If an agency's nonvoting representative does not contribute or fails to attend meetings, then that agency should not be permitted to object to or alter contents of a planning group's adopted plan. It should be noted that TWDB and TPWD staff were very active (and much appreciated) in the Plateau Region planning process. Also, the Texas Water Resource Institute and the Texas Cooperative Extension provided welcome assistance.

8.2.2 Conservation Management of State-Owned Lands

All state-owned land should be managed in ways that enhance water conservation. State agencies need to take the lead in water conservation and it should start on state-owned properties. Unless State agencies set good conservation examples for the public, any public program encouraging such conservation will likely be perceived as "do as I say, not as I do", something that never plays well. Considering that approximately 95 percent of Texas land is privately owned, the State needs to be convincing when making recommendations to the public if it hopes to be successful.

8.3 STATE FUNDING AND ASSISTANCE

8.3.1 New Studies and Data

The State should fund or conduct specific studies that will shed more information on specific water-resource issues. The questions unanswered by current sources of information are critical to future PWPG decisions. Monitoring studies should be continuously funded. Additional studies needed for the Plateau Region are discussed in Section 8.5.

8.3.2 Best Management Land Use Practices

Selective Brush Management, as a tool to improve watershed yields and water quality, is a strategy of great interest in the Plateau Region, as well as in surrounding planning regions. The legislature should dedicate funds to expedite funding of multi-disciplinary research to develop methodology of defining watersheds of greatest potential for increasing water yields. Teams of geologists, hydrologists, ecologists, wildlife biologists, economists and rangeland scientists working with GIS and various types of aerial photography would have the highest probability of developing tools to identify and quantify the best yielding watersheds for treatment. These studies would estimate the cost-benefit ratios of this Best Management Practice (BMP) including cost of initial brush management; ecological benefits; grazing benefits; reseeding costs, if necessary; and other range management BMPs as needed to restore brush-infested rangelands while preserving or enhancing wildlife and esthetic values. The end product would quantify both the short-term and long-term costs and benefits per acre-foot of water to such a regional program. Downstream and aquifer users in urban areas would possibly be major beneficiaries and as such should be part of the final equation and possibly part of the funding mechanism. Studies should be of a realistic, large-scale size in order to more accurately correlate with full-scale watershed treatments.

The State should draft legislation based upon the best available science and input from all stakeholders to provide a cost-share funding program to landowners in the targeted watersheds for the Selective Brush Management BMP and required other practices. It is generally recognized that brush infestations are the symptom of deeper ecological disturbances such as fire control, drought, grazing mismanagement, wildlife overpopulations and other causes. As such, the cost-share program should involve a long-range contract between the State and the landowner for at least ten (10) years of post-treatment management with required brush re-invasion treatments. A successful model program exists with the Natural Resources Conservation Service, USDA's (NRCS) Great Plains Conservation Program and many Texas landowners are familiar with it. To accurately assess the benefits, treated watersheds will require thorough monitoring of groundwater, springs and surface waters by the US Geological Survey (USGS) or other agencies.

Currently, Texas Parks & Wildlife Department (TPWD) has a program specifically directed at utilizing BMPs for landowners involving brush management in areas possibly containing endangered species. As has been proven on the Kerr Wildlife Management Area (TPWD) with long-term studies, selective brush management coupled with good rangeland management can benefit endangered species and ranchers as well. It is highly likely that watershed values will fit into the same package to provide a win-win situation for all. The voluntary partnership of landowners and TPWD is important to this program, just as it was under the NRCS' Great Plains Program. However, as major parts of targeted watersheds must be treated in order to provide the desired hydrological benefits, it is likely that a high percentage of watershed landowners must opt-in to the program before it could be accepted by the State for treatment and management contracts.

8.3.3 Recharge Structures

Recharge structures are relatively low cost BMPs to improve aquifer recharge if sited to provide adequate streambed water percolation based upon the best available science. These small dams can provide multiple benefits under ideal conditions as has been proven along the Edwards Aquifer Recharge Zone. This interest in recharge structures should be encouraged, funding provided, and perhaps some streamlining of any required permitting procedures as possible and as advised. Programs and funding should be available to identify appropriate locations for recharge structures and technical assistance provided for construction and maintenance.

8.3.4 Rainwater Harvesting as an Alternative Sources of Water

Programs such as rainwater harvesting should be supported by the State. Rainwater harvesting is one way to meet rural or urban domestic water demands, as well as use for limited irrigation, such as vineyards, orchards or small farms under drip irrigation. Livestock and wildlife can also be provided supplemental water by rainwater harvesting. This should be widely encouraged by funded education programs and cost-share funding to individual homeowners, farmers, businesses, public entities and ranchers.

8.3.5 Training for New Regional Water Planning Group Members

A training session for new members of regional water planning groups should be provided by the TWDB. There is no formal plan to educate new regional water planning group members on the complexities of the planning process and associated technical information. On-the-job training of new members is not an efficient use of planning group meeting time.

8.3.6 Eliminate the Unfunded Mandate

The State should also provide funding for the mandated administrative portion of the regional water planning process. For those planning regions that chose to fully participate in the regional water planning process, the provision that requires regional water planning groups to raise money to fund a substantial portion of the administrative cost of developing the plan should be eliminated. Requiring volunteers to develop the plan, sell the plan, and be fundraisers to support the plan is not only unwise but burdensome, as well. The provision in Title 31, TAC §357.5(j) that allows for simplified planning at a substantially reduced cost does not apply to the Plateau Region, which chooses to fully participate in the regional planning process.

Regional water planning group members who are not employed by entities are especially hard-pressed, as they donate time and monies out of their own personal resources. Such individuals could be discouraged from serving on a regional water planning group simply because their personal resources may not be adequate to cover the time and expense involved.

8.3.7 Reasonable Expenses Incurred by the Planning Group

The time commitment of planning group members is excessive. It is neither fair nor reasonable that planning group members should be expected to incur the cost of travel to meetings. This will likely deter other interested persons from serving on planning groups.

Under the current process there is great disparity and inequity in planning group member compensation or expense reimbursement. Some members are compensated for their time and expenses as part of jobs, such as employees of river authorities, water districts and utilities. However, other members such as public, small business and agriculture representatives must pay their own way and take a significant amount of time away from their permanent occupation. This disparity results in an unequal amount of influence on the planning group because the "compensated" members and entities tend to have more time and funds to devote to the planning effort and this in turn gives such members and entities a disproportionate amount of influence in the planning process.

8.4 PLANNING AND MANAGEMENT

The following recommendations are categorized as those that would help with the planning process.

8.4.1 Irrigation Surveys

Irrigation application is the largest use of water in the State, yet its quantification is probably the least accurate. Irrigation use is only being accurately determined in areas where groundwater conservation districts are requiring the installation of irrigation well flow meters and where irrigation districts record surface water diversions. Elsewhere, planning group members directly involved in the agricultural industry have viewed irrigation surveys with skepticism in many counties. Nursery farms, greenhouse operations, and non-municipal golf courses are just a few of the irrigation activities that are often not accounted for in the surveys. The TWDB is encouraged to develop a more confident means of estimating actual irrigation use.

8.4.2 Transient Population Impact on Water Demand

Municipal water use reports capture the total amount of water produced and distributed by the city. In concept, this volume includes water consumed by both permanent and transient populations within the community. However, the counties of the Plateau Region have a high transient influx of vacationers and hunters that frequent the more remote areas and are not likely included in the water demand estimates. Likewise, there is a high percentage of second-home owners in the rural counties that is also not accounted. This transient water demand likely has a significant impact on water demand estimates used by the planning group. The PWPG encourages the TWDB to consider this water-use category and develop a method for estimating its impact.

8.4.3 Peak-Use Management

Drought management plans need to be developed based on peak use demand instead of annual production capabilities. The current plan is based on drought-of-record conditions on an annual basis. While this is a good starting point in the planning process, it would be beneficial to also plan based on peak demand during a year. For example, current planning not address water needs during the peak use period of summer months. During the summer, in many areas of the State, severe water problems may exist that are not apparent based on an annual water management plan. This results in a plan that may indicate that water supply needs are satisfied for a region, when in reality such needs may not be satisfied throughout the year. This presents a significant problem in the current planning process.

8.4.4 Standardize Groundwater Evaluations Statewide

In the past, the method for estimating groundwater availability was not standardized statewide, which resulted in aquifer availability estimates made for the same aquifer in adjoining regions being non-comparable. This problem has been significantly improved with the availability of groundwater availability models (GAMs) for many of the aquifers in the State. The PWPG encourages the continued development and improvement of GAMs. It may be beneficial for the TWDB to sponsor workshops for adjoining regions that share a single modeled aquifer such that the regions could agree on a practical procedure for establishing source supply projections for the shared aquifer. Groundwater conservation districts, in particular, need to be trained in the use of GAMs.

8.4.5 Develop Better Methodologies for Estimating Population and Water Demand

The revision of population or demand estimates should be discussed by regional water planning groups and put before the public for several months, and then be presented to the planning groups for consideration and adoption. This will allow more time for water users within the region to hear about the planning effort and to have input to the revisions of population, water demand, and water supply.

Modification of demand numbers should be allowed further into the planning process. Demand errors may not be discovered until the supply-demand analysis is performed. Some entities or water-use categories may have been overlooked early in the process and their demands need to be added later for the supply-demand analyses to match.

8.4.6 Development of Educational Programs by the State for Regional Water Planning Groups

There is a need for the development of educational programs by State agencies to assist Regional Water Planning Groups in educating both the public and private sectors. Examples of the educational programs include the following:

- Encourage development and construction of recharge structures
- Encourage rainfall harvesting to supplement or replace aquifer pumping
- Educate and encourage municipalities to manage water systems to maximize their preparedness for drought conditions
- Encourage the public to conserve water through low-flow appliances and fixtures, low-water landscaping and elimination of waste

8.4.7 Conservation and Drought Planning

Because portions of the Plateau Region are particularly susceptible to water-supply shortages during periods of drought conditions, these areas are especially encouraged to develop conservation oriented management plans. Likewise, water-user entities within these areas should become actively involved in the regional water planning activities associated with this plan.

8.4.8 Management of Edwards Aquifer in Western Kerr County

Numerous springs in western Kerr County generate the base flow in the three branches of the upper Guadalupe River. The maintenance of this base flow is thus dependent on long-term preservation of the springs. It is therefore reasonable that the Headwaters Groundwater Conservation District should consider management rules for the Edwards (Plateau) aquifer in Kerr County that sustain flow to these important springs.

8.4.9 Local Groundwater Management

The PWPG considers all groundwater sources recognized in this plan as being critical to the future health and economic welfare of the Plateau Region. Because of the reliance on groundwater to meet current and future water needs, the PWPG recommends that local groundwater conservation districts be formed throughout the entire Region to administer sound, reasonable, and scientifically-based management objectives.

8.5 NEEDED STUDIES AND DATA

The following are recommendations pertaining to specific studies and data acquisition that the PWPG believes would provide significant insight into specific planning issues in the Region.

8.5.1 Edwards-Trinity (Plateau) Aquifer

All six counties in the Plateau Region are partially or fully underlain by the Edwards-Trinity (Plateau) aquifer. Even though a groundwater availability model (GAM) has been constructed for this aquifer, there remain many hydrological questions about the aquifer. Specific counties are embroiled in controversy pertaining to groundwater supply availability. At issue is the disagreement about the total amount of water in the county that is available on an annual basis to meet all of the counties projected water demands now and into the future, and the amount of groundwater in excess of that amount that might be available for other purposes other than in-county use. All concerned agree that sound science is needed to assess this quantification.

A basic, unbiased, scientific study that encompasses the hydrologic characterization of the Edwards-Trinity (Plateau) aquifer and adjacent associated aquifers (Edwards-BFZ and Austin Chalk) and the inter-formational flow between them, their contribution to surface water flows, and the historical withdrawals from the aquifers is needed in order for the local groundwater management entities and the PWPG to make sound management decisions and recommendations.

8.5.2 Trinity Aquifer

The Trinity aquifer is the principal source of water supply in Bandera and Kerr Counties, and is of vital importance during drought conditions when minimal flows occur in the Guadalupe and Medina Rivers. A reliable system of observation wells in the Trinity aquifer is presently being put in place and managed by the local groundwater conservation districts. The districts would benefit from technical assistance from TWDB staff in gathering and interpreting water level and other appropriate data on the local aquifer system. The PWPG also encourages the further revision of the Hill Country Trinity Aquifer GAM and particularly the inclusion of the lower Trinity aquifer layer.

The Plateau, Lower Colorado, and South Central Texas Regions share the Trinity aquifer and should jointly evaluate and determine in what context the Trinity GAM should be used in current and future planning efforts.

8.5.3 Frio River Alluvium

Numerous shallow wells in the Frio River Alluvium in Real County provide water for municipal use to the Community of Leakey and for domestic use above and below Leakey. A local committee of citizens that are dependent on this aquifer voiced their concern to the PWPG that the aquifer may be becoming overdeveloped and that there may also be a negative impact to the aquifer's contribution to flow in the Frio River. The citizens suggested that a study is needed to better determine how best to manage the aquifer. The PWPG agrees that this study is needed

8.5.4 Riparian Water

A significant amount of unpermitted riparian water is withdrawn from rivers and their tributaries in the Region. This water use is unaccounted for in the Water Availability Models that are developed for these waterways. State water agencies should devise a survey method to establish a reasonable estimate of these diversions.

8.5.5 Emphasis on Basic TWDB Water Evaluation Studies

In the past, the TWDB has provided significant knowledge concerning the groundwater resources in the State in the form of basic data and reports. The Board's current emphasis on groundwater modeling with its intended use as a water management planning tool, is recognized as an important advancement in providing planning tools. However, the Board should not abandon its important basic data gathering and evaluation responsibility. The Board should emphasize more realistic and useful groundwater studies that include the extensive field data collection necessary for such studies. TWDB staff effort and funding should go to these more realistic and focused studies.

8.5.6 Groundwater/Surface Water Relationship

The PWPG defines groundwater availability as a maximum level of aquifer withdrawal that results in an acceptable level of long-term aquifer impact such that the base flow in rivers and streams is not significantly affected beyond a level that would be anticipated due to naturally occurring conditions. This water supply policy definition can best be achieved when the relationship between groundwater and surface water is fully understood. The PWPG encourages the State (TWDB) to embrace this concept and focus water availability studies on this topic.

8.5.7 Impact of Transient Water Demand in Rural Counties

The concern pertaining to transient population water demand in rural counties was expressed in Section 8.4.2. A study is needed to quantify this impact.

8.5.8 Salt Cedar Eradication

The PWPG joins with the Rio Grande Region (M) and the Far West Texas Region (E) in encouraging funding for projects aimed at the eradication and long-term suppression of salt cedar and other nuisance phreatophytes in the Rio Grande watershed.

8.6 POLICY ISSUES

The TWDB provided regional planning groups with water issue discussion topics divided into the following categories:

- Agricultural and Rural Water
- Conservation
- Data
- Environmental
- Groundwater
- Innovative Strategies
- Providing and Financing Water/WW Services
- Surface Water
- Other Issues

The PWPG reviewed and discussed the topics during several meetings, and culminated the discussions by prioritizing the issue topics in each category (Appendix 8A). The priority order displayed in the survey provides a view of those issues that are of greatest concern in the Plateau Region. A common theme throughout the policy issue survey is the interest in water-use and land-use management that protects each of the five river basins in the Region.

8.7 CONSIDERATION OF ECOLOGICALLY UNIQUE RIVER AND STREAM SEGMENTS

Under regional planning guidelines, each planning region may recommend specific river or stream segments to be considered by the Legislature for designation as ecologically unique. The Legislative designation of a river or stream segment would only mean that the State could not finance the construction of a reservoir that would impact the segment. The intent is to provide a means of protecting the segments from activities that may threaten their environmental integrity.

Texas Parks and Wildlife Department (TPWD) provided a list of stream segments that were identified as meeting ecologically unique criteria. This list and map can be viewed in Appendix 8B. For each segment, TPWD lists qualities of each segment that support the stream's candidacy. These qualities may include but are not limited to biological function, hydrological function, location with respect to conservation areas, water quality, the presence of state- or federally-listed threatened or endangered species, and the critical habitat for such species.

The Plateau Region contains some of the most ecologically pristine areas in the State. The preservation of this natural environment is an important component of the Region's economy, which is closely tied to these natural resources. The PWPG recognizes the uniqueness of this region and has followed a policy throughout this planning period of always considering the impact that their decisions have on the area's ecological resources. However, because the subsequent ramifications of designation are not fully understood, the Plateau Water Planning Group has chosen to refrain from recommending specific segments for designation as "ecologically unique" at this time. The PWPG strongly maintains that all river and stream segments in the Plateau Region are vitally important and their flows constitute a major consideration in adoption of this plan.

8.8 CONSIDERATION OF UNIQUE SITES FOR RESERVOIR CONSTRUCTION

Regional water planning guidelines (§357.9) instruct that planning groups 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 plan; or

(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.

Following consideration of the above criteria the Plateau Water Planning Group makes no recommendation of unique sites for reservoir construction.

APPENDIX 8A

PLATEAU REGION POLICY ISSUES SURVEY

APPENDIX 8A. PLATEAU REGION POLICY ISSUES SURVEY

A.	**Agricultural and Rural Water**
1	Quantification of impacts to rural Texans of water transfers (e.g. effects on income, employment, population)
2	Protecting agricultural and rural water supplies, considering economic constraints and competing uses
3	Impacts on water supply and quality resulting from conversion of agricultural lands to urban lands
4	Improved water use information for irrigation and livestock watering categories
5	Effects of Safe Drinking Water Act on Small Water supply systems
6	Conservation of agricultural water for additional agricultural use, urban uses or for environmental purposes (i.e. how to treat this “new” water)
7	Incentives for individual projects, including stock tanks
8	Use of playa lakes for recharge, considering impacts and constraints

B.	**Conservation**
1	Relationship between drought contingency planning and regional water planning
2	Per capita water use analysis considering commercial and institutional use, income, hosting stock characteristics, and geographical location
3	Retail customer water pricing
4	Quantifying conserved water
5	Incentives (e.g. landscaping and plumbing rebates)

C.	**Data**
1	Consistent analytical techniques
2	Data for rural areas
3	Compatibility of data from different sources
4	Linkages of databases
5	Trends in data collection and availability
6	Access to data, including security constraints

D.	Environmental
1	Springflow protection
2	Instream flows
3	Watershed planning/source water protection
4	Regional or statewide environmental mitigation system
5	Environmental criteria to measure and maintain a sound ecological environment
6	Integrating water quality and water supply considerations
7	Environmental water permits
8	Sustainable growth, including impacts of growth
9	Invasive species
10	Bays and estuaries
11	Unique stream segments
12	Wildlife resources, including threatened and endangered species
13	Texas Water Trust

E.	Groundwater
1	Sustainability and groundwater management
2	Linking groundwater and surface water models (see also surface water)
3	Coordination between Groundwater Conservation Districts and Regional Water Planning Groups
4	Groundwater export and potential equity issues (e.g. use of export fees)
5	Conjunctive use of groundwater and surface water (see also surface water)
6	Rule of capture
7	Standardized methods/policy for determining groundwater availability
8	Improving groundwater availability data
9	Water marketing (e.g. water rights leases, sales, transfers)
10	Impacts of Texas Water Code of 36.121, “Limitation on Rulemaking Power of Districts Over Wells in Certain Counties”
11	Clarifying state roles and district roles
12	Adequate financial resources for districts
13	Variability of “historical water use” definition
14	Storm water runoff for groundwater recharge purpose (see also surface water)
15	Abandoned oil and gas wells, including waters supply and quality impacts

F.	Innovative Strategies
1	Brush management, including potential impacts on water supply and wildlife
2	Desalination of seawater and brackish water
3	Reuse (including basin-specific assessment of reuse potential and impacts)
4	Planning beyond the current fifty-year time horizon
5	Groundwater banking
6	Weather modification
7	Climate change

G.	Providing and Financing Water/WW Services
1	State participation
2	Incentives for planning implementation
3	Potential funding sources for water supply
4	Public-private partnerships
5	Ranking proposals as a component of financial assistance
6	Regionalized water supply

H.	Surface Water
1	Water marketing (e.g. water right leases, sales, transfers)
2	Cumulative effects on water availability of exempt water storage facilities (e.g. stock ponds)
3	Linking groundwater and surface water models (see also groundwater)
4	Conjunctive use of groundwater and surface water (see also groundwater)
5	Interbasin Transfer (IBTs)
6	Assessment of the current water resource regulatory system to meet water management needs of the 21st century
7	Competing demands on reservoir operation (e.g. B&E flows, recreation, municipal supply, aesthetics, etc.)
8	Reservoir storage reallocation (e.g. from flood storage to water supply storage)
9	Subordination agreements (including basin-specific assessment of subordination agreements)
10	System operation of water facilities (e.g. coordination of multiple reservoirs)
11	International treaty compliance
12	Watermaster program (e.g. expansion, funding, enforcement)

I.	**Other Issues**
1	Education
2	Consistency between regional water planning and rules for drinking water systems regarding minimum requirements for water supply
3	Security of supply from potential disruptions
4	Public involvement
5	Inter-regional cooperation / Inter-regional water sharing
6	Heritage / tourism / recreation / cultural resources

APPENDIX 8B

TEXAS PARKS AND WILDLIFE

SUGGESTED ECOLOGICALLY SIGNIFICANT

RIVER AND STREAM SEGMENTS

Texas Parks and Wildlife

Suggested Ecologically Significant River and Stream Segments

Devils River - From a point 0.4 mile downstream of the confluence of Little Satan Creek in Val Verde County upstream to the Val Verde/Sutton County line (within TNRCC classified stream segment 2309).

Biological function - National Wild and Scenic Rivers System nominee for outstandingly remarkable fish and wildlife values (NPS, 1995)

Riparian conservation area - Devils River State Natural Area

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream (Bayer et al., 1992); highwater quality and exceptional aquatic life use (TNRCC, 1996); exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - Devils River minnow (Fed.E/St.T), Conchos pupfish (SOC/St.T) (Hubbs et al., 1991); proserpine shiner (SOC/St.T), Rio Grande darter (SOC/St.T) (Bayer et al., 1992; Hubbs et al., 1992); largest known population of Texas snowbells (Fed.E.St.E) (J. Poole, 1999, pers. comm.)

Fessenden Branch - From the confluence with Johnson Creek upstream to Fessenden Springs.

> Hydrologic function - valuable hydrologic function relating to groundwater discharge (Brune, 1975)

Frio River - From the Real/Uvalde County line upstream to the confluence of the West Frio River and the East Frio River in Real County (within TNRCC classified stream segment 2113).

> Biological function - Texas Natural Rivers System nominee for outstandingly remarkable wildlife values (NPS, 1995)

> Hydrologic function - valuable hydrologic function relating to groundwater discharge and recharge of the Edwards Aquifer (Brune, 1981)

> High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996); exceptional aesthetic value (NPS, 1995)

Guadalupe River - From the Kerr/Kendall County line upstream to the confluence of the North Fork Guadalupe River and the South Fork Guadalupe River in Kerr County (within TNRCC classified stream segment 1806).

> Hydrologic function - valuable hydrologic function relating to groundwater recharge and discharge of the Edwards Aquifer (Brune, 1975)

Riparian conservation area - Kerrville State Park

High water quality/exceptional aquatic life/high aesthetic value - exceptional aquatic life use (TNRCC, 1996); rated #2 Scenic river in Texas (NPS, 1995)

Threatened or endangered species/unique communities - one of only four known remaining populations of endemic Texas fatmucket freshwater mussel; one of only four known remaining populations of endemic golden orb freshwater mussel (Howells, 1997; Howells, 1998)

Johnson Creek - From the confluence with the Guadalupe River in Kerr County to a point 0.7 mile upstream of the most upstream crossing of SH 41 in Kerr County (TNRCC classified stream segment 1816).

High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996)

Las Moras Creek - From the Kinney/Maverick County line upstream to its headwaters four miles north of Brackettville in Kinney County.

Hydrologic function - valuable hydrologic function relating to groundwater discharge of the Edwards Aquifer (Brune, 1975)

High water quality/exceptional aquatic life/high aesthetic value - high water quality, diverse benthic macroinvertebrate community (Bayer et al., 1992)

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T) (Hubbs et al., 1991)

Medina River - From a point immediately upstream of the confluence of Red Bluff Creek in Bandera County to the confluence of the North Prong Medina River and the West Prong Medina River in Bandera County (TNRCC classified stream segment 1905).

Biological function - Texas Natural Rivers System nominee (NPS, 1995)

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream (Bayer et al., 1992); exceptional aquatic life use (TNRCC, 1996)

Mud Creek - From the confluence with Sycamore Creek in Kinney County upstream to its headwaters located about six miles northeast of Amanda in Kinney County.

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; high water quality, diverse benthic macroinvertebrate community (Bayer et al., 1992)

North Fork Guadalupe River - From the confluence with the Guadalupe River in Kerr County to a point 11.3 miles upstream of Boneyard Draw in Kerr County (TNRCC classified stream segment 1817).

Hydrologic function - valuable hydrologic function relating to groundwater discharge of the Edwards Aquifer (Brune, 1975)

Riparian conservation area - Kerr Wildlife Management Area

High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996)

Nueces River - From the Real/Edwards/Uvalde County line upstream to the confluence of the East Prong Nueces River and Hackberry Creek in Edwards County (within TNRCC classified stream segment 2112).

Biological function - Texas Natural Rivers System nominee for outstandingly remarkable fish and wildlife values, Top 100 Texas Natural Areas list (NPS, 1995)

Hydrologic function - valuable hydrologic function relating to groundwater discharge and recharge of the Edwards Aquifer (Brune, 1981)

High water quality/exceptional aquatic life/high aesthetic value - exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - Texas snowbells (Fed.E/St.E) (J. Poole, 1999, pers. comm.)

Pecos River - From a point 0.4 miles downstream of the confluence of Painted Canyon in Val Verde County upstream to the Val Verde/Crockett County line (TNRCC classified stream segment 2310 and part of 2311).

Biological function - Texas Natural Rivers System nominee for outstandingly remarkable fish and wildlife values (NPS, 1995)

High water quality/exceptional aquatic life/high aesthetic value - diverse benthic macroinvertebrate community (Bayer et al., 1992); exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - Rio Grande darter (SOC/St.T) (Hubbs et al., 1991); proserpine shiner (SOC/St.T) (Hubbs et al., 1991; Linam and Kleinsasser, 1996)

Pinto Creek - From the confluence with the Rio Grande in Kinney County upstream to its headwaters northeast of Brackettville in Kinney County.

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; diverse benthic macroinvertebrate community (Bayer et al., 1992)

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T) (Hubbs et al., 1991)

Sabinal River - From the Bandera/Uvalde County line upstream to the most upstream crossing of RR 187 in Bandera County (within TNRCC classified stream segment 2111).

Biological function - Texas Natural Rivers System nominee for outstandingly remarkable wildlife values (NPS, 1995).

Hydrologic function - Insufficient information to confirm significance.

Riparian conservation area - Lost Maples State Park (National Natural Landmark)

High water quality/exceptional aquatic life/high aesthetic value - exceptional aesthetic value (NPS, 1995)

Threatened or endangered species/unique communities - genetic refuge for pure strain Guadalupe bass (SOC) (G. Garrett, 2000, pers. comm.)

San Felipe Creek - From the confluence with the Rio Grande in Val Verde County upstream to a point 2.5 miles upstream of US 90 in Val Verde County (TNRCC classified stream segment 2313).

Hydrologic function - valuable hydrologic function relating to groundwater discharge of San Felipe Springs, which contributes to baseflow of Rio Grande River (Brune, 1981)

Riparian conservation area - Insufficient data to merit designation.

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T), Devils River minnow (Fed.E/St.T), Rio Grande darter (SOC/St.T) (Hubbs et al., 1991)

South Fork Guadalupe River - From the confluence with the Guadalupe River in Kerr County to a point three miles upstream of FM 187 in Kerr County (TNRCC classified stream segment 1818).

Hydrologic function - valuable hydrologic function relating to groundwater discharge of the Edwards Aquifer (Brune, 1975)

High water quality/exceptional aquatic life/high aesthetic value - high water quality and exceptional aquatic life use (TNRCC, 1996)

South Llano River - From the Kimble/Edwards County line upstream to SH 55 in Edwards County (within TNRCC classified stream segment 1415).

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; high water quality, diverse benthic macroinvertebrate and fish communities (Bayer et al., 1992; Linam et al., 1999)

Threatened or endangered species/unique communities - only major watershed containing a genetically pure population of Guadalupe bass (SOC) (G. Garrett, 2000, pers. comm.)

Sycamore Creek - From the confluence with the Rio Grande in Val Verde/Kinney County upstream to US 90 on Val Verde/Kinney County line.

High water quality/exceptional aquatic life/high aesthetic value - ecoregion stream; diverse benthic macroinvertebrate community (Bayer et al., 1992 and Davis, 1999)

Threatened or endangered species/unique communities - proserpine shiner (SOC/St.T) (Hubbs et al., 1991); Rio Grande darter (SOC/St.T) (Hubbs et al., 1991; Bayer et al., 1992); Devils River minnow (SOC/St.T) (Hubbs et al., 1991)

West Nueces River - From the Kinney/Uvalde County line upstream to the Kinney/ Edwards County line.

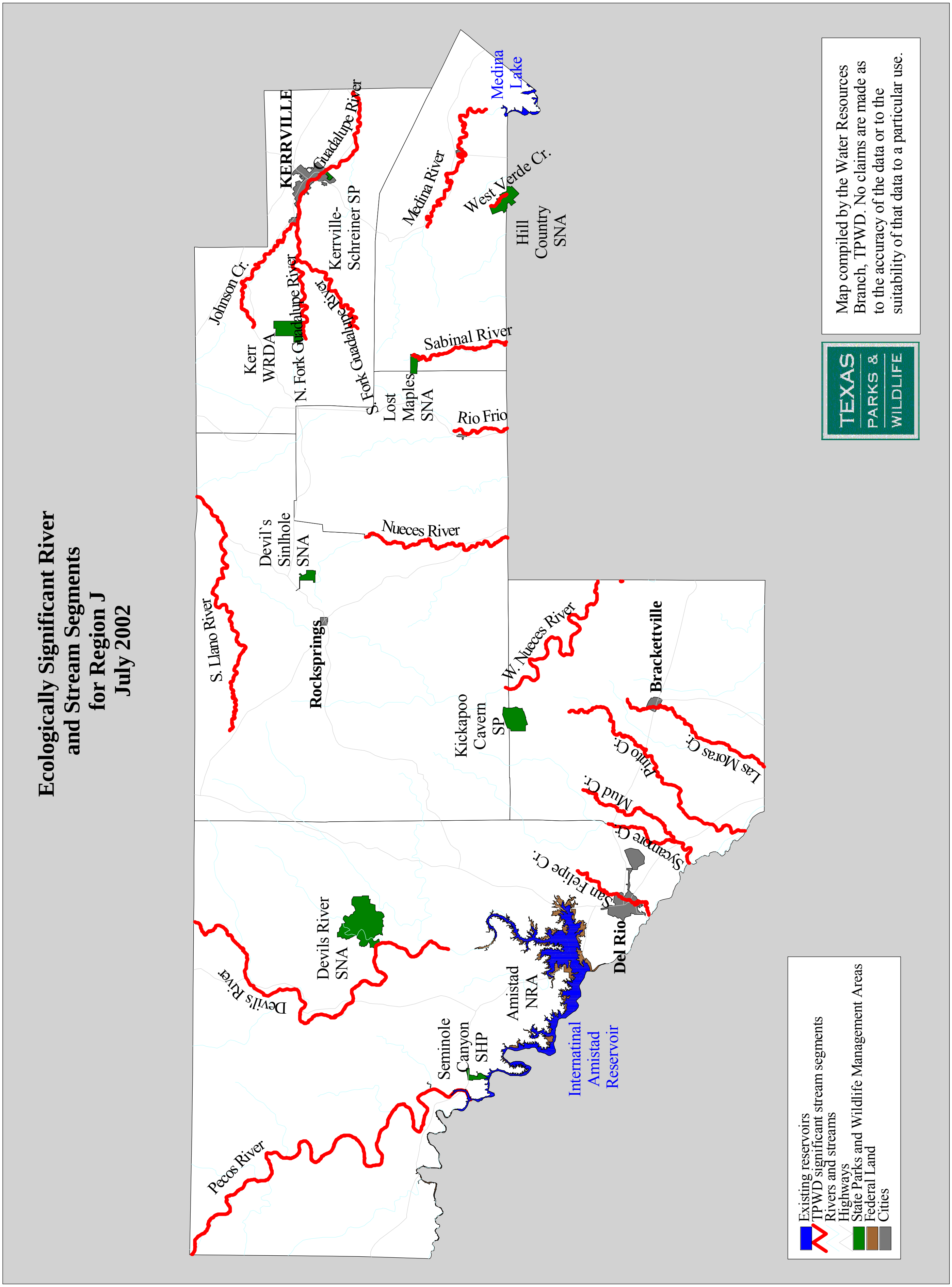
Hydrologic function - valuable hydrologic function relating to groundwater discharge and recharge of the Edwards Aquifer (Brune, 1981)

Threatened or endangered species/unique communities - Texas snowbells (Fed.E/St.E) (J. Poole, 1999, pers. comm.)

West Verde Creek - From the Bandera/Medina County line upstream to its headwaters in Bandera County.

Hydrologic function - valuable hydrologic function relating to groundwater recharge of the Edwards Aquifer (Brune, 1981)

Riparian conservation area - Hill Country State Natural Area


Ecologically Significant River
and Stream Segments
for Region J
July 2002
KERRVILLE
Guadalupe River
Kerrville-
Schreiner SP
Johnson Cr.
N. Fork Guadalupe River
S. Fork Guadalupe River
Kerr
WRDA
Medina
Lake
Medina River
West Verde Cr.
Hill
Country
SNA
Sabinal River
Lost
Maples
SNA
Rio Frio
Nueces River
Devil's
Sinlhole
SNA
S. Llano River
Rocksprings
W. Nueces River
Brackettville
Kickapoo
Cavern
SP
Pinto Cr.
Las Moras Cr.
Mud Cr.
Sycamore Cr.
San Felipe Cr.
Del Rio
Devils River
SNA
Devil's River
Amistad
NRA
International
Amistad
Reservoir
Seminole
Canyon
SHP
Pecos River
Existing reservoirs
TPWD significant stream segments
Rivers and streams
Highways
State Parks and Wildlife Management Areas
Federal Land
Cities
TEXAS
PARKS &
WILDLIFE
Map compiled by the Water Resources
Branch, TPWD. No claims are made as
to the accuracy of the data or to the
suitability of that data to a particular use.

CHAPTER 9

WATER INFRASTRUCTURE FUNDING

9.1 INTRODUCTION

Chapter 4 identifies two municipal entities (Kerrville and Camp Wood) and two consolidated irrigation water-user groups in Bandera and Kerr Counties that are projected to have insufficient supply capacity to meet their projected 50-year water needs. Chapter 4 also presents recommended strategies for meeting these needs. The Infrastructure Financing Report (IFR) presented in this chapter identifies the financing options proposed by the municipal entities to meet future infrastructure needs, including the identification of any State funding sources considered. The IFR also presents the Plateau Water Planning Group's consideration of the role that the State should take in financing water supply projects.

9.2 SURVEY PROCESS

The City of Kerrville and the Community of Camp Wood were surveyed using a questionnaire provided by the TWDB. The survey was mailed to either the mayor or the city manager. Surveys were mailed or faxed, along with supporting documentation that summarized the water management strategies included in the regional plan for that entity. Follow-up phone contacts were made with each entity to encourage response to the survey.

9.3 SURVEY RESPONSES

A response to the survey was received from Kerrville, a 50 percent response rate. A copy of Kerrville's completed survey is included below. As shown in the table below, the response represents 99 percent of the regional capital cost for implementation of strategies. The response shows that 5 percent of costs will be paid through cash reserves, 15 percent will be financed through bonds, and 40 percent will come from both state and federal government assistance programs. The specific programs to be used will depend on the needs of the municipality and funding available under each program.

County	User Group Name	Basin	Cost
Kerr	Kerrville	Guadalupe	$14,162,000
Real	Camp Wood	Rio Grande	$206,000
Total			$14,368,000

SURVEY TO OBTAIN INFRASTRUCTURE FINANCING INFORMATION FROM POLITICAL SUBDIVISIONS WITH NEEDS

Regional Water Planning Group __Plateau RWPG (Region J)
Political Subdivision (WUG or WWP) City of Kerrville

Recommended Project/Strategy	*Implementation Date*	*Capital Cost to be paid by Political Subdivision*	*ID# from DB07*
Contract with UGRA	2010	$500,000	
Expansion of ASR	2010	$6,650,000	
Increase treatment capacity	2010	$6,250,000	
Install remote well field	2010	$22,561,453	
TOTAL COST OF CAPITAL IMPROVEMENTS		$35,961,453	

Are you planning to implement the recommended projects/strategies?
✓ YES ☐ NO
If 'no,' describe how you will meet your future water needs.
FOCUS WILL BE ON FIRST 3 STRATEGIES

If 'yes', how do you plan to finance the proposed total cost of capital improvements identified by your Regional Water Planning Group?

Please indicate:
1) Funding source(s)[1] by checking the corresponding box(es) and
2) Percent share of the total cost to be met by each funding source.

✓ %__5__ Cash Reserves
✓ %__15__ Bonds
☐ %____ Bank Loans
✓ %__40__ Federal Government Programs
✓ %__40__ State Government Programs
%____ Other______
%__100__ *TOTAL – (Sum should equal 100%)*

If state government programs are to be utilized for funding, indicate the programs and the provisions of those programs.
DEPENDING ON SPECIFIC NEED

[1] Funding source refers to the initial capital funds needed to construct or implement a project, not the means of paying off loans or bonds used for the construction or implementation.

Person Completing this Form:

Name	Title	Phone
STUART BARRON	ASST. W/WW DIRECTOR	830-792-8317

9.4 PROPOSED ROLE OF THE STATE IN FINANCING WATER INFRASTRUCTURE PROJECTS

The Plateau Water Planning Group (PWPG) acknowledges that the availability and accessibility of adequate funds to finance identified infrastructure needs is essential to the health, welfare, and economic vitality of the Region and the State. To achieve a level of infrastructure stability, the PWPG supports the financing policy recommendations set forth in the *Water for Texas* – 2002 State Water Plan. Specific issues of concern to the PWPG include the following:

- A centralized office should be designated to access information pertaining to all state and federal funding programs. The function of this office would not be to distribute funds, but rather to assist potential recipients in identifying appropriate fund sources. Where appropriate, the office should identify potential sources that can be matched with greatest effect and at least cost to the consumer.
- It is expected that many water sources used to meet future supply needs will be located at ever increasing distances from demand centers. A significant influence on cost to the consumer for these supplies arises in the expense of transportation. The State should continue its efforts to identify the most economical means of moving water from its source to its final destination.
- The State legislature should increase the availability of infrastructure financing funds for water suppliers/users and should assume approximately 80 percent of new infrastructure cost.
- It is obvious that the state and federal agencies cannot bear the total cost of future infrastructure requirements. A major portion of these costs must be assumed locally. Therefore, consumption use fees must increase accordingly. As fees increase, a greater level of conservation is likely to follow. Under no circumstances should utility revenues be obtained through income or property taxes. Also, to prevent negative impact to local economies, utilities should not be burdened with greater percentage of the cost than they currently bear. Likewise, a

sliding scale for consumptive use fees should be established by utilities such that lower-income water consumers will not be costed out of an adequate safe drinking-water supply.

- The State should step up its efforts to assist water utilities in identifying and repairing water distribution leaks. It is recognized that a number of communities in the Plateau Region, and likely throughout the state, experience significant losses through pipeline leaks. Fixing this problem is usually significantly less expensive than developing and treating additional supplies.
- The State should assist water users in improving inefficient water use and development of more conservative practices.
- The PWPG supports the use of "Private Activity Bonds" for generating additional infrastructure financing revenues.
- The PWPG also encourages the State to assist in the establishment of pipeline networks to assist local projects.

CHAPTER 10

PUBLIC PARTICIPATION

AND

PLAN ADOPTION

10.1 INTRODUCTION

Chapter 10, the final chapter of the plan, contains an overview of the Plateau Water Planning Group (PWPG) representation, administrative planning process, specific activities that insured that the public was informed and involved in the planning process, and the implementation of the plan.

10.2 PLATEAU WATER PLANNING GROUP

The TWDB appointed an initial coordinating body or PWPG for the original Region J based on names submitted by the public for consideration. The PWPG then voted to change its name to Plateau and expanded its membership based on the their knowledge of additional persons who could appropriately represent water user groups. State planning provisions mandate that one or more representatives of the following water user groups be seated on each planning group: agriculture, counties, electric generating utilities, environment, industries, municipalities, river authorities, public, small business, water districts, and water utilities. An electric generating utility does not exist within the Plateau Region and is therefore not represented. In addition to the other 10 categories, the PWPG chose to appoint a member to represent the tourism industry because of its prevalence in the Region. Also, to insure adequate geographic representation, the PWPG made sure that at least one member was selected from each of the six counties. Staff persons from both the Texas Parks and Wildlife Department and the Texas Department of Agriculture were also appointed as non-voting members. The PWPG members voluntarily devote considerable amounts of their time to the planning process.

PLATEAU WATER PLANNING GROUP MEMBERS
(as of January 2006)

Name	**Water-use Category**	**County**
Jonathan Letz, *Chair*	Small Businesses	Kerr
Jerry Simpton, *Vice Chair*	Other	Val Verde
Ronnie Pace, S*ecretary/Treasurer*	Industries	Kerr
William Feathergail Wilson	Other	Bandera
Homer T. Stevens, Jr.	Tourism	Bandera
David Jeffery	Water Districts	Bandera
Perry Bushong	Water Districts	Edwards/Real
Vacant	Municipalities	Kerr
Gene Smith	Municipalities	Kerr
Vacant	River Authorities	Kerr
Vacant	Water Districts	Kerr
Charlie Wiedenfeld	Water Utilities	Kerr
Zach Davis	Agriculture	Kinney
Tully Shahan	Environment	Kinney
Cecil Smith	Water Districts	Kinney
W.B. Sansom	Counties	Real
Otila Gonzalez	Municipalities	Val Verde
Alejandro Garcia	Public	Val Verde
Thomas M. Qualia	Public	Val Verde

10.3 ADMINISTRATIVE PROCESS AND PROJECT MANAGEMENT

The PWPG adopted bylaws and submitted a scope of work and associated budget to the TWDB. With planning funds administered through TWDB, the PWPG then hired consultants to perform the work of preparing the regional plan. Work required completing the plan following well-defined guidelines intended to meet the mandated legislation and to establish a degree of format uniformity between all 16 regional plans. The PWPG operates its administrative function through the Upper Guadalupe River Authority (UGRA); all billing of expenses goes to TWDB through UGRA. All meetings of the PWPG are open to the public and meet Open Meetings Act requirements.

10.4 PLANNING GROUP MEETINGS AND PUBLIC HEARINGS

All meetings of the PWPG, including committee meetings, were open to the public where visitors were afforded the opportunity and encouraged to voice their opinions, concerns, or suggestions. Meeting locations were rotated evenly between all six counties so that all citizens within the Region would have an equal opportunity to attend. In accordance with the State Open Meetings Act, meeting notices were posted with the County Commissioners' Courts of each county.

Two public hearings were held to receive comments on the initially prepared plan, one in Del Rio on August 17, 2005, and the other in Kerrville on August 18, 2005. Notice of the Public Hearings was sent to 376 down-river water rights holders as well as to each county commissioner's court and libraries. Hard copies of the initially prepared plan were placed in the courthouse and library of each of the six counties listed below, and the public was given a full month to review the document. The plan was also made available on the Texas Water Development Board web site http://www.twdb.state.tx.us/ PWPG/planning_page.asp

- Bandera County Library
- Butt-Holdsworth Library (Kerr County)
- Edwards County Library
- Kinney County Library
- Real County Library
- Val Verde County Library

Prior to the official comment period during each public hearing, a question and answer session was held so that the public attendees would have an opportunity to gain a better understanding of how the draft plan was formulated. Twenty-seven people attended the two hearings. Responses to all comments (including TWDB, public hearings, and written comments) are provided in the separately attached Chapter 10 appendices.

10.5 COORDINATION WITH OTHER REGIONS

Coordination with other regions was accomplished through liaisons shared with adjacent regions and through active participation in Chairs Conferences scheduled by the TWDB.

10.6 PLAN IMPLEMENTATION

Following final adoption of the 2006 Plateau Region Water Plan, copies of the plan were provided to each municipality and county commissioners' court in the Region.