# KERR COUNTY
# REGIONAL WATER PLAN
# PHASE 1

UGRA

**FOR**

**UPPER GUADALUPE RIVER AUTHORITY**

**WITH**

**CITY OF KERRVILLE**
**CITY OF INGRAM**
**KERR COUNTY**

STATE OF TEXAS
ROBERT F. ADAMS
1/24/92

**January 1992**

***CH2M HILL***

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# INTRODUCTION

Section 1

# INTRODUCTION

The Kerr County Regional Water Plan is a two-part planning effort lead by the Upper Guadalupe River Authority (UGRA). The UGRA is joined in this effort by the City of Kerrville, Kerr County, and the City of Ingram. Funding has been provided by each participant and the Texas Water Development Board (TWDB). Each participant has also appointed a representative to the Technical Advisory Committee to provide local input and periodic review of the planning effort. This report provides the results of the first phase of the study and satisfies the TWDB contract requirement for submittal of a Phase I Interim Report.

## OBJECTIVES

The overall objective of this effort is to develop a long-range plan to meet the water supply needs of Kerr County (Figure 1-1) and population centers within the county through 2040. The objectives of Phase 1 of the planning effort are fairly specific and will provide a basis for Phase 2 efforts. These objectives are:

- To establish county-wide population and water demand projections and projections for the individual population centers within the county.

- To describe the quantity and quality of water resources that are available to meet the future demands within the study area and to quantify any limits to development of these resources.

- To evaluate conjunctive management and use of ground water and surface water resources within the County and provide a basis for management strategies that may be used to fulfill the regional water demands.

- To formulate the basic elements of alternative plans that may be used to reconcile water demands with the resources available.

Individual sections of this report are designed to address each of these objectives.

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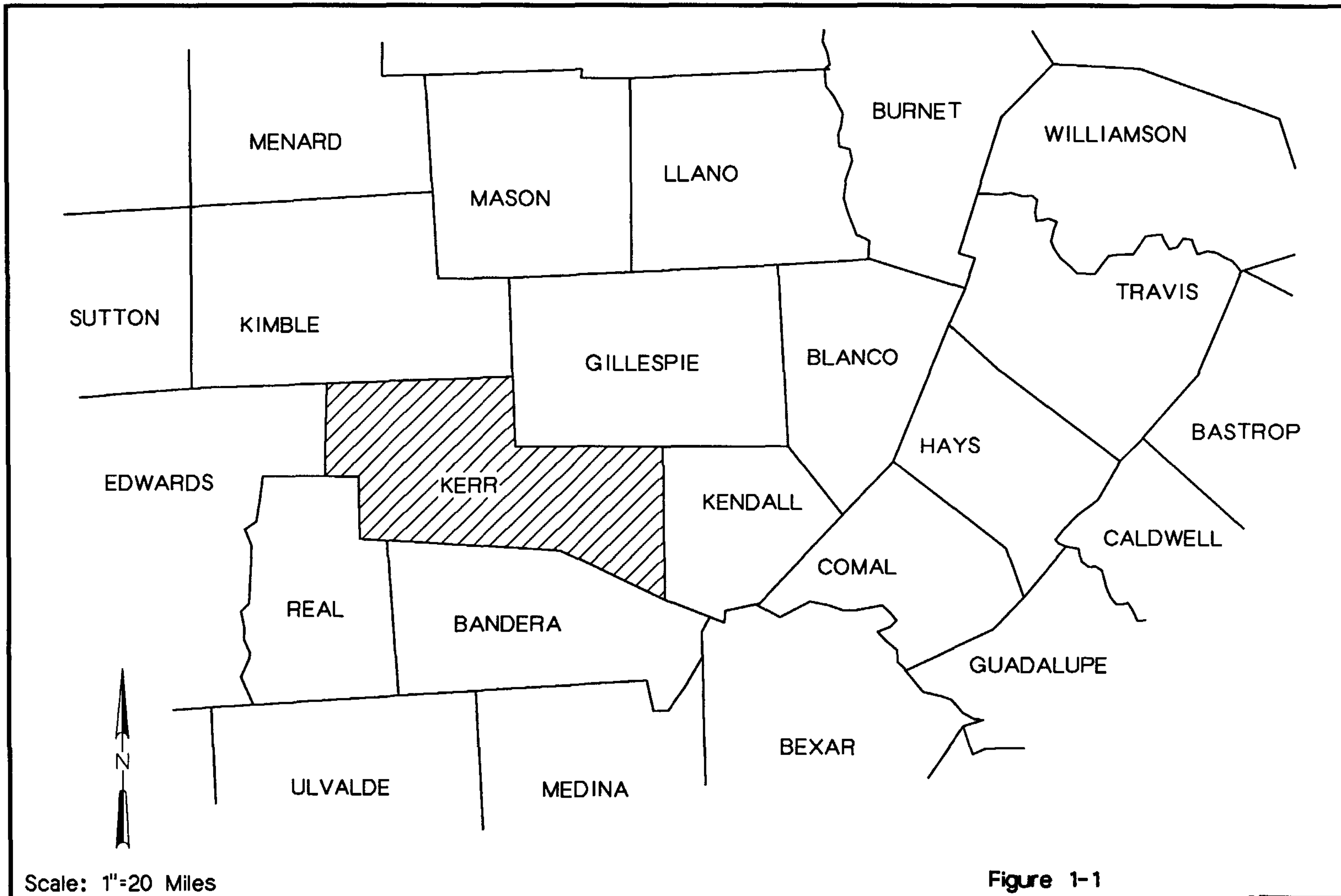


Figure 1-1

KERR COUNTY REGIONAL
WATER SUPPLY PLANNING
STUDY AREA

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## THE STUDY AREA

The geographical area for the planning study is Kerr County (Figure 1-1), which is located in the hill country of south-central Texas near the southern edge of the Edwards Plateau. The county covers 1,101 square miles. The principal physiographic feature is the Guadalupe River which receives drainage from over 75 percent of the county.

## LEGAL AUTHORITY FOR REGIONAL FACILITIES

The UGRA was created in 1939 as a conservation and reclamation district of the State of Texas pursuant to Article 16, Section 59 of the Texas Constitution. This enabling legislation is codified in Vernon's Annotated Texas Civil Statutes as Article 8280-124. Under this and subsequent acts, the UGRA is authorized to plan, develop, and operate regional water facilities. They are also authorized to control, store, and preserve the waters and floodwater of the Guadalupe River and its tributaries for any beneficial and useful purpose, with the right to purchase sites, easements, right-of-way, land or other properties necessary to accomplish any of the other rights.

As the surface water supplier for the City of Kerrville the UGRA has a contractual agreement to allow the City of Kerrville to serve as the regional provider of treated surface water. A resolution providing evidence of Kerrville's commitment to serve as a regional water supplier was recently approved as City of Kerrville Resolution No. 91-136-A. In the event Kerrville chooses not to be a regional supplier, the UGRA may fulfill this role.

## ECONOMIC SETTING

Kerr County has evolved into two types of land uses and settings. In general, the area west of Ingram is relatively sparsely populated with the land remaining as undeveloped rangeland, used primarily for livestock and game. Hunt and Mountain Home (unincorporated cities) are located in this area of the county and are primarily agricultural centers.

The eastern portion of the county includes Ingram, Kerrville, and Center Point which are the larger population centers in the county. Their economies are tied somewhat to agricultural interests including livestock, game, and irrigated agriculture, with the area evolving as a center for vacationing (dude ranches and camps), retirement, and a developing orchard industry. Some associated industries such as medical facilities have emerged as a segment of the local economy, and as the City of San Antonio continues to grow, this area will be increasingly affected by commuters looking to escape from urban sprawl. In this respect, the eastern portion of the county will be affected by economic growth extending out along Interstate 10 from San Antonio.

Growth along Interstate 10 in San Antonio will continue to be strong with the expansion of businesses such as USAA and the development of tourist attractions like Sea World and Fiesta Texas.

## CLIMATE AND HYDROLOGY

The climate of Kerr County is classified as subtropical-humid with hot summers. The mean annual temperature is 65°F with summer highs in the 90's and winter highs in the low 60s. The average annual precipitation is about 30 inches with frontal-type thunderstorms accounting for a large portion of the rainfall. These storms result in high-intensity, short-duration rainfall events.

Combining the frontal storms with the steep slopes and shallow soils on the limestone hills of the Edwards Plateau can result in flash floods. The base flow of the Guadalupe River is largely the result of springs flowing from the exposed Edwards limestone, but can fluctuate widely with rainfall events. Average annual discharge of the Guadalupe River measured at Comfort since 1939 is 147,100 acre-feet per year (ac-ft/yr).

## REPORT ORGANIZATION

The remaining sections of this report focus on the specific tasks included in Phase 1. Section 2 presents the population and water demand projects. Section 3 provides a review of present and previously planned surface water resources. Available ground water resources and their limitations are presented in Section 4, and the water management options: water reuse, aquifer storage and recovery (ASR), and conjunctive management of ground water and surface water are discussed in Section 5. The demand versus supply comparison is presented in Section 6, and water supply alternatives are described in Section 7.

The schedule and objectives for Phase 2 of this planning study are included as Section 8. Various technical information is included in Appendices A through D, and water conservation and drought contingency plans are bound separately as Appendix E (Kerr County) and Appendix F (City of Kerrville).

# Section 2
# WATER DEMANDS

## Section 2
# WATER DEMANDS

## INTRODUCTION

The purpose of this section is to describe the methods used and results obtained in evaluating the future population and water demands anticipated to occur in Kerr county through 2040. Evaluations will be broken down by the following water use categories:

- Municipal
- Manufacturing
- Steam Electric
- Irrigation
- Mining
- Livestock

In general, the methods developed and used by the Texas Water Development Board for projecting population and water demand will be used in this study, and modified based on additional water use data, local input, and consideration of an "Economic Development Corridor."

As with any planning study, one of the objectives of this study is to provide information that can be used to assist local decisionmakers. An additional objective of this study is to provide local decisionmakers with a tool that can be used to manage or encourage growth and development in areas where water is available or can be supplied through a coordinated regional effort. The technical advisory committee was presented with the concept of establishing an Economic Development Corridor (EDC) as a planning tool. The EDC would include the area within the county that has experienced the majority of growth and development in recent years. This is also the area where future economic development is both desired and expected to occur, if basic services (water, wastewater, and power) can be provided. The EDC as identified later in this section is not an officially designated area, but an area identified for planning purposes in this study.

## MUNICIPAL WATER USE

Municipal water demand includes quantities of fresh water used in homes, offices, public buildings, restaurants, and stores for drinking, food preparation, bathing, toilet flushing, clothes laundering, lawn watering, car washing, air conditioning, swimming pools, fire protection, street washing, and other sanitation/aesthetic uses. The total water used for these activities is usually expressed in gallons per person per day, or per capita water use. Multiplying per capita water use by the population projected for a selected area at a future point in time provides the total future municipal water demand for the selected area.

Based on present water use, municipal demands constitute by far the largest component of water demand in Kerr County (81.5%). The majority of this demand is centered in the vicinity of Kerrville, and southeast to the Kendall County line.

## MANUFACTURING WATER USE

Manufacturing water use is the water used in the normal operation of an industry for cooling water, process/product makeup water, sanitation, and landscaping. The future demands for manufacturing water are determined based on the present and expected future industries located in a particular area combined with expected water use. Input from the Kerr County Economic Development Foundation, a non-profit organization established for the purpose of pursuing new businesses and industries in conjunction with the Chamber of Commerce, was used as a basis for developing future manufacturing demands.

## STEAM ELECTRIC WATER USE

Steam electric water demand is the water needed to replace steam or induced evaporation generated through the operation of boilers, cooling the generation equipment and for general plant uses. There are presently no power generation plants located in Kerr County, and none are expected to be constructed within the next 50 years.

## IRRIGATION WATER USE

Irrigation water demand is the water required to meet the consumptive use requirements of agricultural crops cultivated in the study area. Future irrigation demands are based on expected future irrigated acreage, and expected future water use per acre. Present acreage and demand provides a starting reference point. The future water use per acre is adjusted to reflect expected changes in cropping patterns and irrigation system improvements that result in a greater application efficiency.

## MINING WATER USE

Mining water use is the water used in sand and gravel washing operations and in the recovery of oil and gas. Future water demands are based on the projected future level of these kinds of activities and the associated water use coefficients for the type of mining operations expected.

## LIVESTOCK WATER USE

Livestock water use is the water required for drinking and sanitation associated with various livestock operations including: beef cattle, dairies, swine, sheep, goats, and poultry. Usually daily water use requirements for livestock are combined with livestock census information and forecasts of livestock production to determine total water demand.

## POPULATION PROJECTIONS

### BACKGROUND

A variety of methods have been employed by planners in analyzing population growth patterns and projecting future population distributions. Varying types of trend analysis, curve fitting, methods based on future employment demand, methods based on general economic conditions, and graphical methods have been used to make population projections. In addition a wide variety of state and national organizations make independent projections of population using a variety of approaches. The projections most commonly adopted by agencies in Texas and by the Alamo Area Council of Governments (AACOG) which includes Kerr County, are the projections prepared by the TWDB.

The TWDB uses a cohort-survival model that projects births, deaths, and net migration. Their high series forecast reflects the higher levels of migration experienced during the rapid economic expansion of the last 20 years, and their low series projection uses the lower levels of migration experienced on the average during the previous thirty year period. City projections are developed based on the city's historic share of the population being projected forward to 2040.

The TWDB only recognizes two cities, Kerrville and Ingram, as subsets of the County level projections. These are the only cities of sufficient size to be counted separately in the last census. The TWDB made projections for Kerr County and Kerrville before and after the last census (1990). These projections for Kerr County range from a low for year 2040 of 53,021 (TWDB low series 1989) to a high of 62,690 (TWDB high series 1991) as shown in Figure 2-1. The projections for 2040 for Kerr County reflect a change of about one percent after incorporation of the 1990 census data.

The projections for Kerrville vary from a high series projection for year 2040 of 37,735 prior to the 1990 census to a high series projection for year 2040 of 31,275 after the 1990 census (Figure 2-2). The new projections are nearly 20 percent lower for 2040 than the projections done in 1989 even though the county projections were little changed. Because the TWDB does not actually project population for individual cities, but uses a proportion of the county population, this indicates that the population growth in Kerr County has shifted outside the City of Kerrville into rural subdivisions. This is borne out by the proliferation of public water supply systems in rural areas as documented in Texas Department of Health (TDH) Files and TWDB water use records.

Figure 2-2
# KERRVILLE POPULATION PROJECTIONS

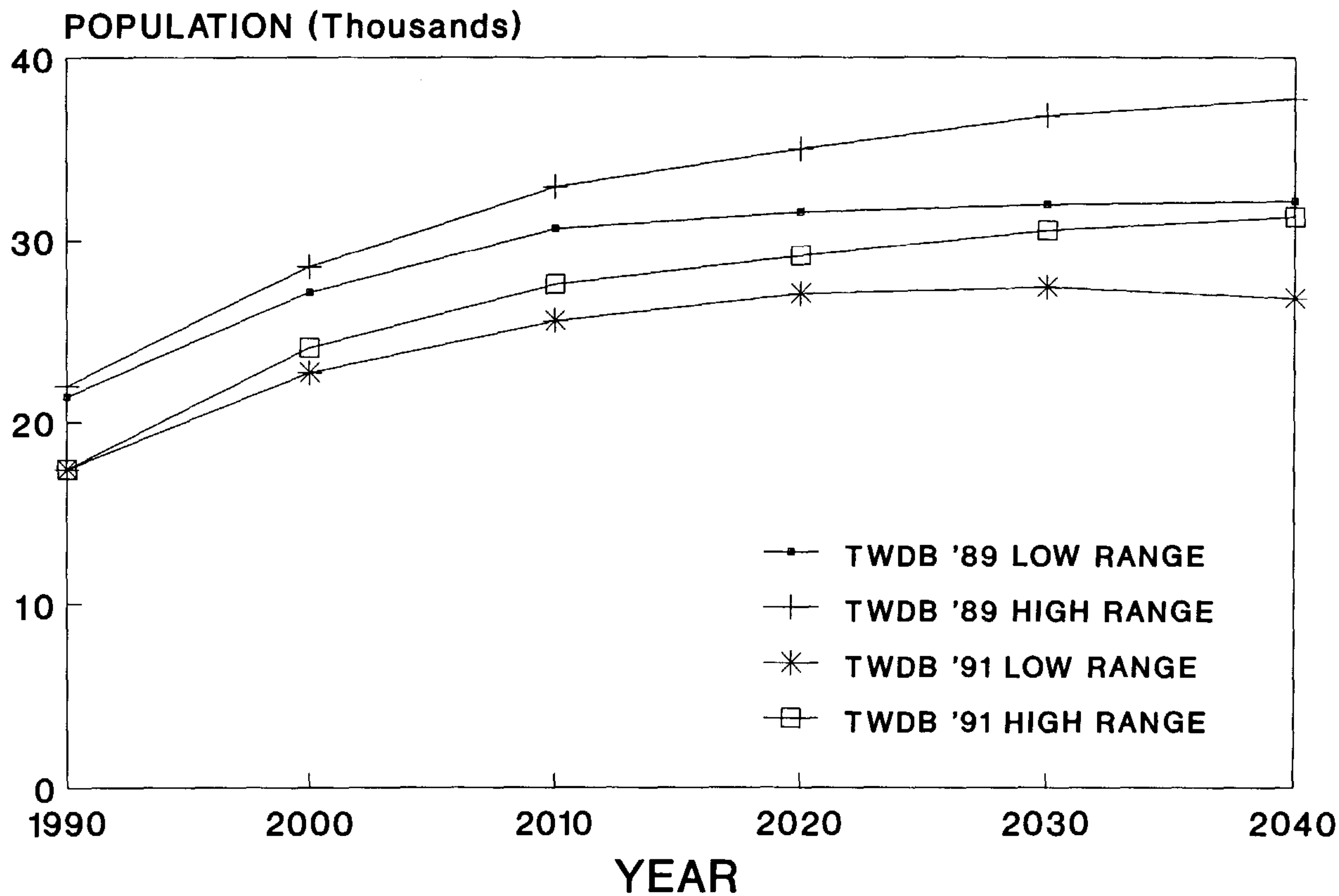


Figure 2-1

# KERR COUNTY POPULATION PROJECTIONS

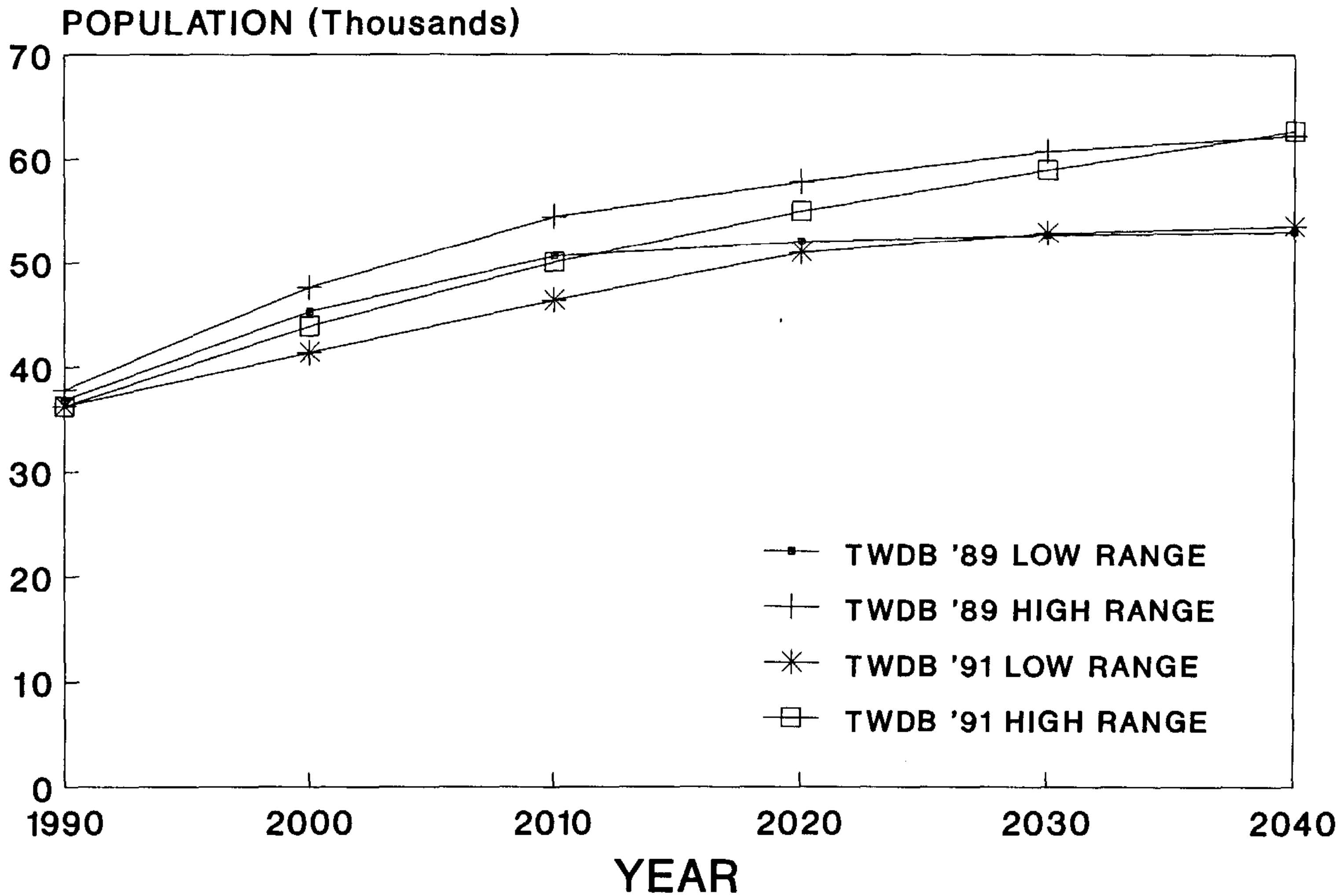
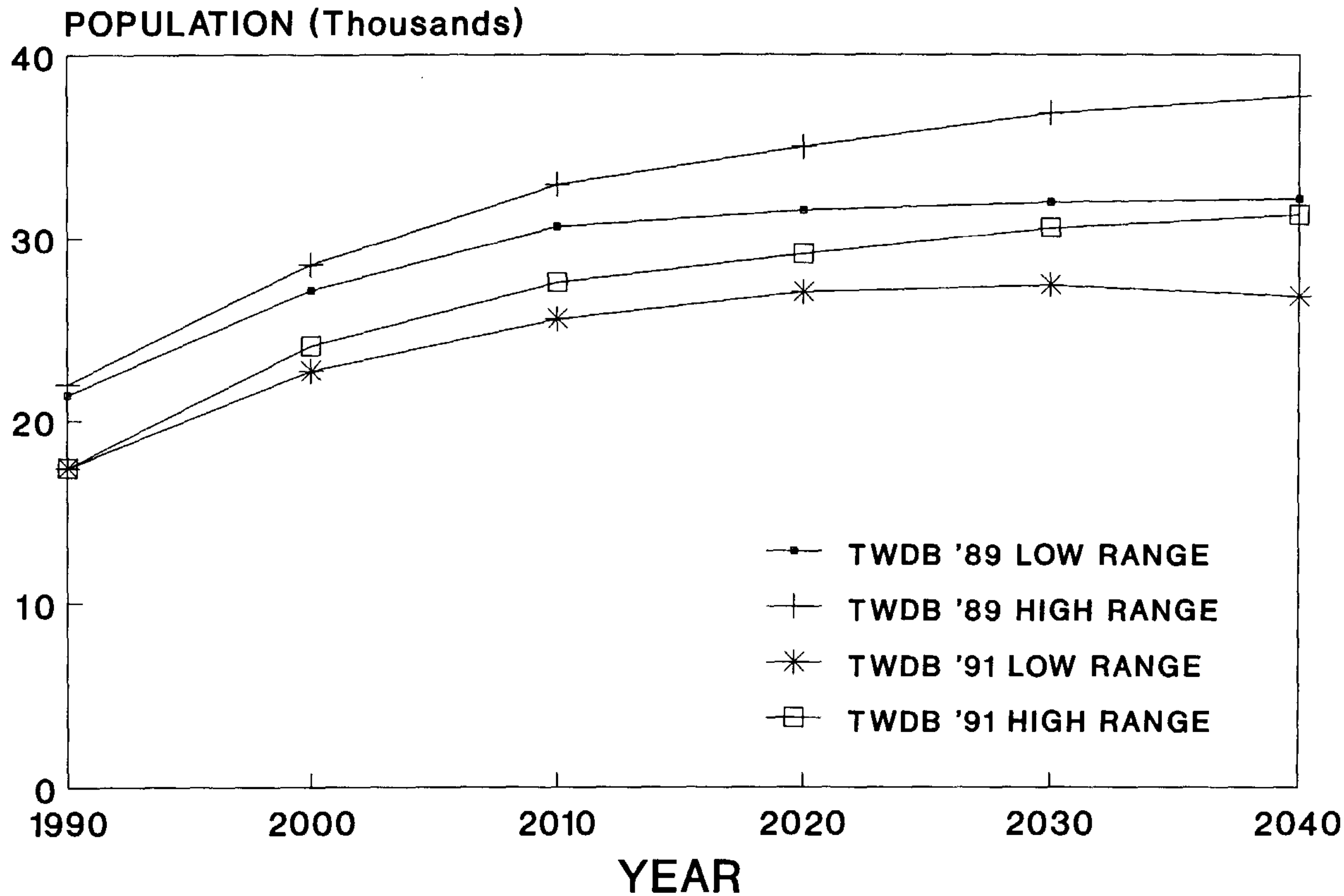


Figure 2-2
# KERRVILLE POPULATION PROJECTIONS



## ECONOMIC DEVELOPMENT CORRIDOR

For the purposes of this study we have adopted the use of an Economic Development Corridor (EDC) as shown in Figure 2-3. This area has been identified by the Economic Development Foundation and Technical Advisory Committee as the area where economic development and population growth is most likely to occur within Kerr County. This area is largely based on the pattern of existing development in the County which can be tied to retirement and vacation homes, tourism, clean industries, and the emerging apple orchard industry.

The population located within the EDC was estimated using 1990 census data. The boundary of the EDC was compared to the boundaries of the individual census tracts or block numbering areas (BNAs), and the population of the EDC was estimated from the population of the corresponding BNAs. In 1990, the Kerr County population was 36,304 with 17,384 in Kerrville; 1,408 in Ingram; 17,165 in the EDC outside of Kerrville and Ingram; and 347 located in other parts of the county. Table 2-1 below gives the population projections for these four areas of the county, as based on the TWDB high-case projections.

**Table 2-1**
**Population Projections**

| | EDC | | | | |
|---|---|---|---|---|---|
| **Year** | **Kerrville** | **Ingram** | **Other** | **Non-EDC** | **County** |
| 1990 | 17,384 | 1,408 | 17,165 | 347 | 36,304 |
| 2000 | 24,044 | 1,812 | 17,554 | 439 | 43,849 |
| 2010 | 27,528 | 2,110 | 19,921 | 501 | 50,060 |
| 2020 | 29,092 | 2,237 | 23,098 | 550 | 54,977 |
| 2030 | 30,531 | 2,358 | 25,477 | 589 | 58,955 |
| 2040 | 31,275 | 2,420 | 28,368 | 627 | 62,690 |

Within the EDC we have further identified seven areas where development (population/water demand) has been concentrated outside of the Kerrville City limits. These seven areas are shown in Figure 2-4. The population and water demand projections for these seven areas are based on the assumption that growth will continue in the same areas of the county in roughly the same proportions that the population is presently distributed.

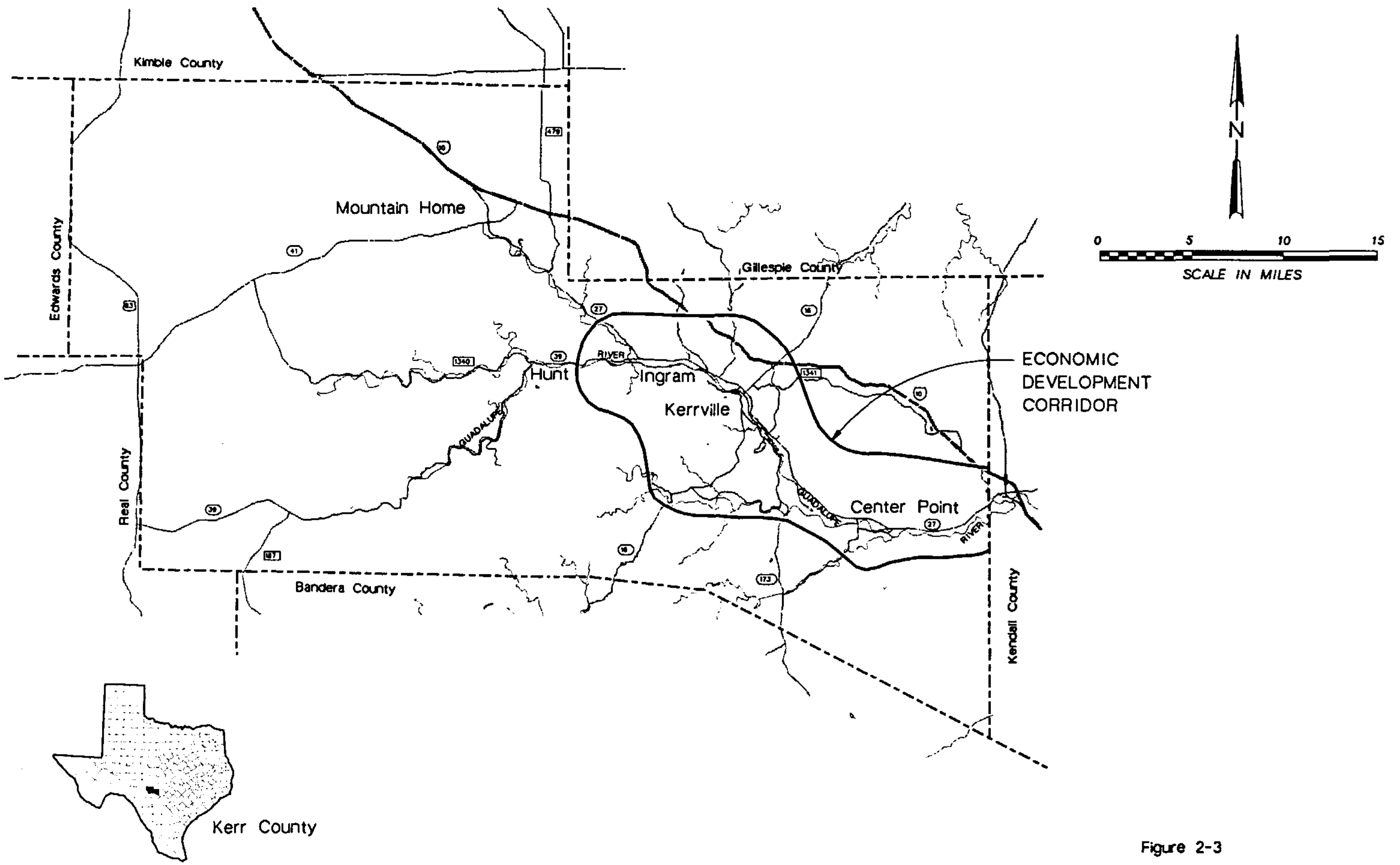



Figure 2-3

ECONOMIC DEVELOPMENT CORRIDOR

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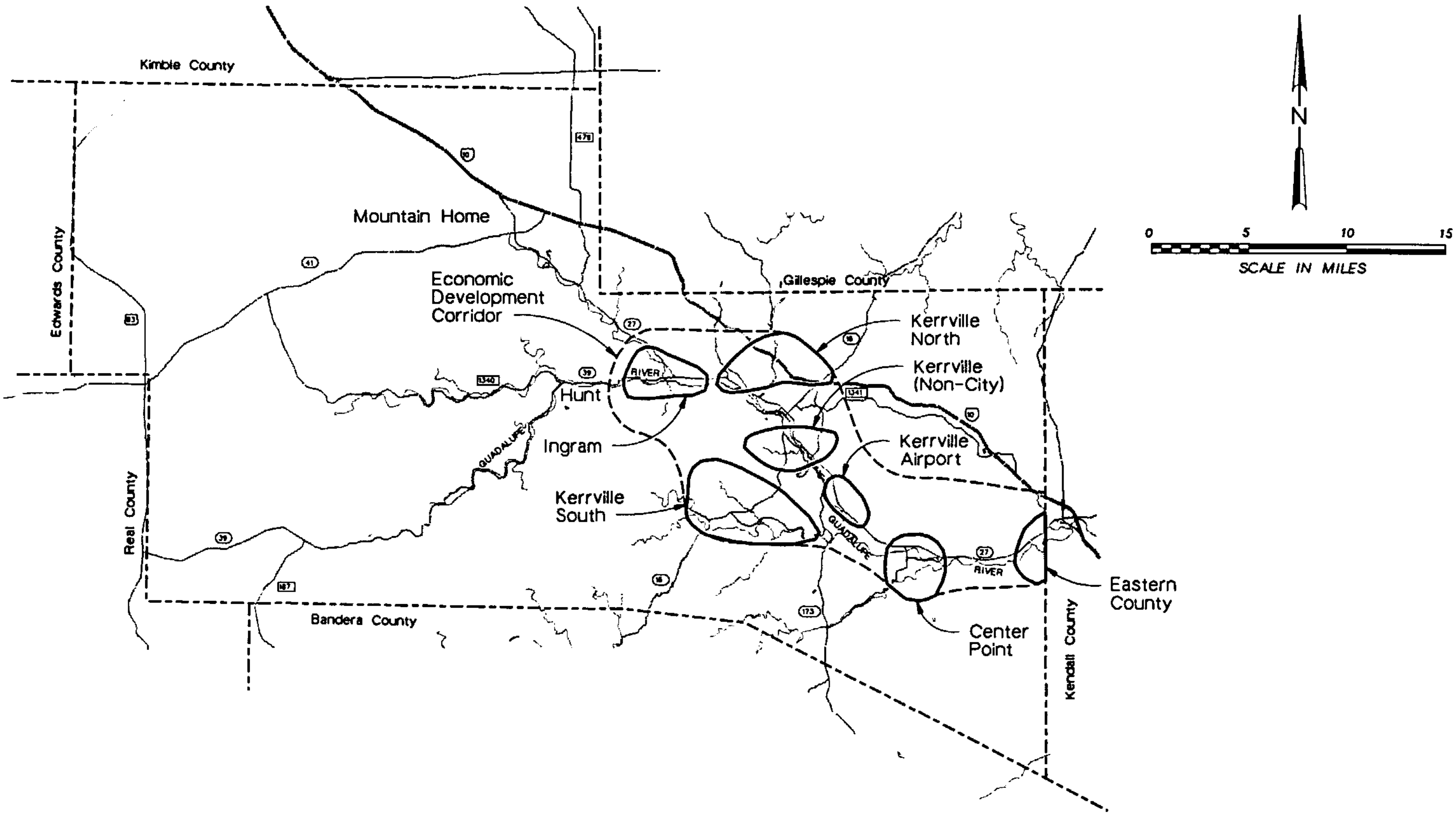


Figure 2-4

MUNICIPAL WATER DEMAND AREAS
OUTSIDE KERRVILLE SERVICE AREA

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## PER CAPITA DEMANDS

Per capita demands or the average volume of water used in gallons per person per day is multiplied by population to arrive at water demand. For this study, we evaluated historical demands in relation to:

- Accepted norms
- Water conservation goals
- Economic impacts

The historical demands for the City of Kerrville have varied from a low of 146 gpcd in 1987 (a high rainfall year) to a high of 192 gpcd in 1981. These figures are within the range of normal consumption figures for southern cities (140 gpcd to 190 gpcd). Per capita consumption in the range of 160 gpcd to 180 gpcd is most common. Estimates of per capita consumption for the County range from a low of 159 gpcd to a high of 244 gpcd but these figures contain irrigation and livestock water components which are highly influenced by rainfall.

Kerrville has established an aggressive water conservation goal of 15 percent which would reduce the per capita consumption from an estimated 166 gpcd to 141 gpcd. The plan for attaining this level of water conservation is outlined in Appendix F. A similar water conservation goal of 15 percent is established in the water conservation plan for Kerr County as described in Appendix E.

In an evaluation of community water demand in Texas (Griffin and Change, 1989), it was noted that "price elasticity" and "income elasticity" are the two key economic factors relating to water use. The premises are that as the price of water increases, water use will decline, and that as income level increases, water use will increase. Other studies (Murdock, 1988) have indicated that sociodemographic and socioeconomic variables affect per capita water use. Characteristics such as size and type of housing, minority group ratios, age of housing, and economic resources affect per capita water use. Holloway and Ball (1991) evaluated nine regions of the state with regard to price and income elasticities. In the San Antonio region (AACOG region), it was determined that a 10 percent increase in the cost of water would bring a 2.2 percent decrease in consumption. It was also determined that a 10 percent increase in income in the San Antonio area would result in a 9.5 percent increase in water use. Because water rates are projected to increase faster than real income, the overall result is that consumption rates will continue to decrease.

Based on the factors described above and the economic goals of the county, as summarized by the Economic Development Task Force, it was determined that the TWDB projections for "high per capita water use with conservation practices" (Municipal Demand Case 4) are a reasonable yet conservative projection of future municipal water demand to use for planning purposes. The per capita demands are shown in Table 2-2.

**Table 2-2**
**Per Capita Demands (gpcd)**

| Year | Kerrville | Ingram | Other | County |
|---|---|---|---|---|
| 2000 | 190 | 170 | 134 | 165 |
| 2010 | 179 | 162 | 126 | 157 |
| 2020 | 171 | 155 | 118 | 148 |
| 2030 | 169 | 153 | 115 | 144 |
| 2040 | 167 | 151 | 113 | 141 |

## MUNICIPAL DEMANDS

Municipal water demands were determined for Kerrville, Ingram, six areas within the EDC, and the balance of the County. Demands for Kerrville and Ingram correspond to the TWDB projections.

Municipal demands within the EDC were determined by collecting water use data on the public water systems located within the corridor (Appendix A). These water systems were grouped into six subareas of the EDC:

- Center Point
- Eastern County
- Kerrville (non-City)
- Kerrville Airport
- Kerrville North
- Kerrville South

The water use for the last year of complete records (1988) was totalled for the water systems located in each of these six areas. A ratio of water use in each subarea with respect to the total water use in the EDC was calculated. These ratios were multiplied by the total water demand projected for the EDC in years 2000 through 2040. The resulting water demand projections are shown in Table 2-3 below.

**Table 2-3**
**Municipal Water Demands (ac-ft/yr)**

| Area | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 |
|---|---|---|---|---|---|---|
| Center Point | 511 | 646 | 689 | 750 | 805 | 879 |
| Eastern County | 126 | 159 | 170 | 185 | 198 | 217 |
| Ingram | 268 | 345 | 383 | 388 | 404 | 409 |
| Kerrville, City of | 3,515 | 5,036 | 5,520 | 5,572 | 5,780 | 5,850 |
| Kerrville (non-City) | 309 | 390 | 416 | 453 | 486 | 531 |
| Kerrville Airport | 763 | 964 | 1,029 | 1,120 | 1,201 | 1,312 |
| Kerrville North | 170 | 215 | 230 | 250 | 268 | 293 |
| Kerrville South | 195 | 247 | 263 | 287 | 307 | 336 |
| Other | 42 | 81 | 79 | 91 | 96 | 99 |
| **TOTAL** | **5,900** | **8,084** | **8,780** | **9,096** | **9,546** | **9,926** |

## MANUFACTURING DEMANDS

Manufacturing demands projected by the TWDB were evaluated in light of economic and manufacturing data and expectations in Kerr County. The major manufacturers include Mooney Aircraft and James Avery Craftsmen (jewelry manufacturer). These are not water intensive industries. This type of industry is consistent with the goals and objectives of the Economic Development Task Force. Therefore, the TWDB projections for manufacturing demand were adopted for use in this study (Table 2-4).

**Table 2-4**
**Manufacturing Demands**

| Year | Total Demand (ac-ft/yr) |
|---|---|
| 1990 | 9 |
| 2000 | 11 |
| 2010 | 14 |
| 2020 | 17 |
| 2030 | 20 |
| 2040 | 24 |

These manufacturing demands are all expected to occur within the EDC and be supplied by the City of Kerrville using surface water or Lower Trinity aquifer water.

## IRRIGATION DEMANDS

The TWDB projected that irrigation demands would remain constant at 1,125 ac-ft/yr from 2000 to 2040 with an initial use in 1990 of 800 ac-ft/yr. The 1989 Irrigation Inventory (TWDB, 1991) indicates that 886 ac-ft was used to irrigate 563 acres with a record high of 2,255 ac-ft used to irrigate 826 acres in 1984. After discussions with agricultural representatives and existing agricultural operations, it was determined that the only planned irrigation expansion in Kerr County is the Shelton Ranches/Hill Country Orchards apple orchard expansion. The ultimate plan as described by the staff (1991) is to irrigate 800 acres of dwarf apple trees using drip irrigation systems. Approximately one foot of water will be applied to each acre (800 ac-ft/yr) with 50 percent of the supply derived from surface water and 50 percent from ground water. This acreage will be in full production by year 2000. Therefore, the irrigation demands adopted for this planning effort are as shown below in Table 2-5. This demand is expected to occur entirely within the EDC with ground water supplied from Upper, Middle, and Lower Trinity aquifers. The component to be supplied from the Middle Trinity aquifer is estimated separately because these irrigation demands compete with the rural water suppliers who satisfy municipal demands from the Middle Trinity aquifer.

**Table 2-5**
**Irrigation Demands**

| Year | Total Demand (ac-ft/yr) | Middle Trinity Demand (ac-ft/yr) |
|---|---|---|
| 1990 | 800 | 136 |
| 2000 | 1,600 | 536 |
| 2010 | 1,600 | 536 |
| 2020 | 1,600 | 536 |
| 2030 | 1,600 | 536 |
| 2040 | 1,600 | 536 |

## MINING DEMANDS

There is very little mining activity in Kerr County and it is not expected to increase substantially in the future. The existing operations will probably maintain production or be replaced by new activities with equal water demands. The mining demands are expected to remain at the 1990 rate (Table 2-6), and be located outside of the EDC.

**Table 2-6**
**Mining Demands**

| Year | Demand (ac-ft/yr) |
|---|---|
| 1990 | 78 |
| 2000 | 80 |
| 2010 | 80 |
| 2020 | 80 |
| 2030 | 80 |
| 2040 | 80 |

## LIVESTOCK DEMANDS

Livestock numbers have declined in Kerr County over the last 20 years with water demand for livestock reaching a low of 306 ac-ft in 1986. Since 1986, livestock demands have increased slightly. The total number of livestock in Kerr County is expected to remain constant or decrease over time (Table 2-7) as rural development and vacation/retirement homes encroach on pasture and range land. These demands will be located outside of the EDC.

**Table 2-7**
**Livestock Demands**

| Year | Demand (ac-ft/yr) |
|---|---|
| 1990 | 390 |
| 2000 | 390 |
| 2010 | 390 |
| 2020 | 390 |
| 2030 | 390 |
| 2040 | 390 |

## TOTAL DEMANDS

The total demands for Kerr County are presented in Table 2-8 below.

**Table 2-8**
**Total Demands (ac-ft/yr)**

| Area | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 |
|---|---|---|---|---|---|---|
| **EDC** | | | | | | |
| Center Point | 511 | 646 | 689 | 750 | 805 | 879 |
| Eastern County | 126 | 159 | 170 | 185 | 198 | 217 |
| Ingram | 268 | 345 | 383 | 388 | 404 | 409 |
| Kerrville, City of | 3,515 | 5,036 | 5,520 | 5,572 | 5,780 | 5,850 |
| Kerrville (non-City) | 309 | 390 | 416 | 453 | 486 | 531 |
| Kerrville Airport | 763 | 964 | 1,029 | 1,120 | 1,201 | 1,312 |
| Kerrville North | 170 | 215 | 230 | 250 | 268 | 293 |
| Kerrville South | 195 | 247 | 263 | 287 | 307 | 336 |
| Manufacturing | 9 | 11 | 14 | 17 | 20 | 24 |
| Irrigation | 800 | 1,600 | 1,600 | 1,600 | 1,600 | 1,600 |
| EDC Total | 6,667 | 9,614 | 10,315 | 10,622 | 11,070 | 11,451 |
| **Non-EDC** | | | | | | |
| Other Municipal | 42 | 81 | 79 | 91 | 96 | 99 |
| Mining | 78 | 80 | 80 | 80 | 80 | 80 |
| Livestock | 390 | 390 | 390 | 390 | 390 | 390 |
| Non-EDC Total | 510 | 551 | 549 | 561 | 566 | 569 |
| **County Total** | **7,177** | **10,165** | **10,864** | **11,183** | **11,636** | **12,020** |

# Section 3
# SURFACE WATER RESOURCES

# Section 3
# SURFACE WATER RESOURCES

## INTRODUCTION

The purpose of this section is to review existing surface water supplies available to serve the water supply needs of Kerr County, review any additional surface water supplies that may be available from the Guadalupe River and any limitations that may be imposed on the supply, with consideration of instream flow requirements and water quality.

## EXISTING SURFACE WATER USE

The natural flows of the surface water streams of the State of Texas are subject to use under an appropriate system managed by the Texas Water Commission. A permit must be obtained from the Texas Water Commission in order to divert or store surface water. A priority of use (municipal, agricultural, industrial) and a priority in time (first in time, first in right) has developed. The surface water rights in each river basin have been adjudicated and are reviewed periodically by the Texas Water Commission. This process confirms existing water rights or in instances where water rights have not been utilized to their fullest extent, cancels them to make water to new users available which utilizes the resource to the greatest benefit without impeding the existing right of other users.

There are a total of 148 permits to divert surface water from the Guadalupe River and its tributaries in Kerr County. The total permitted diversion from these permits is 10,929 acre-feet per year. Irrigation is the largest water use category with 111 permits and 5,336 acre-feet per year diversion. Municipal is the next largest water use category with 14 permits and 3,917 acre-feet per year diversions. The Upper Guadalupe River Authority (UGRA) permit accounts for 3,603 acre-feet per year (92%) of the total municipal water use. Table 3-1 shows the number of permits and permitted diversions for each water use category.

**Table 3-1**
**Kerr County**
**Surface Water Rights Permits**
**and Quantity Permitted by Type of Use**
**September, 1991**

| Type of Use | No. of Permits | Quantity Ac-Ft | % of Total |
|---|---|---|---|
| Municipal | 14 | 3,917 | 35.9 |
| Industrial | 3 | 417 | 3.8 |

**Table 3-1**
**Kerr County**
**Surface Water Rights Permits**
**and Quantity Permitted by Type of Use**
**September, 1991**

| Type of Use | No. of Permits | Quantity Ac-Ft | % of Total |
|---|---|---|---|
| Irrigation | 111 | 5,336 | 48.8 |
| Mining | 2 | 153 | 1.4 |
| Recreation | 18 | 1,106 | 10.1 |
| **Total** | **148** | **10,929** | **100.0** |

Source: Texas Water Commission
Note: Permits with multiple types of use were included in only one use category. Individual permits are listed in Appendix B.

## EXISTING AND PLANNED SURFACE WATER FEATURES

### EXISTING SURFACE WATER FEATURES

There are several existing surface water features in Kerr County. Table 3-2 lists the features with a storage capacity of at least 50 acre-feet and some pertinent information on each.

**Table 3-2**
**Existing Surface Water Features**

| Feature Name | Owner | Stream Location | Capacity Acre-Ft | Type of Use |
|---|---|---|---|---|
| UGRA Ponding Lake | UGRA | Guadalupe River | 840 | municipal |
| DAM | T.J. Moore Estate | Cypress Creek | 100 | irrigation |
| Louise Hays Park Lake | City of Kerrville | Guadalupe River | 75 | irrigation |
| Lake Riverhill | Riverhill County Club | Camp Meeting Creek | 70 | irrigation |
| Dam | Shelton Ranch Corp. | Guadalupe River | 54 | irrigation |
| Dam | Ray Ellison, Jr. | Spring Creek | 50 | irrigation |
| Dam | Roland Walters | Prison Canyon | 420 | irrigation |
| Dam | Tyson Smith | Verde Creek | 120 | irrigation |
| Dam | Rodney Robinson | East Town Creek | 83 | irrigation |

| Feature Name | Owner | Stream Location | Capacity Acre-Ft | Type of Use |
|---|---|---|---|---|
| Dam | River Inn Assoc. | So. Fk. Guadalupe River | 50 | recreation |
| New Lake Ingram | Kerr County | Guadalupe River | 450 | recreation |
| Dam | L.D. Brinkman | Fessender Branch | 184 | recreation |
| Flat Rock Lake | Kerr County | Guadalupe River | 720 | recreation |
| Lake Center Point | Kerr County | Guadalupe River | 87 | recreation |
| Dam | Chloe Cullum Kearney | North Fork Guadalupe River | 100 | recreation |
| Dam | T&R Properties | Palmer Creek | 322 | recreation |
| Dam | Pecan Valley Ranch Owners | Elm Creek | 157 | recreation |
| Dam | Shelton Ranch Corp. | Johnson Creek | 122 | recreation |

## POTENTIAL SURFACE WATER FEATURES

In 1960 the U.S. Study Commission - Texas studied potential reservoir sites all over Texas. Three sites in Kerr County (Figure 3-1) were studied: The Ingram Reservoir site on Johnson Creek in the Town of Ingram, the Bear North Reservoir Site on the North Fork of the Guadalupe River at its confluence with Bear Creek, and the Smith Reservoir Site on the South Fork of the Guadalupe River 5.4 miles upstream from the mouth of the South Fork. The U.S. Study Commission report did not specify a use for the reservoirs but they could be used for water supply or flood control. In the Texas Basin Project performed by the Bureau of Reclamation (1978), only the Ingram Reservoir was identified as a feasible project with a firm yield of 9,000 ac-ft/yr. Dam 7 in Kendall County was considered but dismissed as having serious environmental, cost, or water supply deficiencies. The 1981 Water Supply Project study performed by Espey, Huston and Associates considered reservoir sites at Ingram, Comfort, Dam 7, and an off-channel reservoir (Figure 3-1) in Kerr County. The off-channel reservoir option was selected as the most cost-effective site for surface water storage. The Ingram Reservoir was not considered by the TWDB (1990) in the most recent update of the State water plan. In general, on-channel reservoirs above Canyon Dam in the Guadalupe basin are not cost effective for several reasons:

- Water rights are fully committed.
- Costs to construct an on-channel reservoir with a spillway(s) designed to pass the probable maximum flood (PMF) are extremely high, in relation to the firm yield.

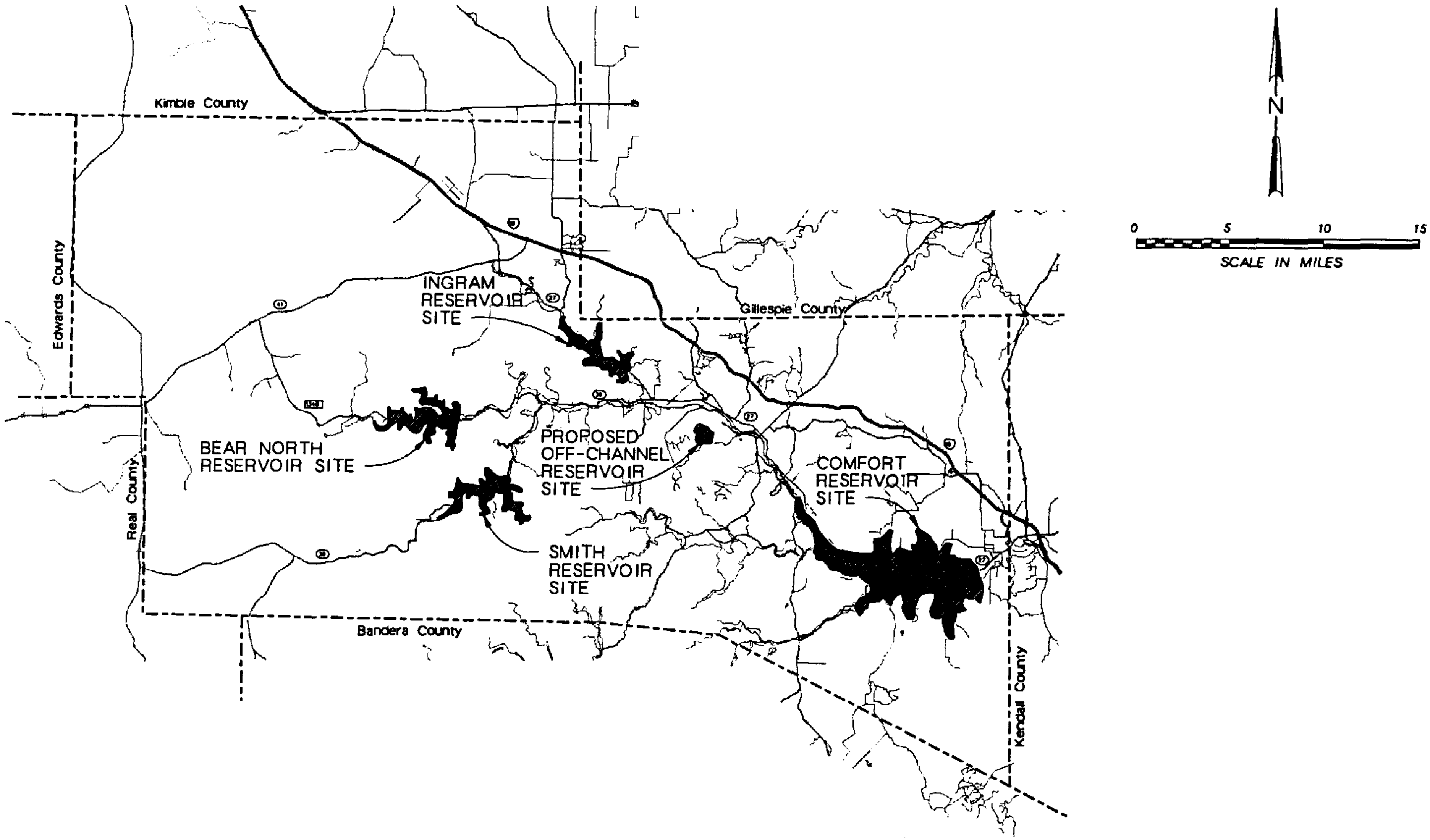


Figure 3-1

POTENTIAL SURFACE WATER FEATURES

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- Environmental issues related to an on-channel reservoir become a major consideration.

Therefore, the off-channel reservoir storage option is considered to be the most viable surface water storage option. In 1988, Espey, Huston and Associates concluded that an off-channel reservoir with capacity to store 15,300 ac-ft would be required to meet a future demand of 8,226 ac-ft/yr while allowing for a 25 cfs flow through requirement on a diversion permit. This reservoir was estimated to cost approximately $28.6 million.

## SURFACE WATER SUPPLY ALTERNATIVES

### NEW APPROPRIATION

There is little or no additional water available for new appropriation for reservoir storage projects or run of the river diversions in the Guadalupe River in Kerr County. (HDR, 1991) The flows are virtually completely appropriated by the permits in Table 3-1 and by hydropower rights held by the Guadalupe-Blanco River Authority (GBRA) under Certificates of Adjudication 18-5488 and 18-5172 and rights for other uses held by GBRA and others.

### SUBORDINATION OF HYDROELECTRIC RIGHTS

Subordination is a process whereby a senior (earlier in time) water right permit holder allows another water right permit holder to exercise diversion or storage rights first, thereby increasing the use by the junior right. This process is presently in use and can continue to be used to provide water to users upstream of Canyon Dam who otherwise would be unable to divert water.

GBRA, through Certificates of Adjudication 18-5488 and 18-5172, has hydroelectric water rights in the Guadalupe River and its tributaries. GBRA has allowed subordination of its hydroelectric water rights to make water available for use at times when the entire flow is required to be allowed to pass to honor the GBRA hydroelectric rights but less than the entire flow is required to pass to honor other water rights. This decreases the flow of water GBRA uses to generate electricity. GBRA charges the recipient of the subordinated water the cost of the foregone hydroelectric power which would have been generated at GBRA's hydroelectric facilities. This process is the most practical alternative for providing additional surface water supplies to Kerr County. GBRA has indicated there is sufficient water available that could be subordinated to meet the needs of Kerr County.

### INSTREAM FLOW REQUIREMENTS

The UGRA presently holds permit No. 3505 issued by the Texas Water Commission (TWC) for diversions of 3,603 acre-feet per year from the Guadalupe River. The UGRA treats this water and delivers it to the City of Kerrville for municipal use. The current level of diversions is nearing the annual permit limit so the UGRA is planning for and has taken steps towards increasing their right to divert water from the Guadalupe River. The UGRA has entered into a subordination agreement with the GBRA whereby the GBRA has agreed to subordinate 4,760 acre-feet per year of its downstream hydroelectric water rights to the proposed new diversion. The UGRA has submitted its application to the TWC for a permit to increase its diversions by this amount.

One of the factors which will affect the overall design of the water supply system and the TWC approval of the permit application is the minimum flow which must be passed through the UGRA lake in Kerrville to satisfy downstream environmental, water quality, and water rights requirements.

The UGRA currently holds a Section 404 permit issued by the Corps of Engineers (COE) which requires that all inflows of 4.3 cfs or less shall be released for the preservation of downstream aquatic life. The TWC did not impose any additional instream flow requirements in Permit 3505. Previous investigations (EHA, 1988) estimated the instream flow requirement needed to satisfy downstream water rights to be 7.7 cfs from April to September and 4.3 cfs (or less) from October through March. During the review of the Riverhill County Club application to amend Certificate of Adjudication (CA) No. 18-2000, the Water Quality Division of the TWC prepared an analysis of Flat Rock Lake on the Guadalupe River, which receives the City of Kerrville wastewater treatment plant effluent, and concluded that the required instream flow requirement should be 25 to 30 cfs to maintain acceptable water quality in Flat Rock Lake, unless evidence is presented that conclusively proves that a lower flow value will not harm the river.

UGRA commissioned a study to determine the minimum acceptable instream flow which would maintain the water quality in the river and Flat Rock Lake. The results of this study (EHA, 1991) indicate that water quality degradation due to nutrient enrichment and algal growth was not a problem until the Guadalupe River flow was less than 12 cfs and the City of Kerrville wastewater treatment plant was discharging at its permitted capacity of 3.5 mgd. UGRA is proposing a minimum instream flow requirement of 15 cfs for which the analyses show that problems would not result until the wastewater discharge levels reached 4 mgd. This study will be presented as evidence to the TWC in support of UGRA's permit application to increase its diversions.

As the City of Kerrville grows, more effluent will be discharged into Flat Rock Lake. At some future point in time, it will be necessary to modify the wastewater quality or quantity to insure that water quality problems do not occur. This can be accomplished by either increasing nutrient removal from the effluent or by diverting the portion of the effluent discharge in excess of 3.5 to 4 mgd to reuse.

**WATER QUALITY**

The treated surface water produced by the 5.0-mgd capacity UGRA water treatment plant presently meets all the requirements of the Safe Drinking Water Act (SDWA) and TDH standards. If the regulations change then the treatment processes and disinfection procedures should be reviewed to insure compliance with the new regulations. The quality of raw water in the Guadalupe River is generally good with low turbidity. At times the turbidity is so low that conventional plant operations are modified to recycle solids in order to maintain the treatment process. After heavy rains, the turbidity can increase dramatically. When this occurs, the plant is temporarily taken off-line and Kerrville uses groundwater as a principal source for a few days.

## CONCLUSIONS

The Guadalupe River is the primary surface water feature in Kerr County. Water rights in the Guadalupe basin are fully appropriated. The only additional water rights that may be easily obtained are those obtained through subordination of hydroelectric rights.

Surface water can play a key role in managing the water resources of Kerr County. As long as in-stream flow requirements and the water quality in both open river reaches and in impoundments such as Flat Rock Lake can be maintained, diversions from the Guadalupe River can continue to increase.

The key factor associated with management of surface water is one of timing. River flows do not correspond to seasonal and annual demands, so storage is required to equilibrate the fluctuations in supply and insure that water is available when it is needed. Sufficient water rights are not available to support construction of a reservoir on the main river channel when considering the project cost and environmental issues. The only two remaining options are storage in an off-channel reservoir, or storage below ground in an aquifer using Aquifer Storage and Recovery (ASR) or another recharge method.

# Section 4
# GROUNDWATER RESOURCES

# Section 4
# GROUND WATER RESOURCES

## INTRODUCTION

### PURPOSE

The purpose of this section is to summarize and evaluate the ground water resources of Kerr County, Texas. This information will be used to evaluate the total water resources available in Kerr County, and provide a basis for ground water modeling efforts which will be used to further define ground water limitations.

Another element of this section is the evaluation and quantification of ground water resources to determine if any limitations to the development of a conjunctive management system exist.

### METHODOLOGY

This section of the study was prepared by reviewing the following published and unpublished data on the ground water resources of Kerr County and the Hill Country areas around Kerr County:

- Texas Water Development Board reports
- Texas Water Commission well records
- Bureau of Economic Geology reports
- UGRA water level and analytical data (Appendix B)
- City of Kerrville Public Utility records
- Private consultant reports
- Data derived from CH2M HILL ASR investigations within the city

### CURRENT STATUS

In 1990 the Texas Water Commission (TWC) and Texas Water Development Board (TWDB) released a report (Cross and Bluntzer, 1990) that proposed critical area designation for all or portions of eight hill country counties (Figure 4-1). Included in this 5,500 square mile area is all of Kerr County. Critical areas are areas that are experiencing or will experience in the next 20 years ground water shortages, land subsidence, or ground water contamination. Based on potential ground water shortages due to lowering water tables and low recovery potential from the aquifers, the Hill Country counties were proposed as a critical area.

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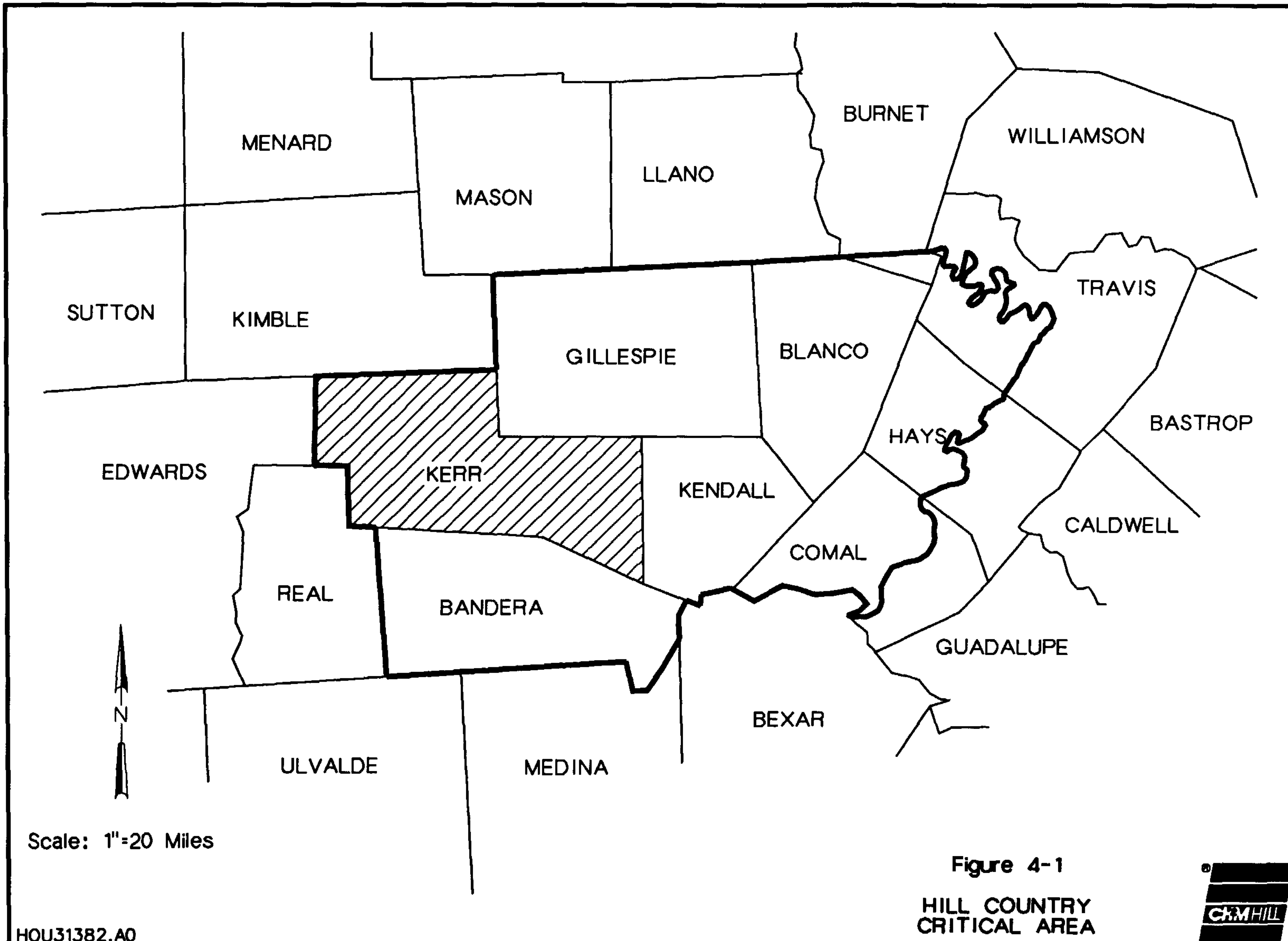


Figure 4-1

HILL COUNTRY CRITICAL AREA

The critical area designation give the TWC the authority to hold a hearing to determine if an underground water conservation district (UWCD) should be formed in the critical area. If an UWCD is formed it has full regulatory authority over ground water use and development in the critical area. Some of the regulatory powers of an UWCD include but are not limited to:

- Eminent domain power
- Water well permitting
- Restricting well spacing
- Restricting ground water use
- Enforcing well abandonment procedures

The Headwaters Underground Water Conservation District has been organized within Kerr County. This district will work closely with the UGRA, and currently the UGRA is providing basic data gathering and other administrative functions of the District.

## OVERVIEW OF THE REGIONAL HYDROGEOLOGY

Kerr County is situated in the Hill Country area of Texas in the southern portion of the Edwards Plateau. The terrain is characterized by gently rolling land with stream-incised plateaus. Elevations in the county range from about 1,450 to 2,310 feet National Geodetic Vertical Datum (NGVD). The area of the county is approximately 1,100 square miles. Surface drainage is to the southeast along major river systems that eventually discharge into the Gulf of Mexico. The most prominent surface water drainage in Kerr County is the Guadalupe River. The watershed of this river comprises 70 percent of the county area.

### STRATIGRAPHY

The surface and near surface bedrock geology of Kerr County includes deposits of the Quaternary, Cretaceous, and pre-Cretaceous systems. Table 4-1 depicts the stratigraphic units or geologic layering present in Kerr County. Figure 4-2 is the county geologic map which is an aerial view of the county showing the geologic units which would be exposed at the ground surface if the topsoil was removed (Ashworth, 1983). Recharge occurs through various exposed geologic units. A cross-section depicting interrelationships of the geologic units is presented in Figure 4-3 (Reeves, 1969). Numerous investigations of the Hill Country hydrogeology and geology have resulted in several stratigraphic nomenclatures. Although individual stratigraphic units generally have been named alike from investigation to investigation, formations and groups have been designated differently from report to report. This study will use the nomenclature of Ashworth (1983), which is summarized in Table 4-1.

## TABLE 4-1
## GEOLOGIC UNITS AND AQUIFERS OF KERR COUNTY

| System | Series | Group | Stratigraphic Unit | | Aquifer Name | Approximate Maximum Thickness (Ft.) |
|---|---|---|---|---|---|---|
| Quaternary | Recent and Pleistocene | | Flood plain, terrace and fan alluvium | | Alluvium | 40 |
| Cretaceous | Comanche | Fredricksburg | Edwards & Georgetown Limestones | | Edwards | 500 |
| | | | Comanche Peak Limestone | | | 50 |
| | | | Walnut Clay | | | 15 |
| | | Trinity | Glen Rose Limestone | Upper Member | Upper Trinity | 385 |
| | | | | Lower Member | Middle Trinity | 210 |
| | | | Travis Peak Formation | Hensell Sand Member | | 155 |
| | | | | Cow Creek Limestone Member | | 70 |
| | | | | Hammett Shale Member | Lower Trinity | 50 |
| | | | | Sligo Limetone Member | | 70 |
| | | | | Hosston Sand Member | | 110 |
| Pre-Cretaceous | | | | | | |

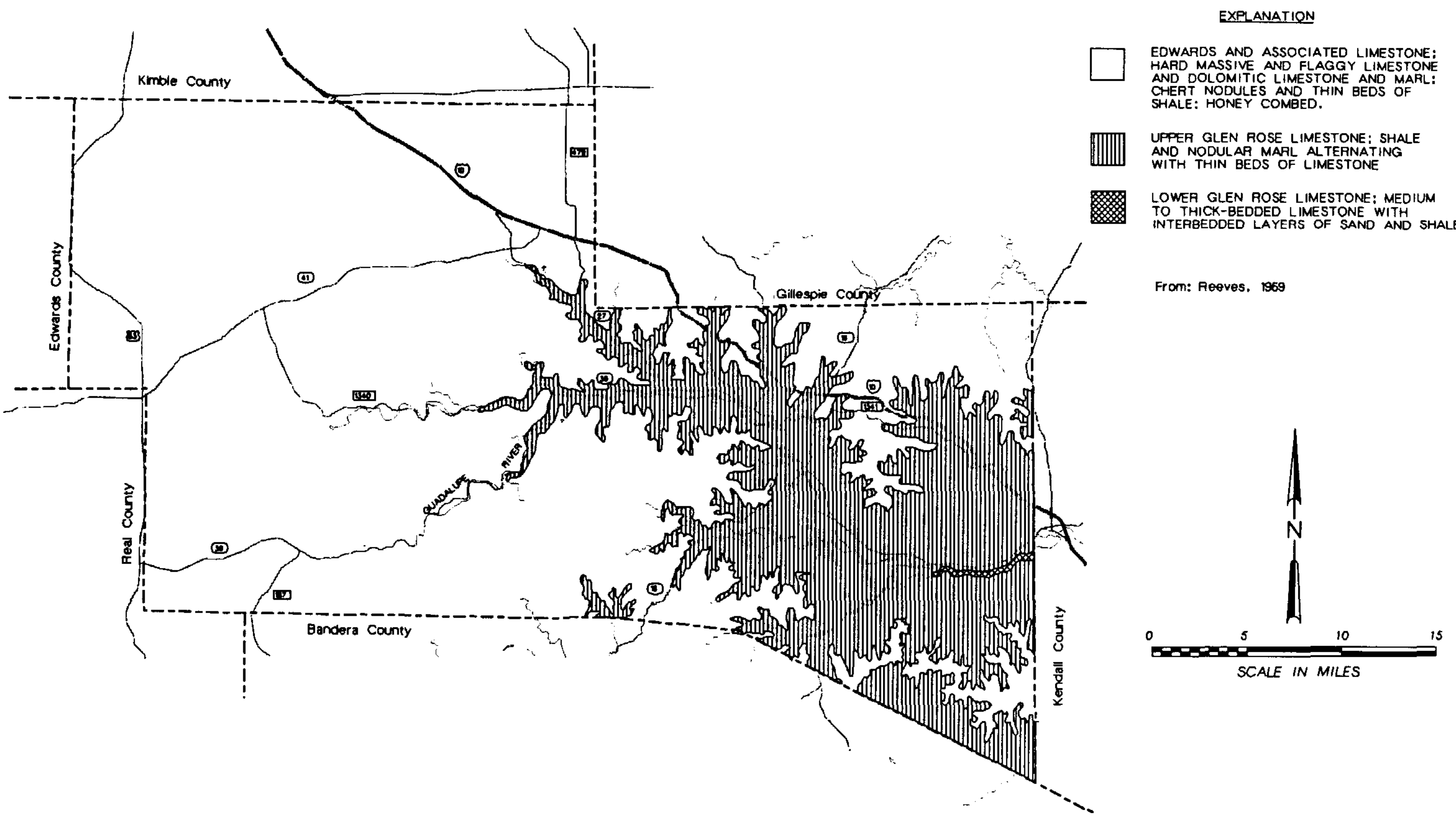


Figure 4-2

GEOLOGIC MAP OF KERR COUNTY

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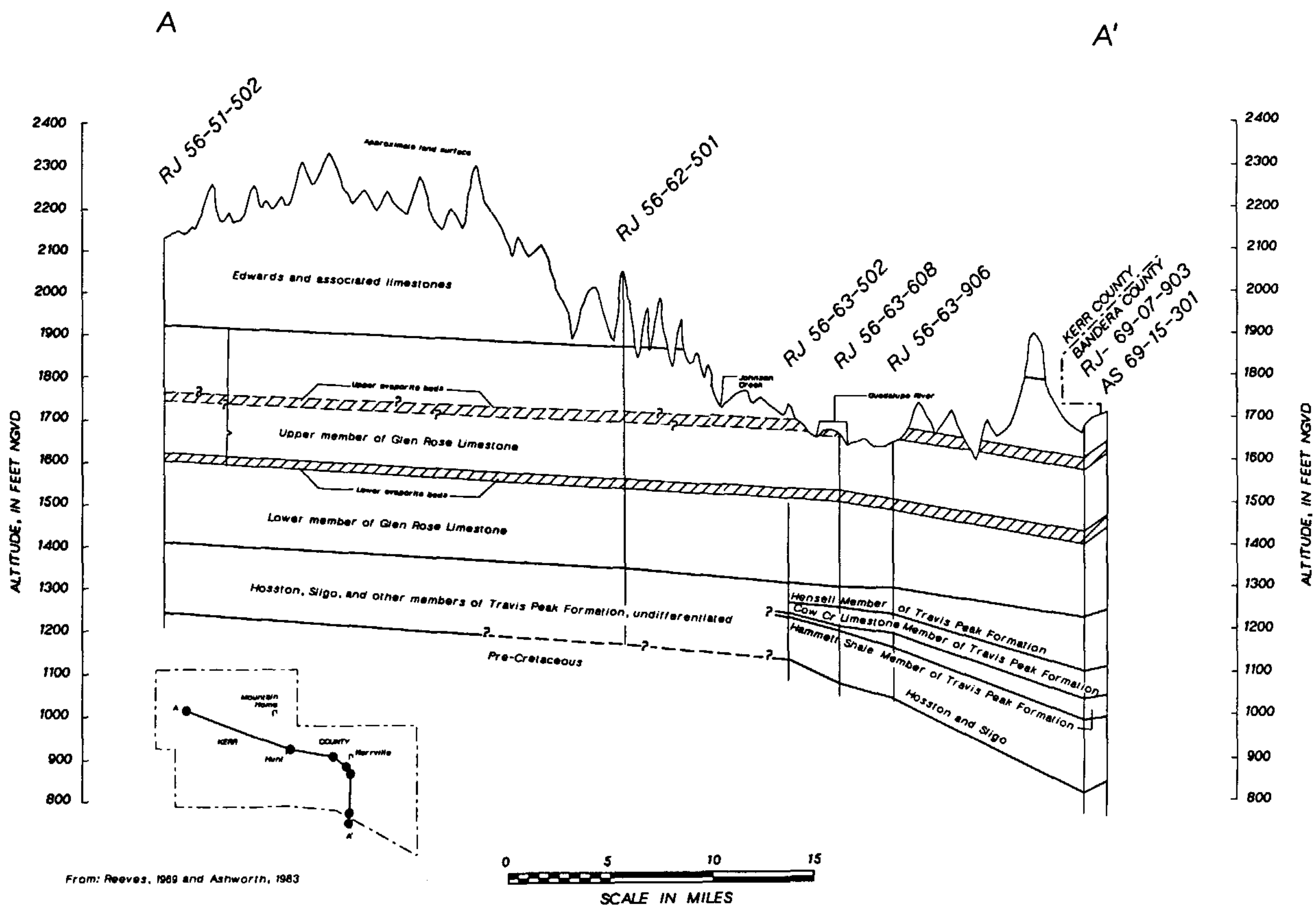


Figure 4-3

GEOLOGIC CROSS SECTION A-A'

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The Quaternary system is represented by a mixture of unconsolidated clay, silt, sand, and gravel. The Quaternary deposits are exposed primarily along the channels of the Guadalupe River and its major tributaries (Turtle, Johnson, and Verde Creeks). Thicknesses of the Quaternary alluvium are generally less than 50 feet. Maximum thickness occurs along the Guadalupe River.

The pre-Cretaceous rocks are of minor consequence in the hydrogeologic and water resource issues of Kerr County. Few, if any, wells are completed into the pre-Cretaceous water-bearing units. Some test holes have penetrated these units in the eastern portions of the City of Kerrville. However, these holes found unsatisfactory supplies with poor quality. In Comfort, just east of Kerr County, a municipal well penetrated the Lower Cretaceous and the pre-Cretaceous rocks. Although the yield of the well was good, the water quality was poor and characterized by high TDS concentrations, primarily chloride.

The most important water-bearing units are found in the Cretaceous aquifers. These rocks were deposited as a wedge-like overlapping sequence that pinches out towards the Llano uplift to the north and thickens downdip to the southeast. The rocks are a combination of limestone, dolomite, sandstone, and shale. The most important of these are listed below:

- Edwards Aquifer
- Upper Trinity Aquifer
- Middle Trinity Aquifer
- Lower Trinity Aquifer

The youngest of these aquifers is the Edwards Aquifer. Included in this aquifer, from youngest to oldest, are the Georgetown, Edwards, and Comanche Peak Limestones. These units are characterized as cherty, nodular-to-massive limestones with some interbedded shale, clay, and dolomite units. The aggregate thickness of these units can exceed 500 feet.

The Trinity Group is subdivided into three units: Upper, Middle, and Lower. The Upper Trinity is comprised of the Upper Glen Rose Limestone. This interbedded shale and clayey limestone reaches thicknesses of up to 350 feet. Also included in these units are two distinct evaporite zones, which are used as marker beds. The most important one demarcates the base of the Upper Glen Rose.

The Middle Trinity contains, from youngest to oldest, the Lower Glen Rose, Hensell Sand, and Cow Creek Limestones. The upper portion of Lower Glen Rose is very similar to the Upper Glen Rose. However, near the base of the unit the stratigraphy is characterized by massive medium to thick bedded limestone. In places the Lower Glen Rose has a sandy facies (Ashworth, 1983).

Characterized by a wide range of lithologies, the Hensell Sand is variable in lithology vertically at each location and internally throughout Kerr County. This unit typically contains red to gray clay, sand, and conglomerate, with interbedded thin limestone units in the northern and western portions of the county. Towards the south and southeast, the unit becomes more calcareous and may contain shaley limestones and dolomites and calcareous shales.

The base of the Middle Trinity is marked by the Cow Creek Limestone. This massive, highly fossiliferous limestone and dolomite contains beds of sand and shale. Thicknesses of the Cow Creek of up to 70 feet have been reported within the county.

The Lower Trinity aquifer is composed of the Hosston and Sligo members of the Travis Peak formation. The Hammett Shale, which is sometimes called the Pine Island Shale, is a thin (typically less than 20 feet thick) dolomitic shale with some interbedded sand lenses. The unit is generally present throughout southern Kerr County, but thins rapidly to the north and pinches out north of Kerrville and west of Hunt (Figure 4-3). The unit acts as a confining and semi-confining bed above the Lower Trinity aquifer.

The Hosston and Sligo in many locations in Texas are represented by two distinct units: the Hosston Sandstone (red dolomitic sandstone) and the Sligo Limestone (sandy dolomitic limestone). In Kerr County, however, the units are often grouped and referred to as the Hosston-Sligo because they are difficult to differentiate using drill cuttings. In most cases, geophysical logs, particularly SP-Resistivity (electric) and Gama Ray type logs, or closed-circuit television (CCTV) logs taken in color can be used to differentiate the two members.

The Hosston and Sligo are thickest in the south and southwest portions of the county, where the combined thickness may exceed 150 feet. In Kerrville a 75-to-100 foot thickness is common. North of Kerrville the Sligo Limestone thins and eventually pinches out near the northern border of the county. Here the Hosston directly underlies the Hammett Shale.

## WATER-BEARING CHARACTERISTICS

The most productive unit in Kerr County is the Lower Trinity aquifer. This aquifer, which can sustain well yields in excess of 1 mgd, is the main aquifer for the City of Kerrville's well field.

The next most prolific aquifer is the Middle Trinity, which can produce at rates of more than 100 gpm. It is composed of the lower member of the Glen Rose Limestone, and the Hensell Sand and Cow Creek Limestone members of the Travis Peak Formation. Residential and small industrial wells are completed in this aquifer. The Cow Creek is not as transmissive as the Hensell. However, most wells that are completed in the Hensell also have open hole intervals in the Cow Creek. Rarely is a well drilled and completed in the Cow Creek alone. The Lower Glen Rose leaks a lower quality water (higher salinity) into the Hensell Sand. This problem is often aggravated by wells having open-hole intervals in the Lower Glen Rose, in addition to the Hensell Sand and Cow Creek Limestone.

The Upper Trinity (Upper Glen Rose) yields quantities of water that are sufficient only for domestic use. Typically, these wells in produce highly mineralized water. Sulfate concentrations are also typically high. Water quality in the Upper Trinity deteriorates downgradient as dissolved solids concentrations increase with increased travel and contact time in the formation.

The Edwards yields only small quantities of water because of its limited recharge area. Most of the water typically emanates from the unit as springs on hillsides. Water quality is characterized by low TDS and moderate hardness.

The yields of the individual aquifers will be discussed in greater detail in subsequent paragraphs.

**RECHARGE**

Recharge to the aquifers in Kerr County occurs primarily as the result of direct precipitation on the outcrop and by leakage from one aquifer to another. To a limited extent within Kerr County, surface waters recharge some aquifers where streams cross the outcrop.

It has been estimated that about five percent of the average annual rainfall in the Hill Country enters the aquifers as recharge. Assuming an average annual precipitation of 31 inches across Kerr County, five percent infiltration would result in 90,900 ac-ft/year, or 81 mgd recharge to the aquifers.

**AQUIFER USE**

The distribution of the aquifers are discussed in detail in the next major part of this section. Generally, the Edwards is used predominantly in the north and northwest portions of the county. In the eastern portion of Kerr County the Edwards is used by residences situated on hilltop locations. The Upper Trinity is used mainly in the central and eastern portions of the county. It is typically used if the Edwards is not present or if drilling to the underlying units is cost-prohibitive due to depth.

The Middle Trinity is also used by residences and small industries in the central and eastern portions of Kerr County. Few wells penetrate the Lower Trinity in Kerr County. The majority of these wells are in the City of Kerrville. To a lesser extent wells penetrating this aquifer are found to the southeast and east of Kerrville.

# MAJOR AQUIFERS IN KERR COUNTY

## EDWARDS AQUIFER

### Distribution

As shown in Figure 4-2, the Edwards Limestone is the dominant surface geologic formation in Kerr County. The Edwards and its associated limestones outcrop over more than 50 percent of the surface area in the county. West and north of Hunt, close to 100 percent of the surface is underlain by the Edwards Aquifer. The base of the unit in this area is approximately 1,900 feet NGVD. In the eastern and south-eastern portions of the county, the Edwards outcrops on less than 25 percent of the area. Here it is found on the tops of hills and plateaus, usually at elevations of greater than 1,850 feet NGVD.

The Edwards in Kerr County does not have the same characteristics as it does in Bexar and surrounding counties. In Kerr County, the Edwards may reach a thickness of more than 400 feet; however, because of the dissected nature of the topography, ground water flow is discontinuous. Thick, saturated, highly transmissive zones do not occur. Instead, water table or unconfined conditions with thin saturated thicknesses are typically the conditions found in Kerr County.

### Flow Direction and Water Levels

Ground water in the Edwards occurs in void spaces caused primarily by secondary porosity. This secondary porosity is formed by solution weathering and dolomitization of the limestone and by fracturing or jointing in the rocks.

The majority of the wells that penetrate the Edwards Aquifer find water table or unconfined conditions. A few wells encounter confining beds within the aquifer that result in small artesian water level rises. Water entering the Edwards through recharge generally flows downdip under the influence of gravity, where the majority of it breaks out along the outcrop as springs. Some downward leakage into the underlying Upper Trinity aquifer also occurs, contributing to its total recharge.

Water levels in the western portion of the county range from 1,900 to 2,000 feet NGVD. In general, ground water flow direction is to the east towards the Guadalupe River. In the extreme northern portion of Kerr County, at the boundary with Kimble County, ground water flow has a northerly component.

Review of well records indicates that the majority of the wells have less than a 50-foot water column inside the well. The majority of the water column may be the result of over-deepening of the well in order to permit the well to store additional water.

**Aquifer Characteristics**

The majority of the wells in the Edwards Aquifer are for domestic use. Therefore, few tests and limited hydrogeological characteristics are readily available. Review of well records and spring information reveals that the majority of the wells in the aquifer pump at rates of less than 15 to 20 gpm. Pumping rates in excess of 50 gpm are uncommon.

Some short-term pump tests on Edwards wells in Kerr County are available. Specific capacities (gallons per minute/foot of drawdown) from these tests were less than 1 gpm/ft.

Springs in the Edwards show highly variable flow rates from location to location. However, the flow at a specific location is relatively constant. At several locations, flow in the springs in excess of 500 gpm has been reported. These high producing springs are found in the Mountain Home area and are the headwaters of Johnson Creek. Discharges from the Edwards also form the headwaters of both the North Ford and South Fork of the Guadalupe River.

**Water Quality**

The Edwards Aquifer exhibits excellent water quality in Kerr County. Water quality data based on historical chemical water analysis for water from wells and springs of the Edwards aquifer in Kerr County is very limited, but the water quality in Kerr County is very similar to the water quality in Gillespie and Bandera Counties where more data is available (Walker, 1979). The available water quality data for the Edwards aquifer was recently summarized by the TWDB (Bluntzer, 1991) in a draft report. In general, the following conclusions regarding water quality can be applied to the Edwards aquifer in Kerr County:

- The concentrations of sulfate, chloride, fluoride, and total dissolved solids are within the limits of the current drinking water standards.

- The waters produced from the aquifer are inherently very hard as a result of calcium and bicarbonate being the primary components of the dissolved solids concentration.

- The nitrate concentrations encountered in Kerr County have increased above the ambient level of 1.0 mg/l but remain below the regional average of 10.6 mg/l (Bluntzer, 1991) and generally below the maximum contaminant level of 10.0 mg/l as promulgated by the Environmental Protection Agency under the authority of Public Law 93-523 (the Safe Drinking Water Act). Nitrate concentrations in the rural western areas of Gillespie and Bandera Counties are substantially higher than those measured to date in Kerr County. Agricultural operations are also more intense in these areas.

- The waters have a near neutral pH and typically low chloride concentration (less than 30 mg/l).

- Sodium is present in low concentrations, and the sodium adsorption ratio (SAR), a measure of irrigation water suitability, is low.

Since the natural discharge from the Edwards aquifer is the main source of the base flow of the Guadalupe River and its tributaries, any degradation of the aquifer quality would adversely affect the water quality of the Guadalupe River. To date, the UGRA has not identified any water quality problems in the Guadalupe River at the UGRA Water Treatment Plant in Kerrville.

## UPPER TRINITY AQUIFER

### Distribution

The Upper Trinity Aquifer is represented in Kerr County by the Upper Glen Rose Limestone. This unit outcrops over approximately 20 percent of the surface area in Kerr County. The majority of the outcrop of the Upper Glen Rose is in the eastern portion of the county, where it is the predominant surfacial geological unit. In these areas it outcrops in the valley floors and banks of the Guadalupe River and Cypress, Verde, and Turtle Creeks.

Although it underlies all of Kerr County except where it is eroded by streams in the east, the Upper Trinity Aquifer thins northward and towards the Llano Uplift and eventually pinches out in Gillespie County north of Fredericksburg. In Kerr County, the unit has a maximum thickness of 385 feet in the southeast part of the county. Minimum thicknesses (350 feet) are found in the north portions of the county. The Upper Glen Rose dips to the south and southeast. In the Kerrville area, the base of the unit is trough-like and probably represents an erosional surface caused by streams that incised the Lower Glen Rose prior to deposition of the Upper Glen Rose. In Kerr County, the top of the Upper Glen Rose is encountered at about 1,900 feet NGVD in the north and just less than 1,800 feet NGVD in the south. Through the Kerrville area the top of the Upper Glen Rose averages an elevation of approximately 1,825 feet NGVD.

### Flow Direction and Water Levels

Ground water in the Upper Trinity occurs primarily as secondary porosity in joints and along bedding planes. Although the Upper Trinity is not characterized by honey-combed solution weathering as is the Edwards, solution weathering does occur and is represented by enlargement of the zones along the joints and bedding planes. This enlargement is a continuing but slow process.

Recharge to the Upper Glen Rose occurs through leakage from the Edwards, through direct precipitation on the outcrop, and through stream losses. With the exception of areas near the outcrop, the aquifer generally exhibits confined or artesian conditions. Flow is a generally to the southeast and following the general dip of the unit. Near the outcrop, unconfined conditions occur, and ground water tends to flow towards the outcrop.

Because wells in the Upper Glen Rose are limited to rural domestic and livestock use, data on historic water levels and measurements are limited. However, interviews with well owners indicate that some of the wells reportedly went dry during the historic droughts of the late 40s and mid-50s (Reeves, 1969). The majority of these wells were shallow dug wells.

**Aquifer Characteristics**

Less data on the aquifer characteristics of the Upper Trinity are available than on the Edwards Aquifer. Typically, wells in the Upper Trinity pump at rates of less than 10 gpm. Specific capacities are probably on the order of 1 gpm/ft.

Reeves (1969) reported that a 60-foot-deep Upper Trinity well produced water at rates of 1,000 gpm and was used to irrigate more than 1,000 acres. However, these rates are inconsistent with the aquifer across the county. The well is completed in one of the porous anhydride zones of the aquifer along Verde Creek. The anamolously high production may be a combination of the porosity and seepage from the creek. Therefore, the yield is not representative of the Upper Glen Rose. Reeves also estimates a 6,000 ac-ft/yr or approximately 3,700 gpm discharge from the Upper Trinity in the form of springs.

**Water Quality**

The Upper Trinity displays the poorest water quality of any of the aquifers in Kerr County. The water in the aquifer is slightly saline. The majority of the dissolved solids are from the dissolution of the gypsum in the aquifer. Reports of high sulfate concentrations in the aquifer are common. Dissolved solids concentrations typically range from 1,000 to 3,000 mg/l, making the water unpalatable for humans, but still potentially usable for livestock or irrigation.

In addition to high sulfates, the water from the Upper Trinity is very hard, as exhibited by calcium and magnesium concentrations in excess of several hundred milligrams per liter. Sodium and chloride concentrations in the aquifer are generally only slightly higher in the Upper Trinity than in the other aquifer. The presence of sodium and chloride further accounts for the high TDS from the dissolution of gypsum and calcite. Because of the low sodium, SAR values are also low, making the irrigation potential better than in most high TDS waters.

## MIDDLE TRINITY AQUIFER

### Distribution

In descending stratigraphic order, the Middle Trinity Aquifer is comprised of the Lower Glen Rose Limestone, the Hensell Sand, and the Cow Creek Limestone. In Kerr County, only the Lower Glen Rose outcrops at the surface. This outcrop occurs in limited areas along the valley walls just west of Comfort (Figure 4-2).

As with most formations in Kerr County, thickness of the units increases downdip away from the Llano uplift. The Middle Trinity ranges in thickness from about 300 feet in the north to just over 400 feet in the southern extremes of the county. In Kerrville, the Middle Trinity averages 300 feet in thickness.

In general, the thickest unit is the Upper Glen Rose, followed by the Hensell Sand and the Cow Creek Limestone. Maximum thicknesses of these units are 210, 155, and 70 feet, respectively.

In Kerr County, the top of the Middle Trinity is encountered at elevations ranging from about 1,525 feet NGVD in the north to about 1,350 NGVD in the extreme southeast. The dip of the unit is very gentle throughout the county, generally about 10 feet per mile.

### Flow Direction and Water Levels

The ground water flow in the Middle Trinity occurs along secondary porosity features and by intergranular flow. Intergranular flow occurs primarily in the Hensell Sand. This unit contains zones of uncemented or unlithified sand grains. Water in these high porosity zones flows through the void spaces between the individual sand grains.

Wells completed in the Middle Trinity encounter artesian or confined conditions. Historic data suggest that water levels in low demand months are on the order of 20 to 50 feet above the top of the unit. Historical data also indicate that water levels have changed with time. In general, water levels in the Middle Trinity have declined due to increasing demand caused by population growth. In the Kerrville area a distinct cone of depression existed. However, these water levels have been rising since the early 1980s due to the construction of the UGRA water treatment plant and the decreased dependency on ground water.

Ground water flow in the Middle Trinity is to the southeast at a hydraulic gradient of 10 to 20 feet/mile or 0.002 to 0.004 ft/ft. A comparison of water level measurements from the winter of 1977-1978 and the winter of 1990-1991 indicates that the overall flow direction has not changed; however, water levels have risen about 30 to 50 feet, and there is no longer a pronounced cone of depression in the Kerrville area.

**Aquifer Characteristics**

Aquifer tests have been conducted on wells and on core samples from the Middle Trinity in Kerr County. Data suggest that the average value of transmissivity in the Middle Trinity is on the order of 1,700 gallons per day, with specific capacities of about 1 gpm/ft of drawdown. Storage coefficients for the unit are $10^{-4}$ to $10^{-6}$.

Individual members of the Middle Trinity have varying aquifer characteristics. In general, the Hensell Sand is the most transmissive unit, followed by the Lower Glen Rose and finally the Cow Creek Limestone. Well yields in the Hensell average about 25 gpm. Distinct values for the Cow Creek are unknown because few, if any, wells are completed solely within the Cow Creek. Well yields from the Lower Glen Rose are generally small. Across the county an average well yield of 15 to 20 would be conservative. Individual well yields, however, have been reported to be as high as 50 gpm.

**Water Quality**

The individual aquifers in the Middle Trinity have variable water quality at each location and at locations throughout the county. The nature of the Cow Creek water quality is unknown because no wells have been recorded as having been completed solely in the Cow Creek.

Several problems exist in acquiring representative water samples from the individual members of the Middle Trinity Aquifer. First, and foremost, is the method of completion of wells in the County. Most of the wells are completed as open-hole wells that connect the Upper and Middle Trinity Aquifers. This has resulted in a mixing of waters in the aquifer. To a lesser extent, there is a natural mixing because there is no definitive confining unit that separates the aquifer. Although natural gradients may minimize mixing, induced gradients caused by heavy pumping may result in downward vertical gradients that will bring water from the Upper Trinity Aquifer into the Middle Trinity Aquifer. The following paragraphs discuss observations found in data from properly completed wells.

Wells completed in the Lower Glen Rose just west of Comfort in easternmost Kerr County exhibited total dissolved solids ranging from 290 to 900 mg/l (Walker, 1979). The majority of the TDS are attributed to calcium and sulfate, chloride, and bicarbonate. Sulfate and chloride concentrations were as high as 209 and 152 mg/l, respectively. The water is hard (total hardness = 275 to 520 mg/l) and slightly alkaline (pH = 7.4 to 7.9).

The Lower Glen Rose has been sampled at a monitoring well adjacent to the UGRA water treatment plant. Water quality in this well was slightly saline (TDS = 895 mg/l). The water is hard and contains abundant sulfate (772 mg/l). Chloride concentrations; however, are relatively low (18 mg/l).

The Hensell Sand exhibits a wide range of water quality in Kerr County. In general, the aquifer produces suitable water for domestic consumption. In northern Kerr County the water quality is characterized by low TDS (less than 300 mg/l), low sulfate and chloride concentrations (27 and 12 mg/l, respectively), and high alkalinity (Ph = 8.5). The predominant constituents in the aquifer are calcium, magnesium, and bicarbonate, all of which are primarily attributable to dissolution of calcite and dolomite.

Downgradient, in the area from Hunt to Kerrville, TDS concentrations increase to about 500 mg/l. However, one well in this location exhibited TDS values of about 1,000 mg/l. The relative percentages of the major ions are similar to those discussed above. The higher concentrations are probably the result from greater mineral dissolution opportunity arising from increased travel time and distance. A few of the Hensell wells in this area that exhibit high TDS also have high sulfate concentrations. These wells may have been affected by downward leaching of Upper Glen Rose waters.

In southeasternmost Kerr County, the Hensell exhibits TDS concentrations in the 600 mg/l range. Here, TDS is predominantly sulfate, calcium, bicarbonate, and, to a lesser extent, magnesium. This characterization of TDS may reflect an increased concentration of gypsum (calcium sulfate) in the area. Sulfate concentrations ranged from 120 to 222 mg/l. Chloride in the water samples were relatively low, ranging from 24 to 25 mg/l.

Because no wells have been completed solely in the Cow Creek layer of the Middle Trinity, water quality is unknown. However, by reviewing its stratigraphic position and mineralogy, an estimation of water quality can be made. The location of the Cow Creek beneath the Hensell indicates that the concentration of sulfate, which is primarily the result of leaching from the Glen Rose units, would be low. The mineralogy of the Cow Creek is primarily calcite, with lesser amounts of dolomite. These mineral assemblages tend to produce hard water. The major ions would probably include bicarbonate, calcium, and magnesium. Sulfate, sodium, and chloride should be present in low concentrations and should not adversely affect water quality.

## LOWER TRINITY AQUIFER

### Distribution

The Lower Trinity Aquifer in Kerr County is comprised of the Sligo Limestone and Hosston Sand. Neither of the members outcrops within Kerr County. The Hosston is probably present in the subsurface at all locations within Kerr County, as the Sligo member pinches out in the northern portions of Kerr County. The Hammett Shale is also believed to pinch out just west of Hunt and in the northern portion of the county.

The Lower Trinity is the most productive aquifer in Kerr County. The Hammett Shale is an aquitard or water bearing layer with very low permeability that yields little or no well water. The importance of the Hammett Shale is the establishment of a confining bed above the Lower Trinity that helps maintain artesian heads in the aquifer and prevents mixing with the upper formations. In the northwest portion of the County where the Hammett Shale does not exist, mixing between the Lower Trinity and Middle Trinity does occur. The extent of this interaction is undefined.

The Pine Island ranges in thicknesses from zero feet at its edges to 50 feet in the southeastern portions of the county. The Hosston and Sligo were deposited on an erosional surface above the pre-Cretaceous rocks. This erosional surface generally dips to the south and southwest at about 10 to 20 feet per mile. The top of the Lower Trinity dips at a rate of 10 to 40 feet per mile. The steepest dips are within and just east of Kerrville.

The top of the Lower Trinity ranges in elevation from just 1,300 feet NGVD along Texas Highway 16 at the Kerr-Gillespie county line to about 900 feet NGVD at the Kendall, Bandera, and Kerr County junction. Depths of the unit are highly variable throughout the county. The unit is shallowest along the Guadalupe River between Kerrville and Comfort. Here, it is within 450 feet of the ground surface. In the southwest portion of the county, the depth to the top of the unit exceeds 1,350 feet.

**Flow Direction and Water Levels**

Data on flow directions and water levels are limited to eastern Kerr County. Few wells penetrate the formation in western Kerr County for several reasons. In the west, the unit is at greater depths. In these locations, the population and water demands are lower; therefore, these needs can be met by the shallower Hensell formation.

Historically, flow directions in Kerr County are towards the south, with a slight westerly flow component. This westerly component is probably the result of pumping within the City of Kerrville. Figure 4-4 is a flow diagram with data from February 1991. As shown in this figure, ground water flow is to the south through the Kerrville area. Ground water gradients are steepest within the city (up to 35 feet per mile) and decline to less than 10 feet per mile south of the city.

Historical water level changes are a direct result of ground water use patterns. Data from the mid 1940s indicate that the ground water elevations were about 1,560 feet NGVD in the center of Kerrville. These water levels declined until the UGRA water treatment plant was constructed. Just prior to the startup of the plant, water levels in the center of the city were approximately 1,350 feet NGVD. Following 10 years of surface water use with less ground water use, water levels have started to rise. These levels in non-pumping seasons (February 1991) are now approximately 1,500 feet NGVD, or within 50 feet of their 1945 levels.

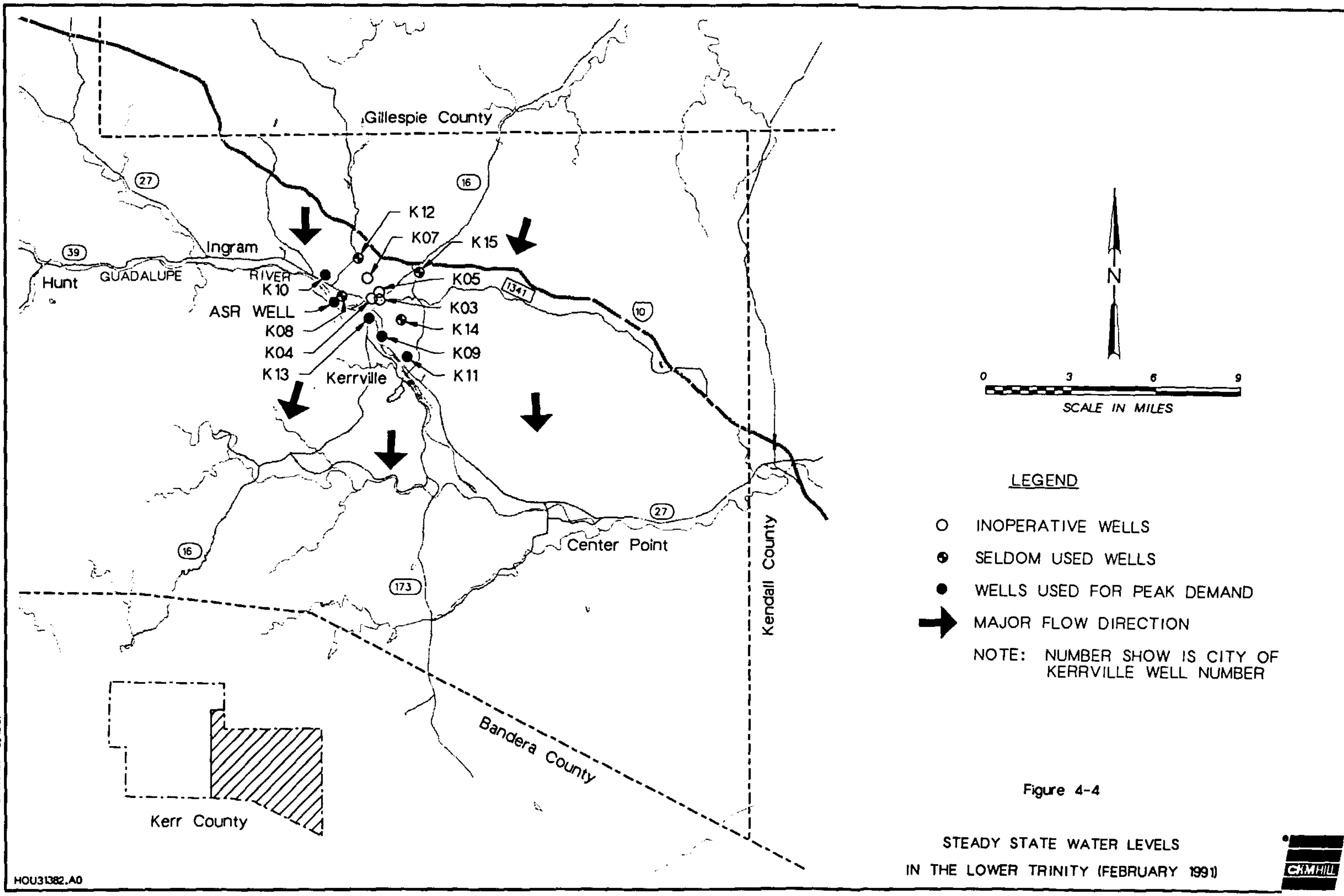


Figure 4-4

STEADY STATE WATER LEVELS
IN THE LOWER TRINITY (FEBRUARY 1991)

Ground water pumping rates in the city gradually increased over the historic record to the time the WTP was put into use. In the mid-40s the average annual pumping rate was just below 1 mgd. In the mid-50s this rate increased to about 2 mgd. By 1980, ground water use exceeded 2.5 mgd.

Currently, the city owns 13 completed wells in the Lower Trinity as indicated in Figure 4-4. In addition to the 13 wells shown in Figure 4-4, the UGRA has installed one Aquifer Storage and Recovery (ASR) well, which is designed to recharge water into the aquifer for storage and subsequently recover this water through the same dual-function well. This would allow the UGRA to store surplus treated water and recover it later to meet peak demands without stressing the Lower Trinity and causing water levels to decline significantly.

**Aquifer Characteristics**

Because of its importance to the City of Kerrville, the Lower Trinity has received more attention than any other aquifer in the county. Abundant aquifer tests have been conducted and a computer model of the ground water flow conditions has been developed for the Kerrville area.

The Lower Trinity displays variable aquifer characteristics. In the Kerrville area, transmissivity has ranged from about 1,500 gdf to almost 30,000 gdf. The highly transmissive zones are in the central portion of the city and follow a narrow trend with a bearing that follows the Guadalupe River. These zones may be the result of fracturing within the unit, as is suggested by the linear trend of the zone and the similar trend of surface lineaments in the area.

Further to the east and south, however, the Lower Trinity increases in thickness and the transmissivity decreases. The decrease in transmissivity is assumed to be a decrease in the interconnected pore spaces caused by fewer joints or possibly cementation by ground water fluids.

Storage coefficients have been calculated from pump tests. These range from about $7 \times 10^{-4}$ to $1 \times 10^{-5}$. The weighted average throughout the Kerrville area is about $7 \times 10^{-5}$.

Specific capacities have been determined for numerous city wells. These range from less than 1 gpm/ft of drawdown near the airport to about 20 gpm/ft of drawdown in the center of the city. An average across the area would be 10 gpm/ft of drawdown. The specific capacity in a well is enhanced by acidization of the well. Increases of about 300 percent are common after hydrochloric acid has been added to the well and allowed to react with the calcite and limestone in the Hosston and Sligo components of the Lower Trinity.

Pumping rates are a function of the transmissivity of the aquifer and the capacity of the pump in the well. Within the city and in the high transmissivity zones, pumping rates in excess of 1,000 gallons per day can be achieved and maintained for months at a time. For example, City of Kerrville Well No. 11 (Figure 4-4) has produced at rates of more than 1.5 mgd for several months during the summer. Pumping rates to the east, near the airport, are less than 100 gpm. North of the city, where the aquifer thins, the pumping rates are on the order of 100 to 200 gpm (i.e., City of Kerrville Well No. 15).

**Water Quality**

Well water from the Kerrville municipal wells is of good quality. It has a fairly high total dissolved solids content of 500 to 700 mg/l, but the concentrations are under the limit of 1,000 mg/l set by the Texas Department of Health. Calcium carbonate hardness (as $CaCO_3$) values of 270 to 380 mg/l put the water in the "very hard" category, which is anything greater than 180 mg/l. Iron concentrations from specific wells have exceeded the 0.3 mg/l limit, but the water from a combination of wells has been well below the limit in the few sample results that were reviewed. Analyses of water quality taken from individual well tests dated 1966 to 1973 are shown in Table 4-2. More recent test results (1983 to 1991) of Kerrville wells and the ASR well indicate similar or better quality.

Water quality samples from Hosston-Sligo wells east of the city exhibit water quality that is poorer than that of the city wells. Hosston-Sligo wells in the Cypress Creek area are characterized by higher TDS values (700 to 900 mg/l). These wells contain four to five times the amount of chloride (up to 200 mg/l) and more than twice as much sulfate (up to 220 mg/l). The reason for the poor water quality in this area is unknown. The water quality is similar to that of the Lower Glen Rose in the area and may suggest poorly completed wells.

## GROUND WATER DEVELOPMENT POTENTIAL AND AQUIFER CRITICALITY

The ground water supply potential of an area depends on several important factors. These include ground water recharge to the area, storage potential within the aquifer, and the ability of the aquifer to release the water. The recharge volume can be calculated by determining the percent of infiltration and the amount of precipitation. Additional recharge may also come from interaquifer flow and stream losses.

Storage potential is calculated from the storage coefficients, water levels, and area and thickness of the aquifer. This information is available from pump tests and historical data. Estimates can be made by understanding the hydrogeology and comparing that with data from similar aquifers.

Although an area may have sufficient storage, the aquifer characteristics may not be favorable to release the water at required rates. Transmissivity data can be used to

## Table 4-2
## Quality of Kerrville Well Water

| Constituent | Concentration Range, in mg/l | Texas Department of Health Limits |
| --- | --- | --- |
| pH | 7.3 to 8.0 | >7.0[a] |
| Total dissolved solids | 540 to 710 | 1,000 |
| Total hardness as $CaCO_3$ | 312 to 445 | None (water is very hard) |
| Bicarbonate | 354 to 382 | None |
| Calcium | 60 to 97 | None |
| Chloride | 13 to 109 | 300[a] |
| Fluoride | 0.9 to 1.5 | 1.6 for air temperature of 71° to 79° |
| Magnesium | 37 to 56 | None |
| Nitrate (as N) | <0.4 | 10 |
| Sodium | 12 to 34 | None |
| Sulfate | 27 to 92 | 300[a] |
| Arsenic | <0.01 | 0.05 |
| Barium | <0.5 | 1.0 |
| Cadmium | <0.005 | 0.01 |
| Chromium | <0.02 | 0.05 |
| Copper | <0.02 | 1.0[a] |
| Iron | 0.06 to 1.15 | 0.03[a] |
| Lead | <0.02 | 0.05 |
| Manganese | <0.05 | 0.05[a] |
| Mercury | <0.0002 | 0.002 |
| Selenium | <0.002 | 0.01 |
| Silver | <0.01 | 0.05 |
| Zinc | 0.02 | 5.0[a] |

[a]These are "secondary standards" related to aesthetics and taste, but not to health risks.

Source of Data: 17 samples were taken from 13 individual City of Kerrville wells by Texas Department of Health between 1963 and 1973. Quoted from Report on Groundwater Conditions in the Kerrville Area, William F. Guyton & Associates, December 1973 with TDH limits adjusted to current requirements. Heavy metals concentrations are for a sample taken from the distribution system on November 12, 1985, by the Texas Department of Health. Well water constituted about 60 percent of the supply that day.

determine the ability of the aquifer to release ground water. Transmissivity data can also be obtained from pump tests or estimated from a knowledge of the hydrogeologic regime.

Aquifer "criticality" refers to the current condition of the aquifer and how it may relate to possible critical area designation. Although Kerr County is in the Hill Country Critical area, this designation is the result of a study on several aquifers in many counties. The following subsections will address the state of "criticality" for each aquifer based on current data.

**EDWARDS AQUIFER**

Recharge to the Edwards from precipitation has been estimated to be about 1 inch per year, or approximately 44,000 ac-ft/yr. Upland stream discharge has been calculated to be approximately 52,000 ac-ft/yr. Ground water pumpage is approximately 1,000 ac-ft/yr. Additional ground water discharge occurs through evaportranspiration and discharge to stream alluvium. The extra 9,000 ac-ft/yr is attributable to ground water flow within the aquifer from sources outside the county. Historic data indicate that water levels have changed very little in the more than 40 year recording period. This indicates that present use does not exceed the ground water flux.

The water in storage in the Edwards can be estimated. In Kerr County, unconfined conditions predominantly occur in the Edwards. A conservative estimate of storativity for this type of aquifer is about 0.03. The average saturated thickness throughout the area is estimated to be approximately 25 feet. Using a conservative drawdown of 50 percent, the amount of water in storage is approximately 200,000 ac-ft.

Although 200,000 ac-ft of water is estimated to be available from storage, another 53,000 ac-ft (32,900 gpm) discharges annually from the Edwards. The water in storage is not readily available due to the low transmissivities (less than 2,000 gdf). Calculations based on average pumping rates of 5 to 10 gpm indicate that well spacing should be no more than one per acre. These rates and spacing would prevent excessive drawdown in the typical Edwards well in the Hill Country.

Full development of the aquifer at these pumping rates and well spacings would exceed the aquifer flux and cause gradual lowering of the water table across the county. The aquifer flux or yield has been determined to be 53,000 ac-ft/yr for the Edwards. Pumping at rates in excess of the current 1,000 ac-ft/yr will reduce the amount of water discharged from springs. These springs, because they feed the Guadalupe River, are important to maintain the flow rates in the river. Decreased springflow will impact the UGRA's water treatment plant diversions during periods when springflow is the main component of river flow. Therefore, the maximum average sustained use without adversely affecting spring flow is estimated at or slightly greater than the present 1,000 ac-ft/yr.

The Edwards Aquifer in Kerr County cannot be considered to be in a critical status. Water levels have not been dropping nor did many wells dry up during the historic drought of the 50s. Furthermore, the current use of the Edwards does not exceed the estimated recharge.

**UPPER TRINITY AQUIFER**

Recharge to the Upper Trinity Aquifer from precipitation is approximately 1 inch per year. Over the 250 square miles of outcrop, this amounts to about 14,700 ac-ft of recharge per year. Upland spring discharges have been estimated to be 6,000 ac-ft/yr. Additional water is withdrawn from wells, but estimates of total volume are unavailable. Other sources of discharge from the aquifer are evapotranspiration and subsurface discharge to river alluvium. Data on these discharges are available and beyond the scope of this study. A conservative estimate is that the difference between use and recharge is probably at least 6,000 ac-ft/yr. Because water levels are not rising, this water is leaving the county through flow within the aquifer or is leaking to the underlying Middle Trinity Aquifer through poorly constructed wells or natural pathways between the water bearing strata.

A safe yield for the Upper Trinity would be equal to the recharge--14,700 ac-ft/yr, or an average of 9,100 gpm. This value is probably a conservative estimate because ground water flow also enters the county in this aquifer from upgradient regions. The maximum sustained use of the Upper Trinity is limited because of water quality and will probably remain at or near the current estimated use of 500 ac-ft/yr.

Estimates of storage can also be made for the Upper Trinity Aquifer. Confined and semiconfined conditions are present in the aquifer. Storage coefficients are probably lower than those in the Edwards. An estimate of 0.0001 is conservative. Most wells in the area have about 50 feet of water in the casing. Using these values and a conservative drawdown (50 percent across the county) an estimate of water in storage could be made. Since the formation is present over about 95 percent of the county, the volume in storage is estimated to be about 12,500 ac-ft.

Water level declines for the Upper Trinity Aquifer have been reported in the Hill Country area. The findings of the Critical Area Advisory Committee indicated that the maximum declines from 1977 to 1987 were on the order of 15 feet. However, water level measurements by UGRA staff indicate that these water level declines are not typical in Kerr County. Rather, the water levels have stayed about the same over the time from 1977 to 1991.

**MIDDLE TRINITY AQUIFER**

Because the Middle Trinity almost exclusively outcrops outside of Kerr County, the estimate of recharge from precipitation cannot be calculated as easily as for the Edwards and Upper Trinity Aquifers. Instead, a safe yield can be estimated by calculating current ground water flow through the area with Darcy's Law:

$Q = TiL$ 

$Q$ = flow volume ($ft^3$/day)
$T$ = transmissivity ($ft^3$/day/ft)
$i$ = gradient (ft/ft)
$W$ = width (ft)

February 1991 water levels were used to determine hydraulic gradient. The hydraulic gradient southeast of Kerrville is approximately 0.0022 ft/ft. Data from the TWDB and recent UGRA pump tests indicate that the average transmissivity for the Middle Trinity is 3,100 gdf or 414 $ft^3$/d/ft in this area. The cross-sectional flow distance is about 24 miles. Solving for Q results in a flow volume of about 970 ac-ft/yr. From the limited data, a range of 500 to 1,500 would be a good estimate of flux through the area east of Kerrville. The maximum sustained use of the aquifer is estimated at 1,000 ac-ft/yr.

The critical Area Advisory Committee reported that water level declines in the Middle Trinity aquifer were significant. Water level declines of close to 100 feet have been reported in the eastern portions of Kerr County near Comfort from 1947 to 1987. Water levels have declined more than 50 feet in the Kerrville area over this same period. Water level measurements taken by UGRA in early 1991 indicate that water levels have risen nearly 50 feet from the 1987 levels, indicating that demand does not exceed the ground water flux. However, with continued growth in the Kerrville area and increasing demand on the Middle Trinity aquifer, significant water level declines may occur in the future, especially under drought conditions such as those occurring during the 1950's.

An initial evaluation of the Middle Trinity with respect to ASR potential indicates that ASR is possible, but recharge and recovery rates would be significantly lower than those experienced in the Lower Trinity. The recharge and recovery rates could be enhanced by acidizing the formations in the Middle Trinity, which would increase the transmissivity in the Cow Creek Limestone near the ASR well. ASR projects are being successfully implemented in aquifers with transmissivities similar to those found in the Middle Trinity.

**LOWER TRINITY AQUIFER**

The majority of information on the availability of ground water in the Lower Trinity aquifer was developed or confirmed through the recent ASR study by the UGRA. From this study a ground water model was developed to model the flow for a major portion of the developed aquifer. Using this model, ground water flows, safe yields, and responses to pumping were determined.

The TWDB has estimated the safe yield to be 560 ac-ft/yr. This is also considered as the maximum sustained use of the aquifer. Based on the ASR ground water model results, flow through the section of the aquifer from Ingram through Kerrville to the Kerrville airport was calculated to be approximately 600 ac-ft/yr. This flux or safe yield is considered conservative or less than the actual safe yield because it was estimated using steady state conditions (i.e. only present static water levels were considered in the calculations and this does not accurately reflect the recovery experienced since 1981). The aquifer may still be rebounding from the effects of previous over-pumping, which indicates the safe yield could be greater than 600 ac-ft/yr. For the purposes of this study, we have considered the maximum sustained use of the aquifer to be 560 ac-ft/yr.

The water conditions in the Lower Trinity Aquifer was one of the main reasons for establishing a Critical Area in the Hill Country. The Critical Area Advisory Committee reported water level declines in excess of 200 feet at Kerrville. However, since the start of operation of the UGRA water treatment plant in 1981, water levels have been recovering. It is estimated that these levels are still at least 50 feet lower than they were in the late 1940s.

Although water levels are recovering, the critical status of the Lower Trinity is still a concern. Continued growth of Kerrville will cause increased demands on the aquifer and a gradual lowering of the aquifer water levels. Computer modeling of the aquifer using 1950's drought demands reveals that water levels may drop in excess of 250 feet. This may result in a condition where ground water levels drop to elevations below the operational settings of the City pumps and in portions of the City may cause the level to fall below the base of the Hammett Shale and result in partially unconfined conditions, or the aquifer is partially dewatered. To prevent this potential, UGRA will continue to investigate and consider ASR as a method to manage the aquifer in case of drought and maintain water levels within the City above the base of the Hammett Shale. The UGRA will continue to seek increased surface water diversion rights and recharge excess treated water in order to maintain present water levels and to avoid a critical ground water condition. This conjunctive management approach is described in more detail in Section 5.

## SUMMARY AND CONCLUSIONS

Ground water is present in four aquifers in Kerr County. These are:

- Edwards Aquifer
- Upper Trinity Aquifer
- Middle Trinity Aquifer
- Lower Trinity Aquifer

The approximate annual recharge, estimated safe yield, and qualitative description of water quality are given in Table 4-3 below:

**Table 4-3**
**Aquifer Characteristics**

| Aquifer | Approximate Annual Recharge (ac-ft/yr) | Estimated Safe Yield (ac/ft/yr) | Water Quality |
|---|---|---|---|
| Edwards | 44,000 | 53,000 | Good but very hard |
| Upper Trinity | 14,700 | 14,700 | Poor<br>Slightly Saline[a]<br>High Sulfate |
| Middle Trinity | Not available | 1,000 | Good to Fair<br>Salinity<br>Hardness |
| Lower Trinity | Not available | 560 | Good but very hard |

[a]Salinity is not the result of sodium and water is suitable for irrigation.

Based on the estimated safe yield of the four aquifers in Kerr County, it would appear that the total ground water available is 69,260 ac-ft/yr. This is not the case. Table 4-4 below provides aquifer use information which is essential to understanding the limitations of the ground water supply in Kerr County.

**Table 4-4**
**Aquifer Use Information**

| Aquifer | Typical Use | Area of Use | Maximum Sustained Use (ac-ft/yr) | Comments |
|---|---|---|---|---|
| Edwards | Residential<br>Agricultural | West Kerr County | 1,000 | Maximum sustained use could be increased slightly if well spacing is limited. |
| Upper Trinity | Agricultural | North and West Kerr County | 500 | Quality limits maximum use to current estimated use. |
| Middle Trinity | Municipal<br>Agricultural | Central and Southeast Kerr County, outside of Kerrville | 1,000 | Some wells yield both from the Upper and Middle Trinity giving the appearance of a greater maximum sustained use. |

**Table 4-4**
**Aquifer Use Information**

| Aquifer | Typical Use | Area of Use | Maximum Sustained Use (ac-ft/yr) | Comments |
|---|---|---|---|---|
| Lower Trinity | Municipal/ Industrial | City of Kerrville | 560 | Current use varies depending on aquifer use to meet peak demands. |

The total maximum sustained use of ground water in Kerr County is estimated to be 3,060 ac-ft/yr or slightly greater depending on additional use from the Edwards aquifer. Further evaluation of the Middle and Lower Trinity aquifers, which provide the majority of the municipal water supply, is presented in Section 5 in a discussion of water resource management options.

## Section 5
# WATER RESOURCE MANAGEMENT OPTIONS

## Section 5
# WATER RESOURCE MANAGEMENT OPTIONS

## INTRODUCTION

The purpose of this section of the report is to present options for managing the available water resources, in order to establish a basis for the formulation of water supply alternatives. Three key management options considered were:

- Role of Water Reuse
- Role of ASR in the City of Kerrville
- Role of Conjunctive Management in Kerr County

## ROLE OF WATER REUSE

The City of Kerrville currently discharges about 2.0 mgd (2,240 ac-ft/yr) of highly treated wastewater to the Guadalupe River. This is expected to increase to approximately 5.2 mgd (5,824 ac-ft/yr in 2040. Studies (EHA, 1988) have indicated that water quality in Flat Rock Lake is potentially adversely affected when wastewater discharges exceed 4.0 mgd at current water quality limits and the flow in the river is 15 cfs or less. Wastewater discharges can be maintained at less than 4.0 mgd if at least 1.2 mgd (1,344 ac-ft/yr) is reused and not discharged to the river, or the wastewater treatment plant is upgraded to improve its phosphorous removal capability.

The following paragraphs discuss the potential for use of reclaimed water in Kerr County, by considering the quantity and quality of reclaimed water available for reuse, identifying public lands that may be available for irrigation with reclaimed water, and identifying agricultural consumptive uses currently relying on ground water that may be replaced with reuse. The complications of using bed and banks for transport to agricultural users will be addressed as well as the option of piping reclaimed water to the end users. The present quality of reclaimed water and the need for improving quality to meet various demands will be considered.

## SOURCES OF RECLAIMED WATER

### *Existing Sources*

The City of Kerrville operates a wastewater treatment plant which serves the City of Kerrville. The plant effluent (reclaimed water) is discharged into Third Creek which enters Flat Rock Lake approximately 4,000 feet upstream of Flat Rock Dam. The plant has a peak daily treatment capacity of 3.5 mgd and has experienced average daily discharges of 2.0 mgd (EHA, 1988). At the present average daily discharge of 2.0 mgd the plant could provide 2,240 ac-ft/yr of reclaimed water for reuse. The design average daily treatment capacity is 2.7 mgd. This could provide 3,025 ac-ft/yr of reclaimed water when the plant is operating at capacity. The discharge permit for the plant has effluent limits of 5 mg/l $BOD_5$, 5 mg/l TSS, 2 mg/l $NH_3$-N, and 1 mg/l P when flows in the Guadalupe River are greater than 50 cfs. The effluent limits for $NH_3$-N and P are reduced to 1 mg/l $NH_3$-N and 0.5 mg/l P when flows in the Guadalupe River are equal to or less than 50 cfs.

James Avery Craftsman, Inc., operates a treatment plant with a peak daily treatment capacity of 5,000 gallons per day. The effluent is stored in holding ponds and irrigated on pastureland.

Presbyterian Mo-Ranch Assembly operates a treatment plant with a peak daily treatment capacity of 5,000 gallons per day.

These two treatment plants were not considered for regional reuse supplies but onsite reuse is occurring with one system and onsite reuse would be the most viable option for the other.

### *Future Sources*

Increased supplies of reclaimed water will be available from the Kerrville wastewater treatment plant as the City of Kerrville grows. However, when return flows to the Guadalupe River exceed 4 mgd, water quality and nuisance algal problems could occur in the Guadalupe River and Flat Rock Lake even with an instream flow requirement of 15 cfs (EHA, 1991) through the UGRA diversion dam. Based on approximately 63.8 percent (present wastewater discharge/water demand) of the water used in Kerrville being discharged to the river, the 2040 return flow will be about 5.2 mgd. Approximately 1.2 mgd (1,344 ac-ft/yr) will need to be reused directly (i.e., never discharged to the river) in order to maintain a maximum 4.0-mgd discharge, or as stated previously, wastewater plant improvements would be required in order to reduce the quantity of phosphorous discharged to the river.

## USES OF RECLAIMED WATER

### *Irrigation of Agricultural Land*

The 1989 irrigation inventory of Kerr County by the Soil Conservation Service reported that there were 474 acres irrigated with surface water and 89 acres irrigated with ground water. Reclaimed water could be used to replace ground water for irrigation and to bring new irrigated acres into production. The 89 acres irrigated with ground water consisted of 66 acres of apple orchards near Kerrville close to the Guadalupe River, 10 acres of pecans near Cypress Creek and 13 acres of pecans near Camp Verde. The only acreage close enough to the supply of reclaimed water is the 66 acre apple orchard near Kerrville (Figure 5-1).

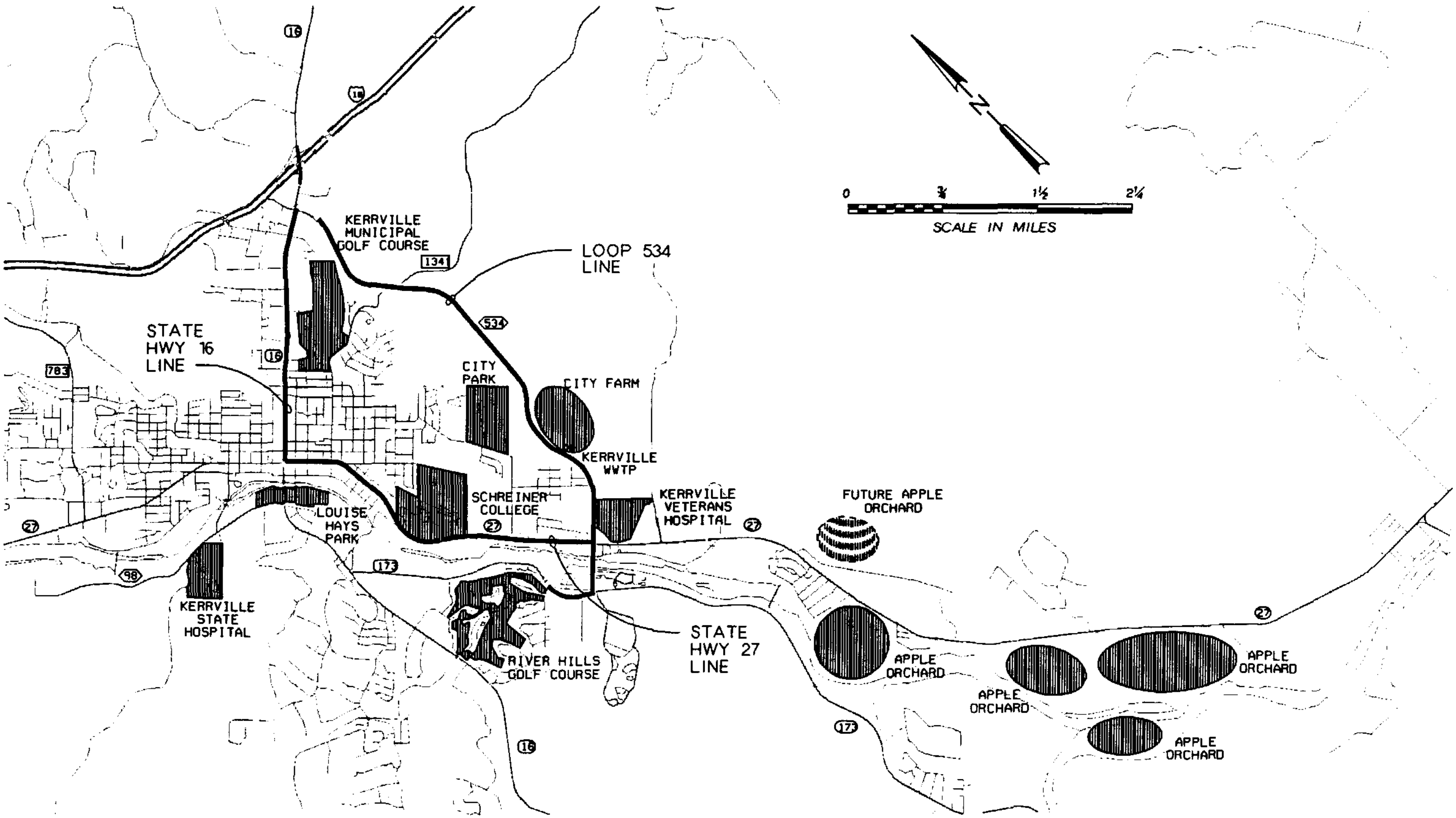


Figure 5-1

POTENTIAL IRRIGATION USES AND PROPOSED DISTRIBUTION LOOP FOR RECLAIMED WATER

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Since the completion of the 1989 irrigation inventory the operator of the 66 acre apple orchard, Shelton Ranch Corporation - Hill County Orchards, has expanded the acreage significantly. There are presently 750 acres of apples planted with approximately 350,000 trees. The orchard is planned for 375,000 trees. The trees are not all in production and are not all presently irrigated. The apples are irrigated using surface water from the Guadalupe River and ground water from four wells. The staff of Hill Country Orchards estimates that they will actually apply about 12 inches of water per acre or 800 ac-ft/yr. The actual consumptive use of the apple trees is greater than 12 inches per acre and a portion of the water will be supplied by rainfall. In dry years, supplemental irrigation could increase fairly dramatically to maintain production.

Shelton Ranch Corporation has two permits from the Texas Water Commission (TWC) to divert 470 ac-ft/yr and 188 ac-ft/yr from the Guadalupe River. Shelton Ranch Corporation has a subordination agreement with the Guadalupe-Blanco River Authority for 600 ac-ft/yr and is applying for a TWC permit to divert the water. These permits are subject to a 25 cfs instream flow requirement which means that the Ranch cannot divert out of the river when the flow remaining in the river would be less than 25 cfs. The total amount of water included in the existing permits and permit application is 1,258 ac-ft/yr. Reclaimed water could be used to supply irrigation water to the ranch and provide a measure of drought protection when the flow in the river is less than 25 cfs. The ranch has indicated they would be interested in using reclaimed water for irrigation if it can be delivered at a reasonable cost.

Production of hay and forage crop are other uses for reclaimed water. However, if water cannot be transported inexpensively such as by bed and banks, or the water source is very close to the point of use, it is not economical to apply reclaimed water to these crops. Since bed and banks transfer is not likely to be permitted by the TWC, the land close to the source of water is the only viable alternative. The City of Kerrville used to land apply the effluent from the wastewater treatment plant before the recent expansion and upgrade of the plant. The City has 96 acres of land that could be used to grow hay or forage crops. Reclaimed water could be applied to this land by the City or it could be leased out to a private operator. Potential water use would be 424 ac-ft/yr.

### *Public Land*

The City of Kerrville owns and operates several city parks and one golf course. These facilities have varying degrees of need for irrigation water which could be supplied by reclaimed water (Figure 5-1). The golf course encompasses 240 acres of which 160 acres is irrigated. The City has two other parks that have significant acreage, Louise Hays Park (45.5 acres) and Singing Winds Park (100 acres). Singing Winds Park presently has 20 acres developed and 80 acres undeveloped. The City has 24 small parks ranging in size from a fraction of an acre to 7 acres. The larger parks and golf course could be considered for installation of conveyance piping to deliver water to each facility. The smaller parks would be economical to serve with reclaimed water only if they were adjacent to the conveyance line to the larger parks or if a city-wide dual distribution system was in place.

There are several other institutions or entities that could be potential customers of reclaimed water. They are Schreiner College, Veterans Administration Hospital, Kerrville State Hospital, public school district facilities and the Riverhill Club golf course. Schreiner College, the Veterans Administration and the Riverhill Club golf course have potentially large enough demands to install a dedicated conveyance system however, the state hospital and public school facilities would be served if a city-wide dual distribution system were installed. Table 5-1 lists the public facilities that could utilize reclaimed water for irrigation.

**Table 5-1**
**Potential Public Facilities to**
**Use Reclaimed Water for Irrigation**

| Park | Area Acres | Consumptive Use (ac-ft/yr) | Distribution Loop Segment |
|---|---|---|---|
| Municipal Golf Course | 160.0 | 400.0 | Loop 534 line |
| Louise Hays Park | 45.5 | 200.0 | S.H. 27 line |
| Singing Winds (Full Devl) | 60.0 | 265.0 | Loop 534 line |
| Minor Parks (Cumulative) | 60.0 | 265.0 | N/A |
| Schreiner College | 50.0 | 220.0 | S.H. 27 line |
| Veterans Admin. Hospital | 10.0 | 45.0 | Loop 534 line |
| Riverhills Golf Course | 150.0 | 660.0 | Loop 534 line |
| Total | 535.5 | 2,055.0 | |

The City of Kerrville is planning a 12-inch potable water line along Loop 534 from S.H. 16 to S.H. 173 on the southeast side of the city. The City is also exploring the possibility of obtaining Texas Water Development Board (TWDB) funding to install a parallel reclaimed water pipeline to serve the municipal golf course, the Riverhill golf course and the public school district athletic fields as shown in Figure 5-1. The Veterans Administration Hospital and Singing Winds Park would also be adjacent to this line.

Louise Hays Park at S.H. 16 and the Guadalupe River could be served by a distribution line that would be installed in the right-of-way of S.H. 27 from S.H. 173 to S.H. 16 (Figure 5-1). This proposed line could also serve Schreiner College.

A distribution line could be installed in the S.H. 16 right-of-way from S.H. 27 to Loop 534. This line would create a main distribution loop for reclaimed water in Kerrville. is loop could be installed in phases as part of a master plan to develop a dual distribution system for reclaimed water in Kerrville. Smaller users of reclaimed water could be connected to the proposed loop as the plan is implemented. Table 5-1 includes the distribution loop segments that would provide water to each major public facility.

### *Dual Distribution System*

The ultimate water reuse option would provide reclaimed water for lawn irrigation to the City's residents and businesses. This would require installation of a reclaimed water distribution system alongside the existing potable water system. It is not usually cost effective or practical to retrofit a dual-distribution system to a developed area except under extreme conditions.

### *Water Diversion Credits*

The Upper Guadalupe River Authority has studied the possibility of having the City of Kerrville wastewater treatment plant return flow credited against the diversion by UGRA for the water treatment plant. For example, only the difference between UGRA diversions and the City of Kerrville return flows would be counted as an actual diversion against UGRA's TWC permit. The Kerrville wastewater treatment plant did not discharge into the Guadalupe River until 1986 even though UGRA began selling treated surface water to Kerrville in 1981. For about 5 years, surface water was diverted from the river with no return flow. Initial discussion with TWC staff and prior TWC rulings indicate the credit system would not be allowed.

### *Water Quality*

The discharge permit for the plant has effluent limits of 5 mg/l $BOD_5$, 5 mg/l TSS, 2 mg/l $NH_3$-N, and 1 mg/l P when flows in the Guadalupe River are greater than 50 cfs. The effluent limits for $NH_3$-N and P are reduced to 1 mg/l $NH_3$-N and 0.5 mg/l P when flows in the Guadalupe River are equal to or less than 50 cfs. These permit limits more than meet the TWC limits for use of reclaimed water for irrigation of food crops, irrigation of pastures for animals milked for human consumption and irrigation of landscaped areas without any further treatment. Proper care should be given to adequate disinfection of the reclaimed water. Irrigation of landscaped areas is divided into unrestricted and restricted areas. The requirements for irrigation of unrestricted landscaped areas equal the currently permitted $BOD_5$ limit of 5 mg/l. If the plant effluent meets its current discharge permit conditions it can be used for any reuse application without further treatment other than proper disinfection.

### *Summary of Potential Uses*

The potential uses and costs of reclaimed water are shown on Table 5-2.

**Table 5-2**
**Summary of Potential Uses of Reclaimed Water**

| Potential Use | Amount, ac-ft/yr |
|---|---|
| Public Facilities | 2,365 |
| Agricultural | |
| Orchards | 3,620 |
| City Farm | 424 |

The agricultural uses are probably the least costly on an acre-foot basis. These potential uses should be investigated first. Shelton Ranch Corporation has indicated they would be interested in using reclaimed water and they should be contacted. Use of reclaimed water at the City Farm should also be investigated, since this use would have a low cost per acre-foot.

The use of reclaimed water on public facilities should be studied in more detail to develop costs and additional water demand data. The proposed distribution loop could be constructed in phases as potential customers are served. The initial phase should be the Loop 534 line and a first phase of the pump station. The S.H. 27 line would be next with an expansion of the pump station. The S.H. 16 line should be constructed when there are potential customers to be served off of this line or if looping the system would increase operational reliability.

A complete dual distribution system should be installed only after the system loop is installed and economic and institutional conditions warrant.

## ROLE OF ASR IN THE CITY OF KERRVILLE

The water demand of the City of Kerrville represents approximately 60 percent the total county municipal water demand. The City's actions have a significant effect on water availability in the county. Since 1988 the UGRA has conducted engineering studies to develop long term strategies for meeting anticipated water demands for the city of Kerrville. These studies have been completed and a plan adopted which envisions future water demands be met with a combination of treated Guadalupe River water from the UGRA's treatment plant, ground water from the City of Kerrville's wells and stored ground water from the City's ASR well system. This combination of facilities will be capable of meeting anticipated 2040 water demands through a recurrence of the 1950's drought of record.

The UGRA currently operates a 5 mgd surface water treatment plant. All treated water is pumped to the city of Kerrville for storage and distribution. The plant currently operates at or near its permitted diversion rate of 3,603 ac-ft/yr. Additional supplies will be needed to meet the anticipated water demands from the City. The existing diversion rate limits the annual plant production to approximately 3.2 mgd.

The City of Kerrville operates 11 wells which are used to meet peak water demands. Well production is limited to an average annual production rate of 0.5 mgd. All wells are completed in the Lower Trinity although some are completed in both the Lower and Middle Trinity formations. Hydrogeological studies of the Lower Trinity suggest a safe yield of 560 ac-ft/yr.

## METHODOLOGY AND RESULTS

ASR's role in meeting the anticipated demands has been evaluated in a series of engineering studies conducted by the UGRA. These studies have addressed issues such as acquiring additional water rights from the Guadalupe river, off-channel reservoir sizing and siting studies, and feasibility studies for ASR. These studies can be summarized as follows:

- **Upper Guadalupe River Basin Water Supply Project,** Espey Huston and Associates, October 1981. This study developed a model and strategy for acquiring additional water rights while meeting flow through restrictions. Established that an off-channel reservoir of approximately 18,000 ac-ft will be required to meet drought demands and downstream flow through requirements. This study has subsequently been modified to include consideration of ASR and used as supporting information for the current application to the TWC for 4,760 ac-ft/yr of subordinated surface water rights.

- **ASR Feasibility Investigation: Preliminary Assessment,** CH2M HILL, April 1988. This study included a literature review and engineering assessment of the feasibility of ASR. Results, favorable to ASR, recommended proceeding with drilling a test well and geochemical modelling to check compatibility of the aquifer with injected surface water.

- **ASR Feasibility Investigation: Monitor Well Construction,** CH2M HILL, December 1989. A monitor well was completed to confirm subsurface geology and hydrogeology. Geochemical modelling was completed. The results indicated conditions were favorable for ASR and recommended proceeding with construction of a full-scale ASR production well.

- **ASR Feasibility Investigation: Demonstration and Evaluation,** CH2M HILL, December 1991 (work in progress). This project involves construction and testing of a 1 mgd ASR well. The feasibility of ASR has been demonstrated and the storage capabilities of the aquifer have been established. A hydrogeologic model of the Lower Trinity in the vicinity of Kerrville was developed and used to quantify the operational characteristics of an ASR system. The model also demonstrated that drought demands could be met without an off-channel reservoir by using ASR in conjunction with existing wells.

## CONCLUSION

Meeting the future water demands for the City of Kerrville will require a combination of additional surface water rights (1,997 ac-ft/yr) from the Guadalupe river to allow the plant to operate at its maximum production rate of 5 mgd, rehabilitation of the City of Kerrville's well field, and operation of two 1-mgd ASR wells. As shown below, a combination of ground water firm yield plus 5 mgd of production capacity will meet the normal (non-drought) water demands for the City of Kerrville. In addition, these projections indicate essentially no excess capacity to serve other water demands in the area:

| Water Source | Capacity (ac-ft/yr) |
|---|---|
| Existing Surface Water | 3,603 |
| Additional Surface Water | 1,997 |
| Treatment Plant | 5,600 |
| Ground Water | 560 |
| Total Capacity | 6,160 |
| Projected 2040 Demand | (5,850) |
| Excess Capacity | 310 |

Based on these projections ASR's role in the City of Kerrville's water plan will be to provide stored water for drought protection. This will involve an annual contribution to the aquifer so that a minimum ground water potentiometric elevation in the Lower Trinity of 1500 NGVD can be maintained. If ground water levels are maintained at this level 2040 water demands can be met even during a drought period like that recorded during the 1950's.

## CONJUNCTIVE MANAGEMENT IN KERR COUNTY

Total water demand in Kerr County is expected to increase from 7,177 ac-ft/yr in 1990 to 12,020 ac-ft/yr in 2040, and as previously discussed, the City of Kerrville's demands can be met through a conjunctive management approach. The EDC is the second largest demand area in the county with total demands increasing from 2,343 ac-ft/yr in 1990 to 3,977 ac-ft/yr in 2040. The primary source of water used in the EDC is the Middle Trinity aquifer which has an estimated firm yield of about 1,000 ac-ft/yr. The purpose of this section is to evaluate the role of conjunctive management, assuming an additional 4,760 ac-ft/yr of surface water is permitted and available for use in Kerr County in accordance with the application pending before the TWC.

## METHODOLOGY

Two scenarios were developed for evaluation of Middle Trinity ground water supplies. One scenario considers that no additional surface water rights are obtained. The Middle Trinity demands are assumed to include the seven demand centers outside of Kerrville identified in Section 2. In addition, the existing ground water demand for irrigation use plus half of the increase in irrigation demand is assumed to occur within the EDC and impact the Middle Trinity (Table 5-3).

**Table 5-3**
**Middle Trinity Demands (ac-ft/yr)**
**With No Additional Surface Water**

| Area | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 |
|---|---|---|---|---|---|---|
| Center Point | 511 | 646 | 689 | 750 | 805 | 879 |
| Eastern County | 126 | 159 | 170 | 185 | 198 | 217 |
| Ingram | 268 | 345 | 383 | 388 | 404 | 409 |
| Kerrville (non-City) | 309 | 390 | 416 | 453 | 486 | 531 |
| Kerrville Airport | 763 | 964 | 1,029 | 1,120 | 1,201 | 1,312 |
| Kerrville North | 170 | 215 | 230 | 250 | 268 | 293 |
| Kerrville South | 195 | 247 | 263 | 287 | 307 | 336 |
| Irrigation | 136 | 536 | 536 | 536 | 536 | 536 |

The second scenario assumes that 4,760 ac-ft/yr of additional surface water rights are obtained before 2000. Demands for Kerrville were assumed to be fully provided by surface water with any surplus surface water distributed proportionately to the six nearest demand centers to Kerrville. This understates the amount of surface water available by 560 ac-ft/yr or the firm yield of the Lower Trinity. The Middle Trinity demands for this scenario are given in Table 5-4, with demands fully met by surface water in 2000.

**Table 5-4**
**Middle Trinity Demands (ac-ft/yr)**
**With 4,760 ac-ft/yr Additional Surface Water**

| Area | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 |
|---|---|---|---|---|---|---|
| Center Point | 511 | 0 | 38 | 106 | 206 | 292 |
| Eastern County | 126 | 159 | 170 | 185 | 198 | 217 |
| Ingram | 268 | 0 | 21 | 55 | 103 | 136 |
| Kerrville (non-City) | 309 | 0 | 23 | 64 | 124 | 176 |
| Kerrville Airport | 763 | 0 | 57 | 158 | 308 | 435 |
| Kerrville North | 170 | 0 | 13 | 35 | 69 | 97 |
| Kerrville South | 195 | 0 | 15 | 40 | 79 | 111 |
| Irrigation | 136 | 536 | 536 | 536 | 536 | 536 |

Mathematical modeling was used to compare the Middle Trinity aquifer's projected response under the two ground water demand scenarios. The model was constructed using WELSIM, an analytical wellfield simulation program. WELSIM was designed to predict the drawdown in an aquifer as a result of pumping or recharge by single or multiple wells, using any of several widely accepted analytical techniques for describing well hydraulics. A detailed description of the WELSIM model, and the assumptions made in preparing the Middle Trinity simulation, is presented in Appendix D.

Each demand scenario was modeled over a period of 50 years, from 1990 to 2040. Hypothetical wellfields were designed to simulate eight major areas of ground water use in the Middle Trinity. These wellfields consisted of from 1 to 9 wells in each area, depending on the projected ground water demands. Simulation pumping rates ranged from 30 to 100 gpm in each of these wells to meet the projected demands.

Since the ground water demands had been projected at ten-year intervals starting with 1990, an assumption was needed to provide the model with average pumping rates within those intervals. The model simulations, therefore, assumed that the projected demands at each ten year interval represented the average demand over the period from five years before the projected demand year until five years after the projected demand year. For example, the 1990 demand was assumed to remain in effect until the year 1995, at which time the 2000 demand would take effect until 2005, and so on. If further refinement of projected drawdowns was needed, the demands within the ten-year interval of interest was modified based on a linear increase.

It is important to consider the model assumptions presented in Appendix C when viewing the results of these simulations. Selection of transmissivity and storage coefficients play a major role in drawdown prediction, as does well efficiency. Since WELSIM allows for only homogeneous conditions, the average transmissivity and storage coefficient used in the model will provide only an overall large-scale depiction of aquifer response. Significant spatial variability in these parameters are expected, and localized well response may be quite different from the model-calculated value.

In addition, well efficiency is a highly dependent on individual well location and construction, and may also be significant in actual aquifer response.

## GROUND WATER IMPACTS WITH CONJUNCTIVE MANAGEMENT

Under the Conjunctive Management scenario, an additional 4,760 acre-feet/year of surface water is available to meet projected total water demands for Kerr County water users. This additional surface water effectively reduces the amount of ground water pumpage required to meet the projected demands. Table 5-4 shows the projected Middle Trinity ground water demands for each of the major areas of pumping with the additional surface water availability.

As for the present permit conditions, the projected ground water demands for this scenario were simulated using the eight hypothetical wellfields for pumping. The same well locations were used for both scenarios. Pumping was again divided equally among the hypothetical wells in each wellfield. Pumping rates in the hypothetical wells ranged from 8 to 53 gpm across the county through the year 2040. Calculated water level and drawdown contour maps were plotted at 1991, 2000, 2010, 2020, 2030, and 2040.

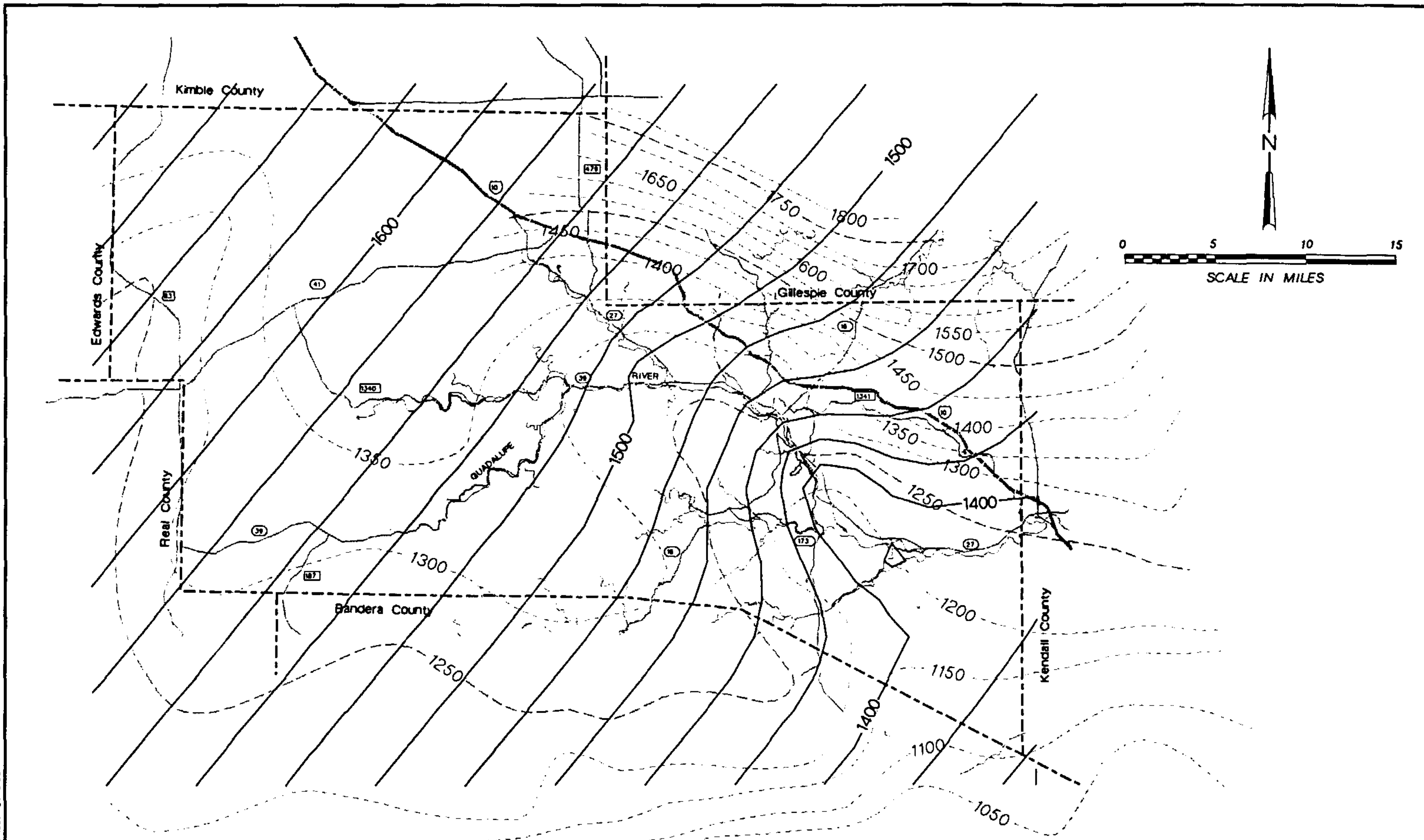
Since the ground water demands for 1990 are the same in both scenarios, calculated water levels and drawdowns in 1991 will also be the same. Refer to Figures 5-2 and 5-3 for the contour maps.

Figure 5-4 shows the projected water level under the present conditions scenario in the year 1995, assuming the projected ground water demands shown in Table 5-3. Figure 5-5 shows projected drawdowns. These figures indicate the maximum allowable drawdown of 200 feet will occur in about 1995. The maximum projected drawdown by the year 2040 is approximately 525 feet.

Figure 5-6 shows the projected water level with conjunctive management or a dual-surface water and ground water supply system. Figure 5-7 shows projected draw-downs. The maximum projected drawdown for the year 2040 is only approximately 210 feet in this scenario as compared to 525 feet in the no additional surface water scenario.

## GROUND WATER IMPACTS

Model-calculated drawdowns for each hypothetical well were reviewed to determine the maximum projected drawdown in any well for each scenario. The maximum drawdown for the present conditions scenario occurred in a hypothetical well in the Kerrville Airport area. The maximum drawdown for the additional surface water scenario occurred in a hypothetical well in the Orchard Irrigation area.




———— Middle Trinity Water Level

- - - - Top of Hensell Sand

Figure 5-2

MIDDLE TRINITY WATER LEVELS IN 1991 -- PRESENT CONDITIONS

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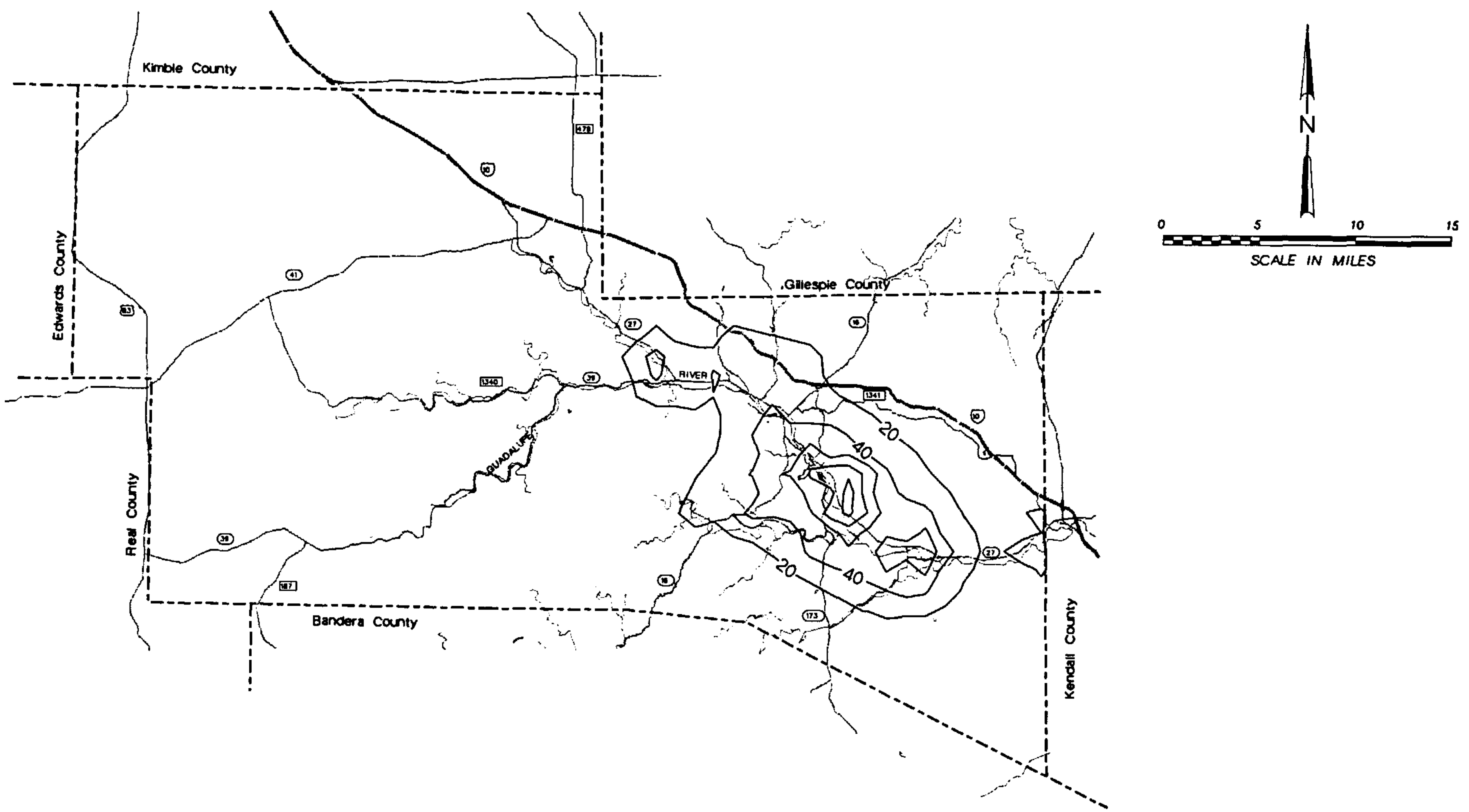


Figure 5-3

MIDDLE TRINITY DRAWDOWNS IN
1991 -- PRESENT CONDITIONS

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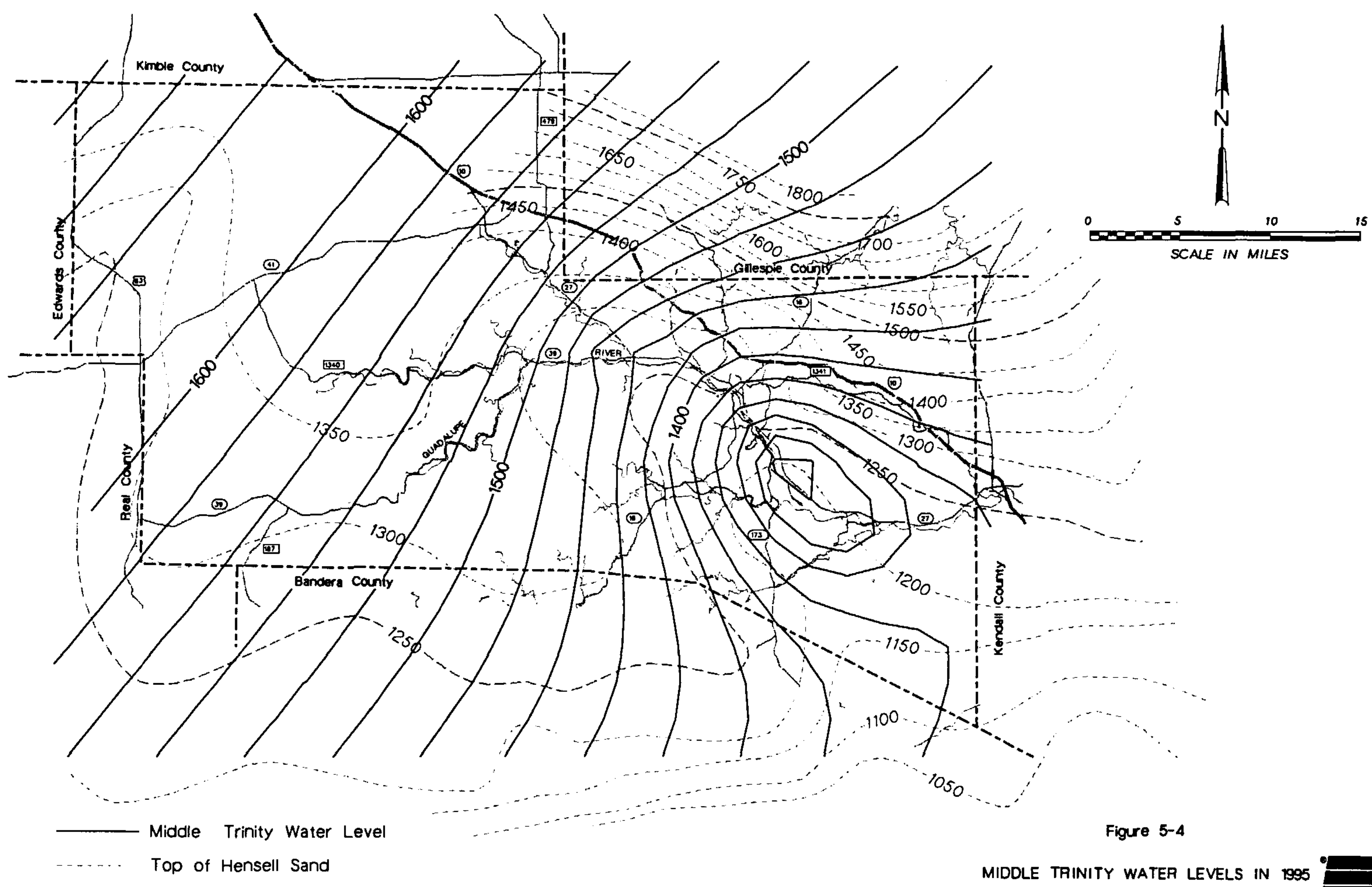


Figure 5-4

MIDDLE TRINITY WATER LEVELS IN 1995
WITHOUT CONJUNCTIVE MANAGEMENT

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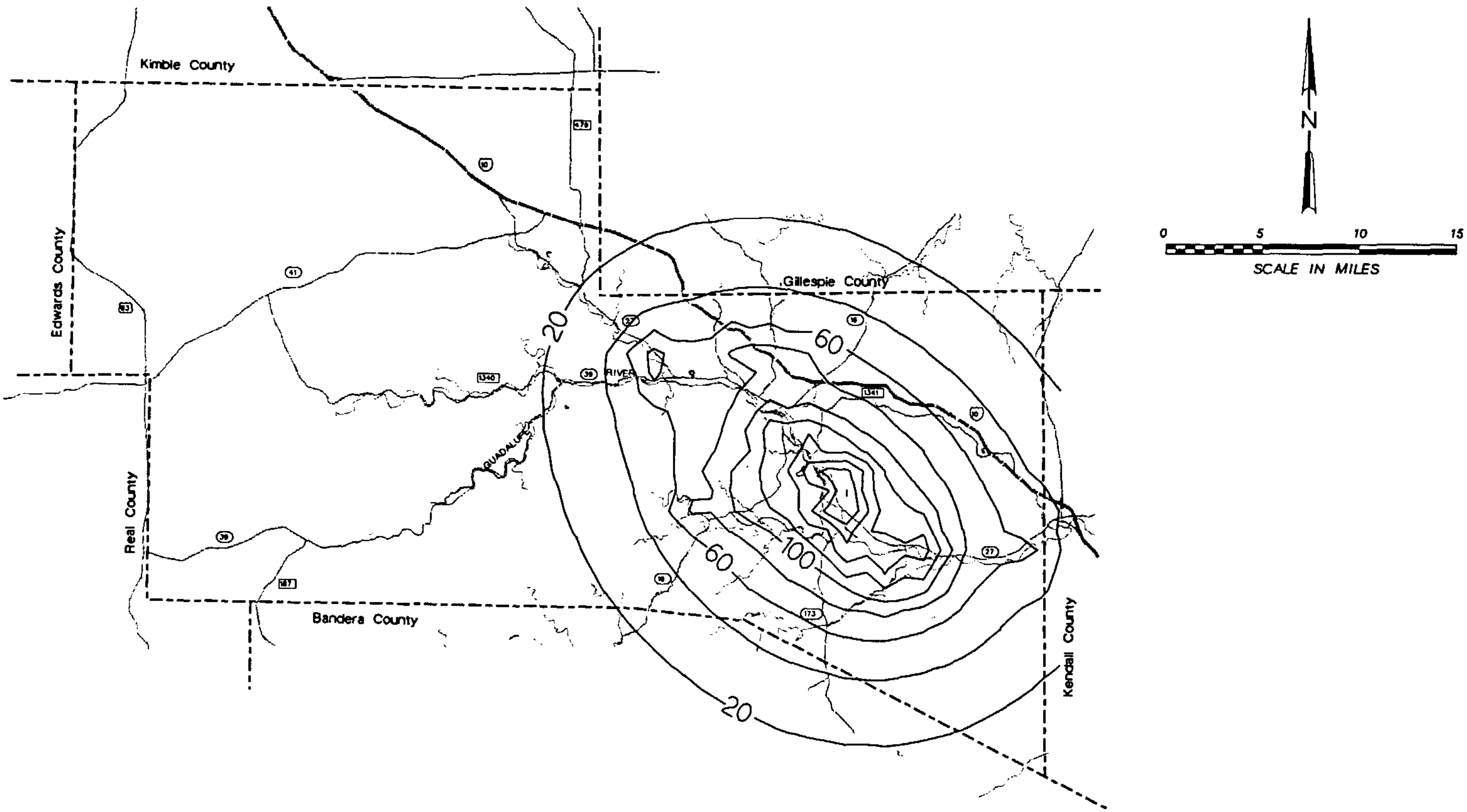


Figure 5-5

MIDDLE TRINITY DRAWDOWNS IN 1995
WITHOUT CONJUNCTIVE MANAGEMENT

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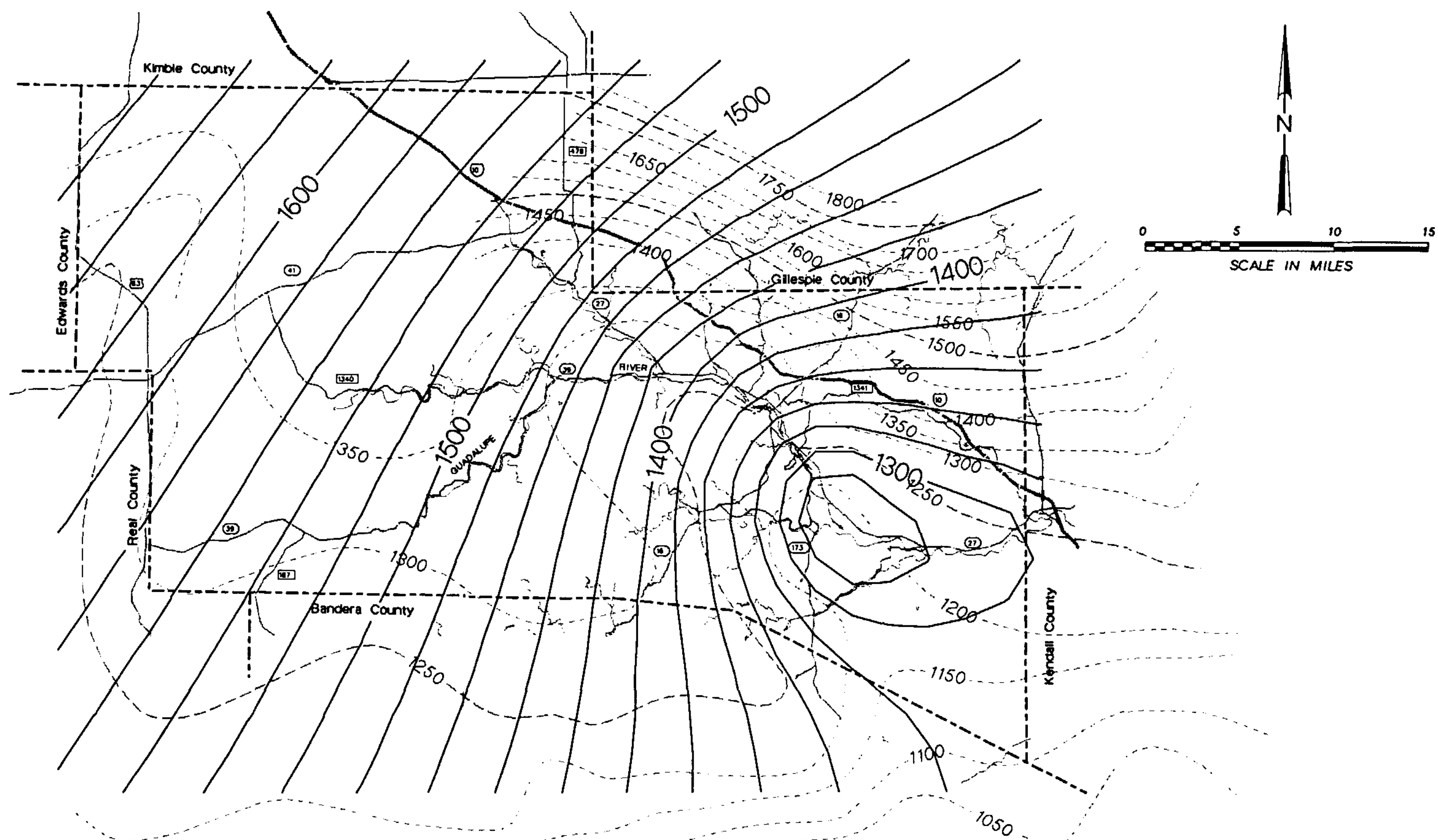


——— Middle Trinity Water Level

- - - - Top of Hensell Sand

Figure 5-6

MIDDLE TRINITY WATER LEVELS IN 2040 WITH CONJUNCTIVE MANAGEMENT

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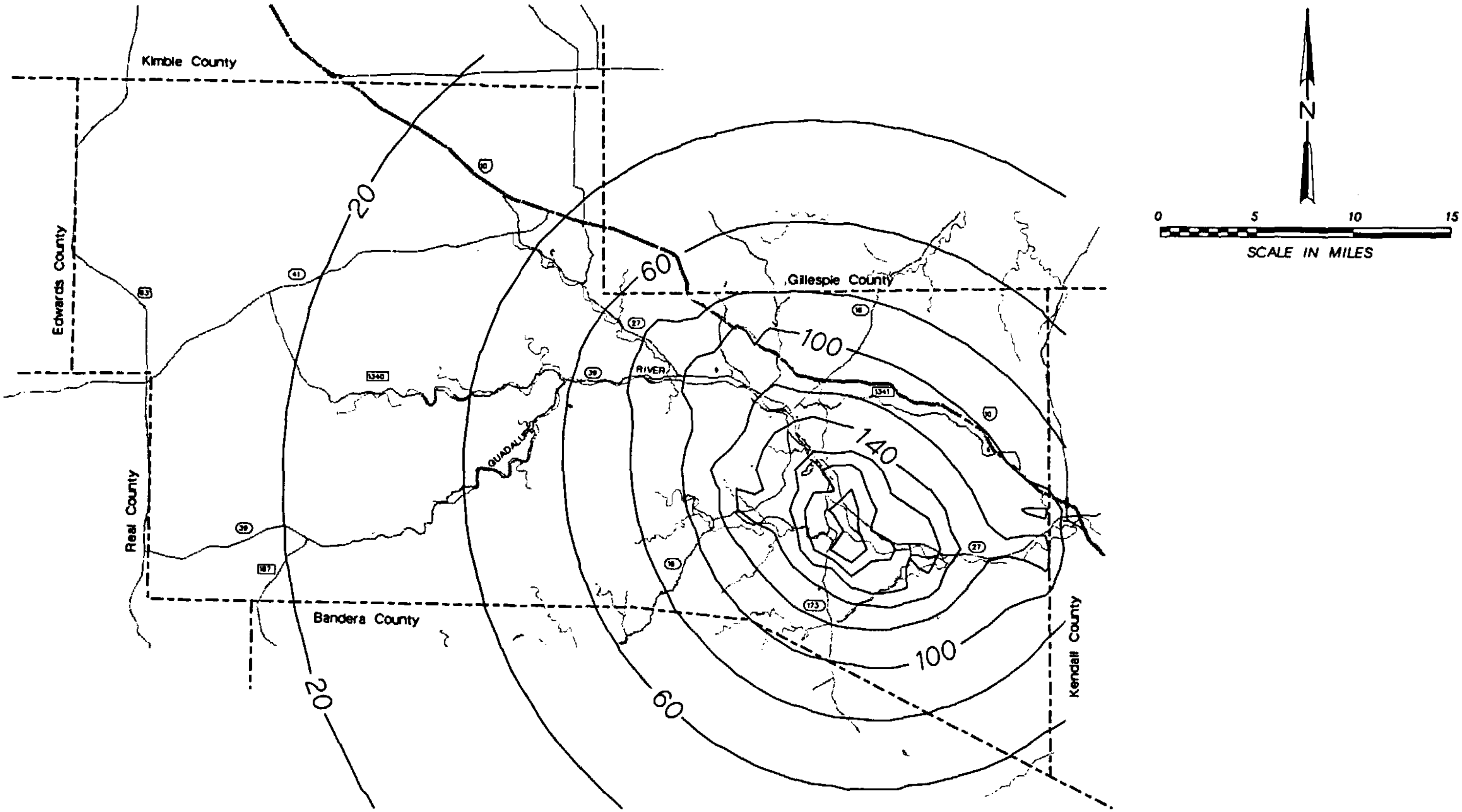


Figure 5-7

MIDDLE TRINITY DRAWDOWNS IN 2040 WITH CONJUNCTIVE MANAGEMENT

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Figure 5-8 illustrates the comparison between the maximum calculated drawdown in each scenario. The assumed allowable 200 feet drawdown is shown as a straight line. This assumed allowable drawdown is exceeded for the present surface water permit scenario as early as 1995, while the conjunctive management scenario does not exceed the allowable drawdown until approximately 2035. This projection can be considered a fairly representative illustration of the average Hensell response under the assumed ground water demands.

## CONCLUSIONS

In considering the three elements covered in this section, several observations or conclusions become apparent:

- The City of Kerrville needs to consider reuse of at least 1.2 mgd of treated wastewater, or will need to upgrade its wastewater treatment plant to improve phosphorous removal during periods of low flow in the Guadalupe River.

- Multiple options for wastewater reuse exist with some being agricultural and others involving public land.

- The City of Kerrville 2040 demand (5,850 ac-ft/yr) can be met through 2040 with the existing surface water treatment plant (5,600 ac-ft/yr) and wells in the Lower Trinity (560 AF/YR) with 310 AF/YR remaining.

- The City of Kerrville can use ASR to store water in the near term for drought protection in the long term.

- Under present policies, the Middle Trinity will be overdrafted, possibly in some areas by 1995.

- If conjunctive management is considered with 4,760 ac-ft/yr additional surface water, the Middle Trinity will not reach critical drawdown until nearly 2040.

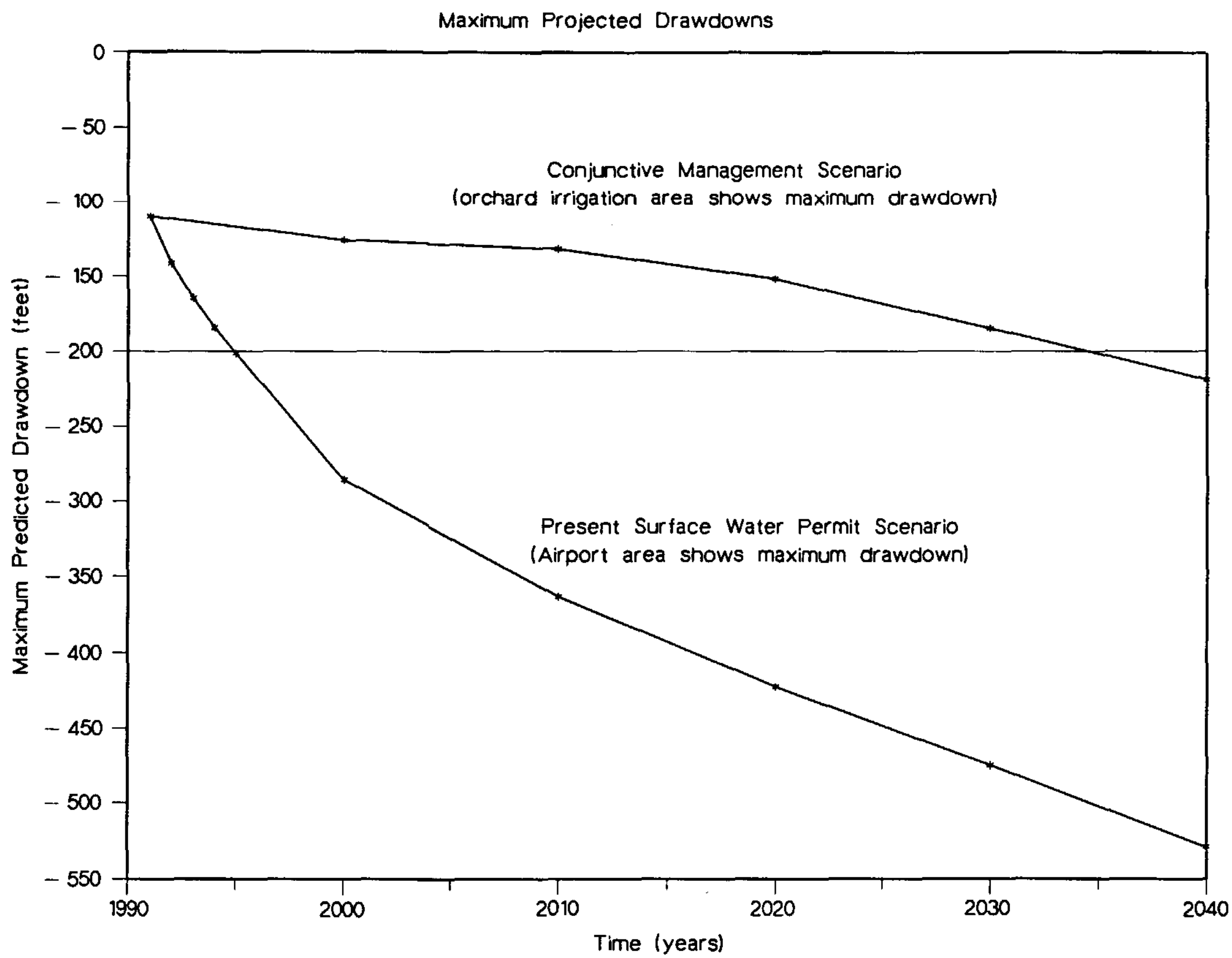


Figure 5-8

MIDDLE TRINITY DRAWDOWNS
THROUGH 2040

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# Section 6
# DEMAND VERSUS SUPPLY COMPARISON

## Section 6
# DEMAND VERSUS SUPPLY COMPARISON

The demand presented in Section 2 and the available water supplies discussed in Sections 3, 4, and 5 will be compared. Demands that can be served from existing ground water and surface water will be identified, and any remaining shortfall quantified. The comparison between supply and demand will be reviewed in the context of three areas:

- The areas outside of the EDC
- The City of Kerrville
- The EDC

In terms of gross quantities, the total water demand in Kerr County is expected to increase from 7,177 ac-ft/yr in 1990 to 12,020 ac-ft/yr in 2040. Approximately 3,060 ac-ft/yr is available from ground water with 3,917 ac-ft/yr of surface water permitted for municipal use, 417 ac-ft/yr of surface water permitted for industrial use, and 5,336 ac-ft/yr permitted for agricultural use, indicating 12,730 ac-ft/yr of water available. This indicates that there is more than enough water, which is not an accurate view of the situation. The most critical problem to be reconciled is the imbalance in municipal demands (9,926 ac-ft/yr) and water available for municipal use (between 3,917 ac-ft/yr and 6,977 ac-ft/yr).

## AREAS OUTSIDE OF THE EDC

The 2040 water demands projected for the areas outside of the EDC include three types of use:

- Municipal type demands (99 ac-ft/yr)
- Mining demands (80 ac-ft/yr)
- Livestock demands (390 ac-ft/yr)

The total 2040 demand for this area is expected to be 569 ac-ft/yr. Currently, these demands are largely met from various ground water sources including:

- Edwards Aquifer (1,000 ac-ft/yr)
- Upper Trinity Aquifer (500 ac-ft/yr)
- Middle Trinity Aquifer (1,000 ac-ft/yr)

The Edwards and Upper Trinity provide most of the water, because the Middle Trinity is primarily used within the EDC.

With ground water supplies of 1,500 ac-ft/yr available from the Edwards and Upper Trinity, it is expected that ground water will continue to supply the areas outside of the EDC. Because of the nature of the Edwards aquifer in particular, well spacing criteria which could be imposed by the Headwaters Underground Water Conservation District should be considered. This will help protect both the users from localized overpumping and the springflows that sustain the Guadalupe River.

## THE CITY OF KERRVILLE

The total demand for the City of Kerrville in 2040 is expected to be 5,850 ac-ft/yr, and as pointed out in Section 5, 5,600 ac-ft/yr could be supplied by the UGRA's Riverside Treatment Plant if 1,997 ac-ft/yr of additional water rights were obtained. Only 250 ac-ft/yr of additional water from the Lower Trinity aquifer would be needed to meet peak demands. This would leave 310 ac-ft/yr out of the yield of the Lower Trinity to meet other demands within the EDC.

## THE ECONOMIC DEVELOPMENT CORRIDOR

With the City of Kerrville demands satisfied, the balance of the 2040 demand for the EDC is expected to be 5,601 ac-ft/yr. This demand figure has three components:

- Municipal demand = 3,977 ac-ft/yr
- Manufacturing demand = 24 ac-ft/yr
- Irrigation demand = 1,600 ac-ft/yr

If the manufacturing and irrigation demands can be supplied by existing surface water or ground water sources, the municipal demands can be met from any remaining ground water and additional subordination of surface water. It is assumed that a negligible amount of ground water will be supplied form the Edwards and Upper Trinity aquifers to meet demands within the EDC.

### MANUFACTURING DEMANDS

Currently, manufacturing demands are supplied using ground water from the Lower Trinity aquifer. If this pattern is continued into the future, the 310 ac-ft/yr of Lower Trinity yield leftover from the City of Kerrville's use will more than supply the 2040 demand of 24 ac-ft/yr. The remainder available from the Lower Trinity would be further reduced to 286 ac-ft/yr.

### IRRIGATION DEMAND

From Section 2 of this report, it is estimated that the 2040 irrigation demand will be 1,600 ac-ft/yr with 536 ac-ft/yr supplied from the Middle Trinity Aquifer. The other 1,064 ac-ft/yr of demand could be supplied by surface water.

The available Middle Trinity yield is then reduced from 1,000 ac-ft/yr to 464 ac-ft/yr.

## MUNICIPAL DEMAND

The 2040 municipal demands of 3,977 ac-ft/yr within the EDC can be supplied by three water sources:

- Middle Trinity Aquifer
- Lower Trinity Aquifer
- Additional Surface Water

The total remaining ground water available from the Middle Trinity (464 ac-ft/yr) and Lower Trinity (286 ac-ft/yr) together is 750 ac-ft/yr. If this water is totally consumed to meet EDC municipal demands, an additional 3,227 ac-ft/yr would still be required from surface water to satisfy the projected 2040 demand.

# SUMMARY AND CONCLUSIONS

The following summary statements can be made with respect to the demand versus supply comparison:

- The 2040 demands (569 ac-ft/yr) for areas outside of the EDC or "West Kerr County" will probably be supplied by the Edwards and Upper Trinity aquifers.

- The 2040 City of Kerrville demand (5,850 ac-ft/yr) can be met from:

    - 3,603 ac-ft/yr of current surface water rights
    - 1,997 ac-ft/yr of additional surface water rights
    - 250 ac-ft/yr from the Lower Trinity aquifer

- The 24 ac-ft/yr of manufacturing demands within the EDC could continue to be supplied from the Lower Trinity aquifer

- The 2040 irrigation demand (1,600 ac-ft/yr) could be supplied by:

    - 536 ac-ft/yr from the Middle Trinity aquifer
    - 1,064 ac-ft/yr from existing surface water permits

- The 2040 municipal demand within the EDC but outside the City of Kerrville (3,977 ac-ft/yr) could be supplied by:

  - 464 ac-ft/yr from the Middle Trinity aquifer
  - 286 ac-ft/yr from the Lower Trinity aquifer
  - 3,227 ac-ft/yr from new surface water rights

- The total additional surface water rights required to meet demands in Kerrville and the EDC is estimated to be as much as 5,224 ac-ft/yr (1,997 ac-ft/yr + 3,227 ac-ft/yr), which exceeds the current application to the TWC for 4,760 ac-ft/yr of subordinated rights.

## Section 7
# WATER SUPPLY ALTERNATIVES

Section 7
# WATER SUPPLY ALTERNATIVES

The comparison of supply and demand in Section 6 has provided a basis for the formulation of three basic alternatives that have optional implementation strategies. These alternatives can basically be described as:

- Continue present policies or no action
- Establish a regional surface water supply system using ASR as a conjunctive management tool
- Establish a distributed surface water supply system using ASR as a conjunctive management tool
- Establish a regional surface water supply system using off-channel storage as a water management tool

The development and evaluation of these alternatives will be performed in Phase 2 of this planning effort. A discussion of each alternative will follow.

## CONTINUE PRESENT POLICIES

This alternative is predicated on the assumption that a regional surface water supply system will not be developed. The City of Kerrville will continue to be the sole UGRA customer for treated surface water. Only enough additional surface water rights will be obtained to meet the long-range demands of Kerrville. The ground water users outside of Kerrville will continue to overdraft their water supply aquifers. The Middle Trinity is the most common aquifer used outside of the City of Kerrville, and it is assumed that as areas of the Middle Trinity lose production or become dewatered, the wells will be deepened to the Lower Trinity.

### UGRA

The UGRA will continue to provide treated surface water to Kerrville. The surface water diversion permit will need to be increased by 1,687 ac-ft/yr to a total of 5,290 ac-ft/yr assuming Kerrville will continue to use the firm yield of the Lower Trinity (560 ac-ft/yr). The Riverside Treatment Plant will need to be maintained at an average capacity of 5.0 mgd (5,600 ac-ft/yr.

## KERRVILLE

The City of Kerrville will purchase treated surface water from the UGRA and implement ASR wells to store water in the Lower Trinity. Lower Trinity wells will be used to recover stored water and the firm yield of the aquifer. The primary benefits of ASR will be drought protection, stabilization of the yield of the Lower Trinity, and restoring the water levels in the Lower Trinity to historical norms. The City of Kerrville will consider implementation of 1.2 mgd (1,344 ac-ft/yr) of water reuse to maintain wastewater discharges at a maximum of 4.0 mgd.

## ECONOMIC DEVELOPMENT CORRIDOR

The public water systems in the EDC will continue to rely on the Middle Trinity as a primary source of water. As water levels drop, well efficiencies will decrease and some areas will begin to dewater (as early as 1995). When this situation occurs, these areas will likely deepen their existing wells to the Lower Trinity and begin competing with the City of Kerrville. Those systems in close proximity to Kerrville will derive benefits indirectly from ASR.

## WEST KERR COUNTY

This area will continue to obtain its water supply primarily from Edwards wells. The new county septic tank restrictions will help control well densities as can the implementation of an Underground Water Conservation District.

# REGIONAL SURFACE WATER SUPPLY

The basic tenet of this alternative is that a regional surface water supply system will be developed. This system can be implemented by one of two entities:

- The City of Kerrville
- The UGRA

There are two methods by which the regional system can supply surface water to the demand areas located in the EDC. Treated surface water can be transported via pipelines to the demand centers where the water would be introduced into the existing utility distribution systems. Treated surface water would be available for direct distribution to the EDC during the winter months when the existing treatment plant has surplus capacity, deferring use of the Middle Trinity to summer demands.

The second option for implementing the regional system is to transport treated surface water via pipelines to the general area of the demands in the EDC. ASR wells would be used to recharge the Middle Trinity during the winter months when surplus treated water is available. Individual utility systems in the EDC will continue to use their existing wells and distribution systems, reimbursing the regional supplier for water recharged and available to their system.

## UGRA

Under this alternative, the UGRA will continue to treat surface water at the Riverside Water Treatment Plant. Their diversion permit would be increased by at least 4,760 ac-ft/yr, and the water treatment plant capacity would be increased to at least 7.5 mgd (8,400 ac-ft/yr). The UGRA may serve as the regional distributor of treated surface water if the City of Kerrville chooses not to fulfill this role.

## CITY OF KERRVILLE

The City of Kerrville will continue to purchase treated surface water from the UGRA. Wells in the Lower Trinity will be used to meet peak summer demands with average withdrawals not exceeding the firm yield (560 ac-ft/yr) of the Lower Trinity. ASR wells will be used to store treated surface water and stabilize the level of the Lower Trinity. Kerrville will consider implementation of 1.2 mgd (1,344 ac-ft/yr) of water reuse, to maintain wastewater discharges at a maximum of 4.0 mgd.

## ECONOMIC DEVELOPMENT CORRIDOR

The public water systems in the EDC will be supplied treated surface water by either the City of Kerrville or the UGRA. The individual utilities will either be directly connected to the regional system or recover surface water that has been recharged into the Middle Trinity. Surface water will only be available for direct use or recharge during the winter months when surplus treated water is available. The only area in the EDC which will not be connected to the regional system is the area along the eastern county line near Comfort. This area will continue to rely solely on ground water.

## WEST KERR COUNTY

This area of the county will continue with ground water supplies as described in the present policies alternative.

# "DISTRIBUTED" SURFACE WATER SUPPLY SYSTEM

This alternative is very similar to the regional surface water supply system with "distributed" indicating that surface water is diverted, treated, and available at more than one location. Small lakes at Ingram and Center Point could both serve as diversion points, giving rise to three options for a "distributed" system. Surface water would be available from:

- The UGRA Ponding Lake and New Lake Ingram
- The UGRA Ponding Lake and Lake Center Point
- The UGRA Ponding Lake, New Lake Ingram, and Lake Center Point

The current and proposed diversion rights of the UGRA would be implemented with a portion of the diversion right reassigned to one or both of the additional diversion points, if the UGRA was requested to operate plants at Center Point and Ingram. Small surface water treatment plants would be constructed at each of the new diversion points. Distribution of treated water would originate from these treatment plants.

## UGRA

The UGRA will continue to provide water to the City of Kerrville. A regional distribution system originating at the Riverside Treatment Plant will serve Kerrville and a limited area around Kerrville with regional transmission lines extending to either Ingram, Comfort, or to neither end of the EDC. If a "distributed" system is selected as the preferred alternative, the UGRA will need to reassign diversion rights to one or both of the additional diversion points. The Riverside Treatment Plant could remain at 5.0 mgd or be expanded depending on the capacity needed at new diversion points.

## KERRVILLE

The City of Kerrville will continue to be the main customer for treated water from the UGRA's Riverside Treatment Plant. The City may also function as a regional supplier by extending transmission lines to areas of the EDC not served from new surface water diversion points. ASR will be implemented to stabilize the Lower Trinity, and reuse of up to 1.2 mgd (1,344 ac-ft/yr) of wastewater will need to be considered.

## ECONOMIC DEVELOPMENT CORRIDOR

The EDC will be served by a conjunctive management system of ground water and surface water. The western and eastern ends of the EDC will have the option of obtaining treated surface water from either the Ingram or Center Point areas, respectively. Surface water will be used exclusively when it is available, and Middle Trinity water will be used to meet peak demands.

## WEST KERR COUNTY

This area of the county will continue with ground water supplies as described in the present policies alternative.

# OFF-CHANNEL RESERVOIR SYSTEM

In this alternative, an off-channel reservoir would be used to store additional surface water diverted from the Guadalupe River. The UGRA's Riverside Treatment Plant would be enlarged to meet the peak demands of the region served and the distribution system would originate in Kerrville.

## UGRA

The UGRA will construct an off-channel reservoir, enlarge the Riverside Treatment Plant, and continue to provide water to the City of Kerrville. A regional distribution system originating from the treatment plant and extending to the limits of the system will be required.

## KERRVILLE

The City of Kerrville will continue to be the main customer for treated water from UGRA and may also be responsible for distributing treated water to outlying areas of the EDC. ASR may be implemented to stabilize the Lower Trinity and provide drought protection for the City of Kerrville. Wastewater reuse will also need to be considered.

## ECONOMIC DEVELOPMENT CORRIDOR

The EDC will be served by a regional surface water system originating in Kerrville. Portions of the EDC may continue to rely on the Middle Trinity if enough demands near Kerrville can be met by surface water to reduce the stress on the aquifer.

## WEST KERR COUNTY

This area of the county will continue with ground water supplies as described in the present policies alternative.

## Section 8
## PHASE 2 SCHEDULE

Section 8
# PHASE 2 SCHEDULE

Phase 2 of the regional planning effort will be used to formulate in greater detail the physical facilities required for each alternative. A preliminary screening will be used to identify feasible alternatives. Detailed cost estimates and implementation schedules will be prepared for these alternatives. A variety of factors will be used to select a preferred alternative including:

- Cost
- Environment
- Local Acceptance
- Financing
- Rates

A final report will be prepared that details the results of both Phase I and Phase II.

The schedule for Phase 2 is as presented in Table 8-1:

**Table 8-1**
**Phase 2 Schedule**

| Task | Description | Start | Finish |
|---|---|---|---|
| 2-A | Perform Alternative Survey | 01/15/92 | 02/29/92 |
| 2-B | Select Preferred Alternative | 03/01/92 | 03/31/92 |
| 2-C | Prepare Completion Report (Draft) | 04/01/92 | 04/30/92 |
| 2-C | Public Meeting | | 05/31/92 |
| 2-C | Submit Final Report | | 06/30/92 |

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# REFERENCES

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# APPENDICES

# APPENDIX A

# APPENDIX A: WATER UTILITIES/USE IN KERR COUNTY (in million gallons)

| No. | Project name | Project # | IN EDC | AREA | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | Ingram Oaks | | Y | | | | | | | | | | | | | |
| 35 | Ox Hollow Water | 632800 | Y | | | | | | | | | 2.175 | 2.073 | 2.263 | 1.917 | 8.4284 |
| 21 | Horshoe Oaks Subdiv. | 395973 | Y | | | | | | | | | 1.161 | 1.99 | 1.907 | 2.322 | 7.3804 |
| 79 | La Hacienda | | Y | | | | | | | | | | | | | |
| 55 | Windwood Oaks Water Sys. | 951500 | Y | | | | | | | | | | | | 1.546 | 1.546 |
| 71 | Camp Chrysallis | | Y | | | | | | | | | | | | | |
| 34 | Oak Ridge Estates | 618185 | Y | | | | | | | | | | 2.49 | 2.13 | 2.208 | 6.828 |
| 59 | Woods Water Supply Corp. | | Y | | | | | | | | | | | | | |
| 29 | Montebello Estates | 576660 | Y | | 1.293 | 1.247 | 1.652 | 1.9 | 1.653 | 2.198 | 2.567 | 3.207 | 2.661 | 2.71 | 1.936 | 23.024 |
| 67 | Real Oaks | | Y | | | | | | | | | | | | | |
| 81 | West Creek Estates | | Y | | | | | | | | | | | | | |
| 28 | Midway Mobile Home | 567050 | Y | | | | | | | | | 1.089 | 1.287 | 1.415 | 1.4 | 5.1917 |
| 38 | Rancho Oaks Mobile Home | 718432 | Y | | | | | | | | | | | 0.11 | 0.125 | 0.235 |
| 66 | White Oak | | Y | | | | | | | | | | 4 | | | 4 |
| 63 | Verde Creek Estates | | Y | CP | | | | | | | | | | | | |
| 10 | Center Point I S D | 143571 | Y | CP | | | | | | | | | 1.905 | 2.4 | 0.86 | 5.165 |
| 30 | Nickerson Farm Water | 389326 | Y | CP | | | | | | | 2.383 | 2.74 | 2.117 | 2.27 | 2.535 | 12.045 |
| 5 | Cardinal Acres | 389319 | Y | CP | | | | | | | | | | 0.853 | 0.879 | 1.732 |
| 9 | Center Point-Weidenfeld | 372350 | Y | CP | 1.115 | 1.505 | 1.668 | 1.796 | 2.005 | 2.314 | 2.33 | 2.49 | 2.768 | 2.81 | 3.108 | 23.909 |
| 62 | Verde Park Estates | | Y | CP | 0.98 | 0.96 | 0.86 | 1.45 | 1.38 | 1.52 | 1.18 | 1.14 | | | | 9.47 |
| 8 | Center Point-Taylor Sys. | 144800 | Y | CP | 8.109 | 8.109 | 8.047 | 8.073 | 8.155 | 10.58 | 10.58 | 12.11 | 12.11 | 11.45 | 12.55 | 109.894 |
| 70 | Camp C.A.M.P | | Y | CP | | | | | | | | | | | | |
| 11 | Center Point N Water Sys. | 143572 | Y | CP | | | | 1.226 | 3.204 | 16.02 | 4.129 | 4.923 | 4.397 | 4.031 | 4.984 | 42.9183 |
| 36 | Park Place Sub-Center Pt. | 651601 | Y | CP | | | | | | | | | | 0.717 | | 0.7175 |
| | TOTAL CENTER POINT AREA | | | | 10.20 | 10.57 | 10.57 | 12.54 | 14.74 | 30.44 | 20.61 | 23.40 | 23.29 | 24.53 | 24.91 | |
| 75 | Pot-O-Gold Camp | | Y | EC | | | | | | | | | | | | |
| 53 | Westwood Park Subdiv. | 938200 | Y | EC | 1.863 | 2.483 | 2.163 | 2.716 | 3.526 | 5.398 | 5.911 | 6.349 | 6.537 | 7.105 | | 44.0513 |
| 74 | Herman Sons Youth Camp | | Y | EC | | | | | | | | | | | | |
| | TOTAL EASTERN COUNTY | | | | 1.863 | 2.483 | 2.163 | 2.716 | 3.526 | 5.398 | 5.911 | 6.349 | 6.537 | 7.105 | 0 | |

## APPENDIX A: WATER UTILITIES/USE IN KERR COUNTY (in million gallons)

| No. | Project name | Project # | IN EDC | AREA | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | River Front Village | 730770 | Y | I | 2.531 | 2.739 | 3.079 | 7.056 | 8.608 | 9.075 | 8.097 | 9.143 | 8.487 | 9.414 | 6.157 | 74.3882 |
| 24 | Ingram-Tom Moore H.S. | 419349 | Y | I | | | | | | | | | 2.095 | 1.685 | 1.918 | 5.698 |
| 23 | Ingram Water Supply | 419370 | Y | I | 76.96 | 95.54 | 86.98 | 108.6 | 105.9 | 139.4 | 122.6 | 134.7 | 125.6 | 136.6 | | 1133.293 |
| 17 | Hideaway Mobile Home Park | 387830 | Y | I | | | | | | | | | 0.198 | 1.44 | 1.825 | 3.463 |
| 65 | Village West | | Y | I | | | | | | | | | | | | |
| 4 | Camp Rio Vista | 389310 | Y | I | | | | | | | | 5.98 | | | | 5.98 |
| 50 | Verde Hills Water Supply | 901300 | Y | I | | 4.123 | 3.307 | 5.247 | 6.992 | 7.772 | 5.847 | 3.633 | 2.245 | 3.017 | 3.686 | 45.869 |
| 7 | Cedar Springs Mobile Home | 141100 | Y | I | 2.24 | 2.283 | 2.052 | 2.706 | 2.532 | 2.933 | 2.697 | 2.762 | 2.214 | 2.784 | 3.094 | 28.297 |
| 46 | Sleepy Hollow | 389320 | Y | I | | 1.587 | 4.676 | 5 | 13.92 | 17.75 | 12.39 | 11.40 | 9.149 | 12.35 | 11.61 | 99.8577 |
| | TOTAL INGRAM AREA | | | | 81.73 | 106.2 | 100.1 | 128.7 | 137.9 | 176.9 | 151.6 | 167.7 | 150.0 | 167.3 | 28.29 | |
| 32 | Oak Forest South Water | 389325 | Y | K | | 7.145 | 6.43 | 13.76 | 16.24 | 14.62 | 18.76 | 20.30 | 17.66 | 18.16 | 18.53 | 151.633 |
| 13 | Del Valle Mobile Home | 221845 | Y | K | | | | | | | | | 0.54 | 0.75 | 0.386 | 1.676 |
| 33 | Oak Grove Mobile Home | 617430 | Y | K | 4.705 | 4.575 | 4.9 | 4.81 | 5.135 | 6.632 | 5.849 | 6.191 | 5.752 | 5.27 | 5.198 | 59.017 |
| 27 | The City of Kerrville | 465000 | Y | K | Listed Separately | | | | | | | | | | | 0 |
| 83 | Kerrville MUD | 465050 | Y | K | 47.2 | 20.83 | 49.73 | 50 | 59.1 | 81.98 | (see kerrville after 1984) | | | | | 308.84 |
| 49 | VA Hospital | 902353 | Y | K | | | | | | | | | | 9.022 | | 9.0228 |
| 3 | Blue Ridge Mobile homes | 82490 | Y | K | | | | | | | | | | 1.836 | 1.445 | 3.281 |
| 18 | Hill Country Mobile Home | 389307 | Y | K | | | | | | | | | 1.045 | 1.071 | 0.42 | 2.536 |
| | TOTAL KERRVILLE | (NOT CITY OF) | | | 51.90 | 32.55 | 61.06 | 68.57 | 80.48 | 103.2 | 24.60 | 26.49 | 24.99 | 36.11 | 25.98 | |
| 16 | Guadalupe Heights Util.Co. | 345850 | Y | KA | 29.68 | 21.76 | 18.23 | 22.35 | 22.03 | 26.62 | 22.66 | 22.80 | 19.53 | 20.22 | 24.56 | 250.489 |
| 48 | Split Rock Water Sys. | 819875 | Y | KA | 1.68 | 1.188 | 1.452 | 1.5 | 1.575 | 1.969 | 1.716 | 2.377 | 2.38 | 3.199 | 2.8 | 21.836 |
| 78 | Hill Country Youth Ranch | | Y | KA | | | | | | | | | | | | |
| 76 | Texas Lions Camp | | Y | KA | | | | | | | | | | | | |
| 39 | Rio Alegre Homeowners | 728500 | Y | KA | | | | | | | | | 0.632 | | | 0.632 |
| | TOTAL KERRVILLE AIRPORT | | | | 31.36 | 22.95 | 19.68 | 23.85 | 23.60 | 28.58 | 24.38 | 25.18 | 22.54 | 23.42 | 27.36 | |
| 26 | Kerr Villa Moble Home | 464250 | Y | KN | | | | | | | | 4.648 | 0.167 | 0.186 | 0.123 | 5.1251 |
| 31 | Northwest Hills Sub. | 389323 | Y | KN | | | | | | | | | | 3.35 | 3.531 | 6.881 |
| 82 | James Avery Craftsman | | Y | KN | | | | | | | | | | | | |
| 80 | USDA Insect Research Lab | | Y | KN | | | | | | | | | | | | |
| 12 | Cherokee Mobile Home Prk. | 148043 | Y | KN | | | | | | | | | 1.344 | 3.6 | 3.6 | 8.544 |
| | TOTAL KERRVILLE NORTH | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.648 | 1.511 | 7.136 | 7.254 | |

## APPENDIX A: WATER UTILITIES/USE IN KERR COUNTY (in million gallons)

| No. | Project name | Project # | IN EDC | AREA | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | Royal Oaks Subdiv. | 750000 | Y | KS | 4.046 | 4.684 | 3.978 | 4.555 | 4.263 | 7.25 | 4.476 | 4.84 | 4.348 | 5.447 | 5.422 | 53.309 |
| 45 | Silver Creek Wt. Supply | 797090 | Y | KS | | | | | 1.368 | 8.342 | 5.747 | 5.172 | 4.177 | 4.06 | | 28.866 |
| 15 | Four Seasons | 389316 | Y | KS | | | | | | | | | | 0.287 | 0.789 | 1.0764 |
| 52 | Westwood Oaks Mobile Home | 389330 | Y | KS | | | | | | | | | 4.681 | 3.839 | 4.307 | 12.827 |
| 43 | Scenic Loop Water Co. | 778025 | Y | KS | | | | | 0.39 | 4.697 | 5.73 | 2.622 | 5.149 | | | 18.588 |
| 77 | Kerrville South Utilities | | Y | KS | | 35.08 | 30.33 | 51.74 | 66.29 | 120.4 | 90.01 | 113.4 | 104.5 | | | 611.91 |
| 2 | Bear Paw water system | 60332 | Y | KS | | | | | | | 3.624 | 3.546 | 2.495 | 2.967 | 3.115 | 15.747 |
| 56 | Wood Trail Water Supply | 478810 | Y | KS | | | | | | | | | | 2.719 | 2.952 | 5.6714 |
| 47 | Southern Hills Water Sys. | 806930 | Y | KS | | | | | | | | | 1.378 | 1.034 | | 2.412 |
| | TOTAL KERRVILLE SOUTH | | | | 4.046 | 39.76 | 34.30 | 56.29 | 72.31 | 140.7 | 109.5 | 129.6 | 126.7 | 20.35 | 16.58 | |

# APPENDIX B

APPENDIX B: SURFACE WATER RIGHTS HELD IN KERR COUNTY

| ADJUDI-CATION CERT. | PERMIT NUMBER | NAME OF OWNER | STREAM | U | AMOUNT OF DIVERSION AC.-FT./YR. | IRRIGATED ACRES | DIVERSION RATE CFS X 10 | RESERV. CAPACITY AC.-FT. | PRIORITY DATE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 001932 | | PRESBYTERIAN MO-RANCH ASSE | N FK GUAD | 1 | 60 | 0 | 6 | 0 | 19481231 | |
| 001943 | | ASM INC | N FK GUAD | 1 | 14 | 0 | 2 | 0 | 19451231 | |
| 001947A | | GUAD VALLEY LOT OWNERS ASSN | N FK GUAD | 1 | 3 | 0 | 1 | 0 | 19601231 | |
| 001956B | | RIVER INN ASSOC OF UNIT OWNE | S FK GUAD | 1 | 10 | 0 | 8 | 0 | 19840703 | AMEND 4/19/84, 1/4/85 |
| 001961 | | WILTON CRIDER | S FK GUAD | 1 | 3 | 0 | 7 | 0 | 19471231 | |
| 001970 | | CARL HAWKINS | GUADALUPE | 1 | 10 | 0 | 8 | 0 | 19130701 | |
| 001996A | | KERRVILLE, CITY OF | GUADALUPE R | 1 | 150 | 0 | 0 | 0 | 19140404 | AMND 3/19/91 ADD PT OF DIV |
| 002008 | | LUTHERAN CAMP CHRYSALIS | TURTLE CREEK | 1 | 11 | 0 | 1 | 12 | 19741118 | |
| 002445 | | CAMP MYSTIC INC | CYPRESS&SFGU | 1 | 14 | 0 | 3 | 20 | 19270315 | |
| 002446 | | BOB/KAT INC | S FK GUAD | 1 | 10 | 0 | 1 | 0 | 19271231 | |
| 002447 | | CAMP LA JUNTA INC | S FK GUADALUPE | 1 | 14 | 0 | 0 | 0 | 19281231 | & RECREATION |
| 003769 | 003505 | UPPER GUADALUPE RIVER AUTH | GUADALUPE | 1 | 3603 | 0 | 97 | 840 | 19770523 | 2450 AF SEWAGE ON 192 AC OF 533 TRS |
| 003896 | 003625 | KENNETH W & MARCIA C MULFOR | RATTLESNAKE | 1 | 0 | 0 | 0 | 13 | 19780103 | 3 TRACTS 34.55 AC, ALSO REC |
| 005331 | 005331 | KATHLEEN B FLOURNOY ET AL | S FK GUADALUPE | 1 | 15 | 0 | 7 | 30 | 19901108 | ALSO REC |
| 001969 | | TOMMIE SMITH BLACKBURN | GUAD & KELLY | 2 | 15 | 0 | 10 | 15 | 19140629 | ALSO HYDROELECTRIC |
| 001975 | | TEXAS PARKS & WILDLIFE DEPT | FESSENDEN BR | 2 | 400 | 0 | 250 | 0 | 19250701 | |
| 001997 | | DARRELL G LOCHTE ET AL | GUADALUPE | 2 | 2 | 0 | 0 | 0 | 19461231 | |
| 001930 | | E T STANDLEY | FLAT ROCK CR | 3 | 69 | 66 | 13 | 35 | 19301231 | |
| 001932 | | PRESBYTERIAN MO-RANCH ASSE | N FK GUAD | 3 | 14 | 7 | 0 | 0 | 19481231 | |
| 001934 | | CHARLES K HICKEY ET AL | DRY CREEK | 3 | 2 | 3 | 1 | 0 | 19671231 | |
| 001935 | | CHARLES K HICKEY ET AL | N FK GUAD | 3 | 8 | 8 | 1 | 0 | 19671231 | |
| 001936 | | WILLIAM H ARLITT JR ET UX | N FK GUAD | 3 | 17 | 6 | 13 | 5 | 19090802 | |
| 001936 | | WILLIAM H ARLITT JR ET UX | INDIAN CREEK | 3 | 134 | 48 | 12 | 0 | 19601231 | |
| 001938 | | LOUIS H STRUMBERG | BEAR CREEK | 3 | 15 | 22 | 29 | 0 | 19331231 | |
| 001938 | | LOUIS H STUMBERG | N FK GUAD | 3 | 2 | 4 | 29 | 0 | 19481231 | |
| 001939 | | LOUIS H STRUMBERG | GRAPE CREEK | 3 | 3 | 6 | 29 | 6 | 19521231 | |
| 001940 | | B E QUINN III ET AL | N FK GUAD/GUAD | 3 | 32 | 16 | 21 | 10 | 19361231 | |
| 001941 | | DELMAR SPIER, AGENT | TURTLE CREEK | 3 | 6 | 9 | 9 | 5 | 19531231 | |
| 001945 | | JOHN P HILL | N FK GUAD | 3 | 25 | 20 | 15 | 0 | 19151231 | |
| 001946 | | JOHN P HILL ADMINISTRATOR | N FK GUAD | 3 | 11 | 9 | 15 | 0 | 19151231 | |
| 001947A | | GUAD VALLEY LOT OWNERS ASSN | N FK GUAD | 3 | 6 | 10 | 1 | 0 | 19601231 | AMND 3/6/91 |
| 001948 | | JOHN H DUNCAN | BRUSHY CREEK | 3 | 7 | 7 | 3 | 0 | 19140918 | |
| 001949 | | CONRAD L MEADOW | HONEY CREEK | 3 | 6 | 2 | 1 | 0 | 19481231 | OUT OF A 80 ACRE TRACT |
| 001949 | | CONRAD L MEADOW | SPRNG ON HONE | 3 | 27 | 9 | 3 | 0 | 19001231 | |
| 001950 | | JOHN H DUNCAN | HONEY CREEK | 3 | 6 | 20 | 6 | 13 | 19031231 | ALSO USE 7 |
| 001953 | | GARLAND M & GLADYS BROOKING | N FK GUAD | 3 | 40 | 24 | 7 | 0 | 19140626 | |

APPENDIX B: SURFACE WATER RIGHTS HELD IN KERR COUNTY

| ADJUDI-CATION CERT. | PERMIT NUMBER | NAME OF OWNER | STREAM | U | AMOUNT OF DIVERSION AC.-FT./YR. | IRRIGATED ACRES | DIVERSION RATE CFS X 10 | RESERV. CAPACITY AC.-FT. | PRIORITY DATE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 001958 | | T J MOORE ESTATE | CYPRESS CREEK | 3 | 20 | 10 | 3 | 100 | 19381205 | |
| 001961 | | WILTON CRIDER | S FK GUAD | 3 | 1 | 3 | 0 | 0 | 19471231 | |
| 001963B | | LAWRENCE L GRAHAM ET AL | S FK GUADALUPE | 3 | 2 | 12 | 10 | 21 | 19170529 | AMEND 9/10/85 |
| 001964 | | T JASPER MOORE JR | TEGENER & TRIB | 3 | 10 | 10 | 14 | 12 | 19481231 | |
| 001968 | | LOUIS DOMINGUES | GUAD & KELLY | 3 | 10 | 20 | 11 | 0 | 18891231 | |
| 001969 | | TOMMIE SMITH BLACKBURN | GUAD & KELLY | 3 | 108 | 80 | 16 | 0 | 19461231 | |
| 001970 | | CARL HAWKINS | GUADALUPE | 3 | 32 | 25 | 0 | 0 | 19130701 | |
| 001972 | | WESLEY ELLEBRACHT | WELSH BRANCH | 3 | 6 | 6 | 11 | 0 | 19001231 | |
| 001973 | | SHELTON RANCHES INC | SMITHS BRANCH | 3 | 10 | 10 | 10 | 6 | 19140629 | |
| 001974 | | SHELTON RANCHES INC | SMITHS BRANCH | 3 | 70 | 35 | 33 | 15 | 19140629 | ALSO JOHNSON CREEK |
| 001976 | | L D BRINKMAN ET AL | FESSENDEN BR | 3 | 29 | 14 | 9 | 0 | 19140610 | |
| 001977 | | TEXAS CATHOLIC BOYS' HOME | JOHNSON CR | 3 | 23 | 23 | 11 | 23 | 19691201 | |
| 001978 | | A J RUST | JOHNSON CR | 3 | 33 | 65 | 18 | 0 | 19021231 | |
| 001979 | | KEITH S MEADOW | BYAS CREEK | 3 | 18 | 6 | 10 | 0 | 19141231 | |
| 001980 | | CHARLES A HABERMACHER ET UX | JOHNSON CR | 3 | 12 | 6 | 1 | 0 | 19180128 | |
| 001981 | | JACK D CLARK JR ET AL | JOHNSON CR | 3 | 32 | 16 | 13 | 0 | 19180128 | |
| 001981 | | JACK D CLARK JR ET AL | JOHNSON CR | 3 | 143 | 76 | 11 | 0 | 19611231 | OUT OF A 111.9 ACRE TRACT |
| 001982 | | LOLA DEAN SMITH | JOHNSON CR | 3 | 133 | 50 | 6 | 12 | 19551231 | |
| 001983 | | N V MAMIMAR ET AL | JOHNSON CREEK | 3 | 32 | 17 | 10 | 0 | 19140429 | |
| 001983 | | N V MAMIMAR ET AL | JOHNSON CR | 3 | 67 | 35 | 10 | 0 | 19531231 | |
| 001984 | | MICHAEL E & GAIL SEARS | JOHNSON CREEK | 3 | 1 | 2 | 1 | 0 | 19140429 | |
| 001985 | | GERVIS H & GLENDA EUDALEY | JOHNSON CREEK | 3 | 80 | 31 | 10 | 0 | 19101231 | |
| 001987 | | REGINALD E WARREN JR | JOHNSON CREEK | 3 | 90 | 30 | 11 | 0 | 19341231 | |
| 001988 | | JIMMIE L QUERNER SR ESTATE | FALL BRANCH | 3 | 128 | 64 | 16 | 0 | 19601231 | ALSO GILLESPIE CO |
| 001990 | | DOROTHY L THOMPSON ET AL | JOHNSON CREEK | 3 | 3 | 1 | 1 | 0 | 19140630 | |
| 001991 | | LAZY HILLS GUEST RANCH INC | HENDERSON BR | 3 | 21 | 28 | 4 | 8 | 19601231 | |
| 001992 | | WILMA & OLLIE LECIL DIXON | JOHNSON CREEK | 3 | 23 | 15 | 8 | 0 | 19140624 | |
| 001993 | | ROY LITTLEFIELD | JOHNSON CREEK | 3 | 50 | 50 | 11 | 4 | 19180218 | |
| 001994 | | M H & MARY FRANCES MONTGOM | GUADALUPE R | 3 | 5 | 4 | 5 | 0 | 19140923 | |
| 001995 | | HENRY GRIFFIN CONSTRUCTION | GOAT CREEK | 3 | 11 | 11 | 7 | 6 | 19511231 | |
| 001996A | | KERRVILLE, CITY OF | GUADALUPE R | 3 | 75 | 44 | 22 | 75 | 19140404 | |
| 001998 | | C W SUNDAY ET AL | TOWN CREEK | 3 | 28 | 28 | 8 | 10 | 19591231 | |
| 002000A | | RIVERHILL COUNTRY CLUB INC | GUAD&CP MEETI | 3 | 350 | 160 | 22 | 70 | 19740429 | & CAMP MEETING CR, 8/31/87 |
| 002001 | | CARL D MEEK | GUADALUPE | 3 | 41 | 30 | 24 | 0 | 19241231 | |
| 002002 | | SHELTON RANCH CORPORATION | GUADALUPE R | 3 | 136 | 99 | 24 | 0 | 19241231 | |
| 002003 | | SHELTON RANCH CORPORATION | GUADALUPE R | 3 | 42 | 21 | 9 | 0 | 19171011 | |

APPENDIX B: SURFACE WATER RIGHTS HELD IN KERR COUNTY

| ADJUDI-CATION CERT. | PERMIT NUMBER | NAME OF OWNER | STREAM | U | AMOUNT OF DIVERSION AC.-FT./YR. | IRRIGATED ACRES | DIVERSION RATE CFS X 10 | RESERV. CAPACITY AC.-FT. | PRIORITY DATE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 002005 | | HARRIET BOCKHOFF ESTATE | GUADALUPE R | 3 | 59 | 98 | 13 | 0 | 19001231 | |
| 002006B | | SHELTON RANCH CORPORATION | GUADALUPE | 3 | 470 | 620 | 40 | 54 | 19521231 | AMEND 2/3/88, 6/18/90 |
| 002007 | | RAY ELLISON JR | SPRING CREEK | 3 | 31 | 31 | 9 | 50 | 19591231 | |
| 002009 | | FRANCIS C & WILLADEAN BOLEN | BUSHWACK CRE | 3 | 5 | 5 | 1 | 5 | 19701231 | |
| 002010 | | G ROBERT SWANTNER JR ET UX | BUSHWACK CRE | 3 | 7 | 5 | 1 | 5 | 19381231 | OUT OF 68.8 ACRE TRACT |
| 002011 | | H J GRUY | TURTLE&LT LAMB | 3 | 80 | 50 | 29 | 10 | 19401231 | ALSO LITTLE LAMBS CREEK |
| 002012 | | JOAN KISIDA | TURTLE CREEK | 3 | 1 | 1 | 9 | 5 | 19531231 | |
| 002013 | | FELIX R & LILLIAN STEILER REAL | WEST CREEK | 3 | 11 | 12 | 9 | 0 | 19531231 | |
| 002014 | | JAMES RICHARD TURNER ET AL | TURTLE CREEK | 3 | 26 | 23 | 11 | 0 | 19321231 | |
| 002015 | | JAMES E NUGENT | GUADALUPE R | 3 | 27 | 21 | 11 | 0 | 18871231 | |
| 002016 | | FRANK R HODGES | GUADALUPE R | 3 | 8 | 8 | 3 | 0 | 19461231 | |
| 002018 | | LEE ANTHONY MOSTY | GUADALUPE R | 3 | 154 | 94 | 22 | 0 | 19511231 | |
| 002020 | | ROBERT LEE MOSTY | GUADALUPE R | 3 | 60 | 30 | 7 | 0 | 19140622 | |
| 002021 | | RAYMOND F MOSTY ET AL | GUADALUPE R | 3 | 103 | 45 | 10 | 5 | 19141124 | |
| 002022 | | ROBERT LEE MOSTY | GUADALUPE R | 3 | 17 | 119 | 7 | 20 | 19141124 | |
| 002023 | | ROY A GREEN | GUADALUPE R | 3 | 7 | 3 | 11 | 0 | 19301231 | |
| 002024 | | CARL E RHODES | GUADALUPE R | 3 | 114 | 125 | 21 | 0 | 19321231 | |
| 002025 | | HARRY J WRAY ET AL | GUADALUPE | 3 | 155 | 80 | 11 | 0 | 19170424 | |
| 002026 | | ZANE H ROBINSON ET AL | GUADALUPE R | 3 | 125 | 80 | 12 | 0 | 19611231 | |
| 002029A | | ROLAND WALTERS | PRISON CANYON | 3 | 25 | 200 | 98 | 420 | 19720821 | & CO 010, 10/5/82 ADD DIV PT |
| 002030 | | TYSON SMITH | VERDE CR&UNNA | 3 | 266 | 133 | 27 | 120 | 19471231 | |
| 002031A | | JOSEPH PAUL MILLER ET UX | GUADALUPE | 3 | 115 | 80 | 16 | 0 | 19511231 | AMEND 11/4/85 |
| 002032 | | ROBERT JORRIE | GUADALUPE R | 3 | 10 | 6 | 1 | 0 | 19601231 | |
| 002033 | | JAVIER G REYES ET UX | GUADALUPE R | 3 | 90 | 90 | 33 | 0 | 19611231 | |
| 002034 | | CHESTER P HEINEN ET AL | GUADALUPE | 3 | 2 | 6 | 2 | 0 | 19611231 | |
| 002037 | | ARTHUR H ALLERKAMP ESTATE | CYPRESS CREEK | 3 | 30 | 38 | 7 | 0 | 19401231 | |
| 002038 | | HARRY E REEH | CYPRESS CR | 3 | 15 | 15 | 6 | 0 | 19651231 | |
| 002039 | | FRED SAUR | CYPRESS CREEK | 3 | 7 | 7 | 20 | 0 | 19641231 | |
| 002040 | | A C & DOROTHY PFEIFFER | CYPRESS CREEK | 3 | 10 | 5 | 10 | 0 | 19180925 | |
| 002041A | | THOMAS L BRUNDAGE ET AL | CYPRESS CR | 3 | 134 | 57 | 8 | 0 | 19551231 | AMEND 2/1/85 |
| 002042 | | E J & VIRGINIA DOWER | CYPRESS CREEK | 3 | 209 | 125 | 10 | 0 | 19641231 | |
| 002043 | | DEANNA D FOCKE ET AL | CYPRESS CREEK | 3 | 40 | 30 | 33 | 0 | 19760830 | |
| 002438 | | JAMES BROCK | N FK GUADALUPE | 3 | 30 | 18 | 13 | 30 | 19411231 | |
| 002439A | | DALE B & MARSHA G ELMORE | N FK GUADALUPE | 3 | 8 | 8 | 1 | 20 | 19371231 | ALSO REC |
| 002440 | | L F SCHERER | N FK GUADALUPE | 3 | 1 | 1 | 1 | 0 | 19611231 | |
| 002441 | | SILAS B RAGSDALE | N FK GUAD | 3 | 21 | 105 | 11 | 0 | 19411231 | |

## APPENDIX B: SURFACE WATER RIGHTS HELD IN KERR COUNTY

| ADJUDI-CATION CERT. | PERMIT NUMBER | NAME OF OWNER | STREAM | U | AMOUNT OF DIVERSION AC.-FT./YR. | IRRIGATED ACRES | DIVERSION RATE CFS X 10 | RESERV. CAPACITY AC.-FT. | PRIORITY DATE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 002442 | | LUTHER GRAHAM | HONEY CREEK | 3 | 28 | 14 | 8 | 17 | 19001231 | |
| 002443 | | JOHN H DUNCAN | HONEY CREEK | 3 | 40 | 20 | 22 | 25 | 19151231 | |
| 002444 | | SHELTON LAND & CATTLE CO ET A | S FK GUADALUPE | 3 | 6 | 3 | 2 | 17 | 19211231 | |
| 002445 | | CAMP MYSTIC INC | CYPRESS&SFGU | 3 | 12 | 15 | 6 | 0 | 19521231 | |
| 002446 | | BOB/KAT INC | S FK GUAD | 3 | 10 | 10 | 2 | 0 | 19271231 | |
| 002447 | | CAMP LA JUNTA INC | S FK GUADALUPE | 3 | 26 | 15 | 10 | 30 | 19281231 | |
| 002448 | | ALICE CYNTHIA SIMKINS | TEGENER CREEK | 3 | 6 | 5 | 6 | 0 | 19551231 | |
| 002449 | | B N SCHUMACHER | GUADALUPE R | 3 | 17 | 11 | 18 | 0 | 19261231 | |
| 002450 | | ROBERT L MOSTY ET AL | GUADALUPE | 3 | 158 | 117 | 27 | 0 | 19321231 | |
| 003904 | 003635 | CITY OF KERRVILLE | QUINLAN CR | 3 | 80 | 56 | 17 | 10 | 19780814 | & REC-2 RES-146-AC TR-EXPIRES 20 Y |
| 004223 | 004100 | SHELTON RANCHES INC | JOHNSON CR | 3 | 20 | 14 | 4 | 39 | 19820614 | |
| 004298 | 004096 | DR J FRED MULLINS | TOWN CR | 3 | 10 | 6 | 6 | 0 | 19830103 | |
| 004486 | 004181 | JAY & HILDA POTH | CYPRESS CR | 3 | 70 | 35 | 0 | 0 | 19840828 | RATE SEE 18-2041 |
| 005060 | 005060 | ROB L HARBISON | FALL BR CR | 3 | 10 | 12 | 9 | 0 | 19860520 | |
| 005122 | 005122 | JAMES C STORM | GUADALUPE | 3 | 75 | 50 | 6 | 8 | 19870319 | |
| 005208 | 005208 | JAMES F HAYES & MARY K HAYES | VERDE CREEK | 3 | 40 | 40 | 6 | 0 | 19881209 | |
| 005315 | 005315 | RODNEY ROBINSON ET UX | EAST TOWN | 3 | 0 | 0 | 0 | 83 | 19901005 | USING PRIVATE WATER |
| 005331 | 005331 | KATHLEEN B FLOURNOY ET AL | S FK GUADALUPE | 3 | 96 | 30 | 0 | 0 | 19901108 | |
| 005348 | 005348 | BYRON DONZIS | NF GUADALUPE | 3 | 5 | 4 | 1 | 0 | 19910305 | |
| 005352 | 005352 | BONITA OWNERS ASSOC | SF GUADALUPE | 3 | 2 | 2 | 1 | 0 | 19910328 | |
| 001997 | | DARRELL G LOCHTE ET AL | GUADALUPE | 4 | 143 | 0 | 18 | 0 | 19461231 | |
| 002003 | | SHELTON RANCH CORPORATION | GUADALUPE R | 4 | 10 | 0 | 0 | 0 | 19171011 | |
| 001932 | | PRESBYTERIAN MO-RANCH ASSE | N FK GUAD | 7 | 0 | 0 | 0 | 20 | 19290403 | |
| 001937 | | BOY SCOUTS- ALAMO AREA | BEAR CREEK | 7 | 0 | 0 | 0 | 10 | 19381231 | |
| 001956B | | RIVER INN ASSOC OF UNIT OWNE | S FK GUAD | 7 | 0 | 0 | 0 | 50 | 19361231 | |
| 001957 | | JOHN F JOBES | S FK GUAD | 7 | 0 | 0 | 0 | 10 | 19281214 | |
| 001963B | | LAWRENCE L GRAHAM ET AL | S FK GUADALUPE | 7 | 0 | 0 | 0 | 16 | 19170529 | AMENDS 5/26/83 CHG PUR USE & ADD R |
| 001967A | | SARAH HICKS BUSS | GUAD & TRIB | 7 | 20 | 0 | 3 | 20 | 19710802 | ALSO USE 1,AMD 3/19/91 |
| 001971 | | COUNTY OF KERR | GUADALUPE | 7 | 0 | 0 | 0 | 450 | 19550404 | |
| 001976 | | L D BRINKMAN ET AL | FESSENDEN BR | 7 | 0 | 0 | 0 | 184 | 19410725 | IMPOUNDMENT |
| 001999 | | KERRVILLE STATE HOSPITAL | UNNAMED | 7 | 44 | 0 | 0 | 44 | 19730604 | TRIB OF GUADALUPE |
| 002004 | | COUNTY OF KERR | GUADALUPE R | 7 | 720 | 0 | 0 | 720 | 19550404 | ALSO USE 8 |
| 002017 | | COUNTY OF KERR | GUADALUPE R | 7 | 0 | 0 | 0 | 87 | 19550404 | ALSO USE 8 |
| 002437 | | CHLOE CULLUM KEARNEY ET AL | N FK GUADALUPE | 7 | 0 | 0 | 0 | 100 | 19481231 | & DOM-LIVESTOCK |
| 002444 | | SHELTON LAND & CATTLE CO ETA | S FK GUAD | 7 | 0 | 0 | 0 | 10 | 19270729 | |
| 003846 | 003651 | T & R PROPERTIES | PALMER CR | 7 | 322 | 0 | 0 | 322 | 19781030 | |

## APPENDIX B: SURFACE WATER RIGHTS HELD IN KERR COUNTY

| ADJUDICATION CERT. | PERMIT NUMBER | NAME OF OWNER | STREAM | U | AMOUNT OF DIVERSION AC.-FT./YR. | IRRIGATED ACRES | DIVERSION RATE CFS X 10 | RESERV. CAPACITY AC.-FT. | PRIORITY DATE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 004007 | 003714 | PECAN VALLEY RANCH OWNERS | ELM CREEK | 7 | 0 | 0 | 0 | 157 | 19791105 | ALSO DOMESTIC & LIVESTOCK |
| 004034 | 003743 | SHELTON RANCHES INC | JOHNSON CR | 7 | 0 | 0 | 0 | 122 | 19800331 | 2 RES, SEE FILE, & ADJ 1974 |
| 005029 | 005029 | SOUTHEASTERN SAVINGS ASSOC | GUADALUPE | 7 | 0 | 0 | 0 | 12 | 19851030 | |
| 005322 | 005322 | E RAND SOUTHARD ET UX | FALL | 7 | 0 | 0 | 0 | 0 | 19901102 | 6 AF EXEMPT |

| U - TYPE OF USE |
|---|
| 1 - MUNICIPAL |
| 2 - INDUSTRIAL |
| 3 - IRRIGATION |
| 4 - MINING |
| 5 - HYDROELECT. |
| 6 - NAVIGATION |
| 7 - RECREATION |
| 8 - OTHER |
| 9 - RECHARGE |

# APPENDIX C

# ANALYTICAL RESULTS OF SELECTED COUNTY WELLS

| Well No. | | 57-57-703 | 68-01-5WWW#3 | 56-63-915 | 69-08-5WWW#2 | MW-GR | MW-CC | R-1 |
|---|---|---|---|---|---|---|---|---|
| Aquifer | Units | Hensell | Cow Creek/ Hosston | Lower Glen Rose/ Hensell | Hosston/ Sligo | Lower Glen Rose | Cow Creek/ Hensell | Hosston/ Sligo |
| Parameter | | | | | | | | |
| Total Alkalinity | ppm | 296 | 308 | 312 | 300 | 32 | 160 | n/a |
| TOC | ppm | 0.5 | 0.7 | 1.1 | 0.7 | n/a | n/a | 2.2 |
| Chloride | ppm | 120 | 55 | 20 | 22 | 18 | 11 | 2.6 |
| Chlorine Free/Total | ppm | n/a | n/a | 0 | 0 | n/a | n/a | 0 |
| Conductivity | umhos/cm | 1,421 | 992 | 876 | 969 | 1,377 | 328 | 658 |
| Fluoride | ppm | n/a | n/a | 1.4 | 2.2 | n/a | n/a | n/a |
| Total-Hardness | ppm | 553 | 426 | 433 | 475 | 859 | 206 | 261 |
| Iron | ppm | 1.2 | 0.3 | 5.6 | 0.4 | 2.3 | 1.8 | 0.07 |
| pH | ppm | 7.2 | 7.3 | 7.3 | 7.4 | 9.1 | 9.5 | n/a |
| Ammonia-Nitrogen | ppm | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Nitrate-Nitrogen | ppm | <0.2 | <0.2 | 1.3 | 0.5 | 0.4 | 0.6 | 0.6 |
| Nitrite-Nitrogen | ppm | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.02 |
| Total Phosphate | ppm | 0.003 | 0.004 | 0.008 | 0.009 | 0.008 | 0.002 | n/a |
| Total Solids | ppm | 929 | 647 | 581 | 681 | 1,458 | 268 | n/a |
| Residue, NonFilterable | ppm | 5 | 2 | 12 | 51 | 563 | 55 | n/a |
| Total Dissolved Solids | ppm | 924 | 645 | 569 | 630 | 895 | 213 | n/a |
| Sulfate | ppm | 194 | 129 | 175 | 138 | 772 | 39 | 24 |
| Turbidity | ntu | n/a | n/a | 32 | 3.5 | 68 | 39 | n/a |
| Calcium | ppm | 88 | 74 | 86 | 80 | 152 | 8 | 27 |
| Magnesium | ppm | n/a | n/a | 44 | 54 | n/a | n/a | 28 |
| Lead | ppm | n/a | n/a | 0.005 | <0.005 | n/a | n/a | n/a |
| Sodium | ppm | n/a | n/a | 22 | 23 | 25 | 22 | 39 |

DFW/KERRCTY.WK1

# ANALYTICAL RESULTS OF SELECTED COUNTY WELLS

| Well No. | | 56-64-605 | 56-52-301 | 56-61-506 | 56-64-205 | 69-06-901 | 56-62-304 | 56-61-601 |
|---|---|---|---|---|---|---|---|---|
| Aquifer | Units | Hosston | Glen Rose/ Hensell | Hensell | Lower Glen Rose | Hensell | Hensell | Hensell |
| Parameter | | | | | | | | |
| Total Alkalinity | ppm | 296 | 96 | 280 | 292 | 300 | 320 | 292 |
| TOC | ppm | 0.5 | 0.8 | 1.1 | 0.6 | 0.6 | 0.9 | 1.1 |
| Chloride | ppm | 82 | 20 | 26 | 32 | 27 | 14 | 23 |
| Chlorine Free/Total | ppm | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Conductivity | umhos/cm | 1,137 | 1,586 | 832 | 756 | 1,017 | 670 | 812 |
| Fluoride | ppm | 1.0 | 2.0 | 1.8 | 0.6 | 1.2 | 0.9 | 2.0 |
| Total-Hardness | ppm | 454 | 812 | 388 | 347 | 475 | 331 | 403 |
| Iron | ppm | 0.4 | 6.0 | 1.7 | 0.4 | 2.0 | 0.3 | 1.3 |
| pH | ppm | 7.4 | 7.2 | 7.4 | 7.4 | 7.3 | 7.5 | 7.6 |
| Ammonia-Nitrogen | ppm | n/a | n/a | <0.5 | n/a | n/a | <0.5 | <0.5 |
| Nitrate-Nitrogen | ppm | <0.2 | <0.2 | 0.4 | <0.2 | 0.3 | 0.4 | 0.4 |
| Nitrite-Nitrogen | ppm | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Phosphate | ppm | <0.001 | 0.006 | 0.007 | 0.002 | 0.003 | 0.002 | 0.004 |
| Total Solids | ppm | 740 | 1,052 | 495 | 493 | 667 | 439 | 575 |
| Residue, NonFilterable | ppm | 1 | 21 | n/a | 2 | 6 | 1 | 47 |
| Total Dissolved Solids | ppm | 739 | 1,031 | 541 | 491 | 661 | 440 | 528 |
| Sulfate | ppm | 145 | 528 | 101 | 49 | 195 | 33 | 101 |
| Turbidity | ppm | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Calcium | ppm | n/a | n/a | n/a | 54 | 81 | n/a | n/a |
| Magnesium | ppm | n/a | n/a | 54 | n/a | n/a | 36 | 45 |
| Lead | ppm | n/a | n/a | 0.008 | n/a | n/a | 0.027 | 0.018 |
| Sodium | ppm | 52 | n/a | 28 | 19 | 25 | 22 | 26 |

# ANALYTICAL RESULTS OF SELECTED COUNTY WELLS

| Well No. | | 56-63-402 | 69-07-902 | 57-57-703 | 68-01-5WWW#3 | 56-63-915 | 69-08-5WWW#2 |
|---|---|---|---|---|---|---|---|
| Aquifer | Units | Hensell | Hosston/ Sligo | Hensell | Cow Creek | Lower Glen Rose/ Hensell | Hosston/ Sligo |
| Parameter | | | | | | | |
| Total Alkalinity | ppm | 316 | 308 | 296 | 308 | 312 | 300 |
| TOC | ppm | 0.8 | 0.7 | 0.5 | 0.7 | 1.1 | 0.7 |
| Chloride | ppm | 19 | 19 | 120 | 55 | 20 | 22 |
| Chlorine Free/Total | ppm | n/a | n/a | n/a | n/a | 0 | 0 |
| Conductivity | umhos/cm | 673 | 945 | 1,421 | 992 | 876 | 969 |
| Fluoride | ppm | 1.5 | 1.8 | n/a | n/a | 1.4 | 2.2 |
| Total-Hardness | ppm | 347 | 454 | 553 | 426 | 433 | 475 |
| Iron | ppm | 0.1 | 1.8 | 1.2 | 0.3 | 5.6 | 0.4 |
| pH | ppm | 7.6 | 7.3 | 7.2 | 7.3 | 7.3 | 7.4 |
| Ammonia-Nitrogen | ppm | <0.5 | n/a | n/a | n/a | n/a | n/a |
| Nitrate-Nitrogen | ppm | 0.4 | 0.3 | <0.2 | <0.2 | 1.3 | 0.5 |
| Nitrite-Nitrogen | ppm | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Phosphate | ppm | 0.001 | 0.001 | 0.003 | 0.004 | 0.008 | 0.009 |
| Total Solids | ppm | 455 | 619 | 929 | 647 | 581 | 681 |
| Residue, NonFilterable | ppm | 18 | 5 | 5 | 2 | 12 | 51 |
| Total Dissolved Solids | ppm | 437 | 614 | 924 | 645 | 569 | 630 |
| Sulfate | ppm | 52 | 156 | 194 | 129 | 175 | 138 |
| Turbidity | ppm | n/a | n/a | n/a | n/a | 32 | 3.5 |
| Calcium | ppm | n/a | 70 | 88 | 74 | 86 | 80 |
| Magnesium | ppm | 41 | 51 | n/a | n/a | 44 | 54 |
| Lead | ppm | <0.005 | <0.005 | n/a | n/a | 0.005 | <0.005 |
| Sodium | ppm | 18 | 25 | n/a | n/a | 22 | 23 |

DFW/KERRCTY.WK1

# APPENDIX D

# Appendix D
# GROUND WATER MODELING

## MODFLOW FOR ASR - CITY OF KERRVILLE

The United States Geological Survey (USGS) three-dimensional finite difference ground water flow model MODFLOW was used for simulation of the Lower Trinity aquifer in the Kerrville area as part of the UGRA ASR project. The model allowed prediction of the aquifer's response to projected city ground water demands and the use of ASR in the Kerrville area. The Kerrville project team selected this model for its three-dimensional simulation and time-discretization capabilities and for its variable grid feature.

MODFLOW is formulated with a modular structure, in which similar model functions simulating various hydrologic processes are grouped. The processes available for simulation include wells, rivers, recharge, drains, and evapotranspiration. This modular structure allows the inclusion and/or exclusion of the hydrologic processes that affect the flow of ground water. In this way, the user may choose which processes are important in the ground water system to be modeled, and simulate only those processes. Since the Lower Trinity (Hosston-Sligo) is a deep semi-confined system, only the well and recharge features were utilized in the Kerrville model.

To set up the MODFLOW model, a grid block is created to approximate the physical area of the geologic system of interest. The grid block is then subdivided into a mesh of blocks called cells, which are described in terms of rows, columns, and layers. The center of each is called a node. Spacing of the nodes is chosen by the user so that the hydraulic properties over the extent of the cell can be assumed to be fairly uniform. This variable grid spacing feature enables the user to specify closely-spaced nodes in areas where physical data, such as transmissivity, layer thicknesses, and storage coefficient, is abundant, and widely-spaced nodes where data is sparse. This discretization of the hydrogeologic system in space, in addition to time, allows an approximate three-dimensional solution, through the finite-difference method, of the partial-differential equation which describes ground water flow in a continuous system. Ground water heads are calculated by MODFLOW at each cell's center point, or node, as a function of time.

For Kerrville, the effective model grid covered approximately 156 square miles and was subdivided into 30 columns, 34 rows, and two layers (representing the Hosston-Sligo and the Middle Trinity). Aquifer parameters for each cell were estimated based on aquifer tests conducted as part of the ASR study and published ground water resource reports. These parameters were then calibrated within the model to actual field data from aquifer tests.

The period of simulation in MODFLOW can be divided into a series of stress periods, within which certain stress parameters, such as pumping and recharge rates, are constant. Each stress period is divided into a series of discretized time steps, during which multiple iterations of calculations yield the head at each model node through iterative solution methods.

In the Kerrville model, each month was simulated as a separate stress period, during which the demands on and/or recharge to the ground water system were input at an average monthly rate. Water levels in the Hosston/Sligo were predicted by the model at the end of each month from 1992 until 2005, based on the projected ground water demands and projected volumes of water available for recharge through the ASR well and various hypothetical ASR wells. In this way, the projected decline of water levels with increasing demand on the Hosston-Sligo was simulated, as was the benefit of utilization of ASR.

## WELSIM - KERR COUNTY

The modeling for the county water resources plan was conducted using WELSIM, a computer program developed by CH2M HILL for wellfield simulation. WELSIM is an analytical model, designed to calculate the drawdown caused in an aquifer by a single well or by several wells operating simultaneously. The calculations are made using one of several widely accepted analytical techniques for describing well hydraulics, such as the Theis method. Ground water drawdown and/or water levels are calculated at each grid point as if it was an observation well, using the principle of superposition.

### ASSUMPTIONS

WELSIM was utilized to model the Middle Trinity, which is comprised of the Lower Glen Rose, the Hensell, and the Cow Creek, and supports most local supply wells across the county. The aquifer parameters used in the model generally represent conditions in the Hensell sand, because most of the available data is from this zone, and because it is the most transmissive zone of the Middle Trinity.

One of the basic assumptions used in the setup of the county simulation model was that the aquifer could be represented by the Theis equation for a confined system. It is an accepted position that the Hensell sand is not a true confined system, but receives some recharge from the overlying Lower Glen Rose, and provides recharge to a certain degree in the southeastern half of the county to the underlying Cow Creek limestone and the Hosston-Sligo formation (Lower Trinity). On a county-wide basis, however, the leakage parameters are not well-defined, and were not added to the model simulation. Ignoring recharge through leakage is considered to be conservative, therefore, the model will arrive at a worst-case scenario with respect to drawdown.

Another assumption is that the WELSIM model is based on a uniform and homogeneous grid. The model assumes that the transmissivity and storage coefficient are uniform throughout the simulated aquifer. Although actual aquifer properties are likely to vary widely throughout the study area, the scale of the county-wide model is such that use of average values are not likely to significantly hinder the overall predictive capabilities of the model. A numerical model such as MODFLOW would be required to simulate spatial variations in the aquifer, and not enough physical data is available at this time for the Middle Trinity to allow such a simulation.

Although WELSIM is capable of utilizing well efficiency in its drawdown calculations, well efficiency information is not currently available for a large number of Hensell supply wells. The county model ground water demands were simulated using a series of hypothetical well locations, and the wells were assumed to be operating at a relatively high efficiency. It is likely that assuming a high well efficiency may not be representative of a majority of the Middle Trinity supply wells, and this fact should be considered when reviewing the model-projected drawdowns in the Hensell. Drawdowns may be significantly higher in actual wells under similar demand conditions.

Pumping rates in the hypothetical wells were assumed to be on the order of 30 to 100 gpm for the model simulation. This range was based on reported pumping rates. The model, however, simulates annual average pumping rates on a continuous basis, which will de-emphasize aquifer recovery and peak pumping. In actuality, Middle Trinity pumpage will vary both daily and seasonally, resulting in potential recovery of the water levels and/or peak pumping, both of which may significantly affect drawdowns.

## CALIBRATION OF MODEL

Existing water level data in Hensell wells throughout the county were used to create a regional ground water contour map. Since very few data points were available for concurrent time periods, all available data as presented in TWDB Report 273 and collected recently by the UGRA was combined to create a compilation of water levels to approximate the average ground water surface across the county. Considering its origins, the resulting contour map (Figure D-1) correlates relatively well with Report 273's depiction of the Middle Trinity ground water surface.

Figure D-1 demonstrates an average ground water gradient of approximately 0.001, or 5 feet per mile. This value, along with a ground water level at the origin of the grid of 1563 feet msl and a direction of flow of 40 degrees (clockwise from east) was used to provide the model with a regional ground water gradient which approximates steady-state conditions. The calculated contour map is illustrated in Figure D-2. This figure also shows the model grid. A spacing of 2 miles between grid points was used in the simulations.

Transient calibration was achieved by varying transmissivity and storage coefficients so that resulting drawdown was close to that demonstrated through recent selected UGRA pumping tests. These tests were of too short duration to give detailed information of the aquifer on any more than an extremely localized scale, however, and the transient calibration was refined using hydrogeologic judgement based on reported regional data.

The average transmissivity selected for use in the model simulations was 3000 gpd/ft, with an average storage coefficient of 0.0005. It should be noted that significant variation in localized transmissivity and aquifer storage capacities is likely to occur across the county, and may significantly affect actual drawdowns in some wells based on their locations and open intervals. The model is highly sensitive to these values. For example, if a transmissivity of 2,000 gpd/ft and storage coefficient of .0001 is used instead, maximum calculated drawdowns after only eight months simulation time change from 97 feet to 212 feet.

## DEMAND SIMULATIONS

Two ground water demand simulations were run using the calibrated model. The demand predictions were made at ten-year intervals, and for simplification, these values were assumed to represent the average demand for ten years surrounding each prediction year. For example, the average annual demand used for 1990 was also assumed for each year up to 1995, at which time the average annual projected demand for the year 2000 came into effect, until the year 2005. Drawdowns and water levels were printed at each ten-year interval up to 2040.

The ground water demands were projected for eight high usage areas of the county: Ingram, City of Kerrville, Kerrville North, Kerrville South, Airport, Orchard Irrigation (southwest of the Airport area), Center Point, and an area referred to as Eastern County (located along the eastern county boundary). These demands were met through the model by simulating wellfields in each area. The maximum number of hypothetical wells used by the model in any area was 9, based on an average approximate pumping rate of between 30 and 100 gpm. Some of the wellfields with lower total demands consisted of fewer wells to balance out the pumping rates.

Based on reported information for Hensell wells, it was assumed for purposes of this project that any drawdown beyond 200 feet would likely result in water levels sinking below the casing, and probably the pump, in the average Hensell well. For the simulation using the present surface water permit, projected demands were so high that this estimated allowable drawdown was exceeded in the Kerrville Airport area by the year 2000. Further refinement of this simulation was therefore required, and demands between the years 1990 and 2000 were estimated based on a straight-line projection. A drawdown of approximately 200 feet was reached for this simulation by 1995. Drawdowns of 200 feet were not reached in the simulation of 4760 ac-ft/yr additional surface water availability until approximately 2035.

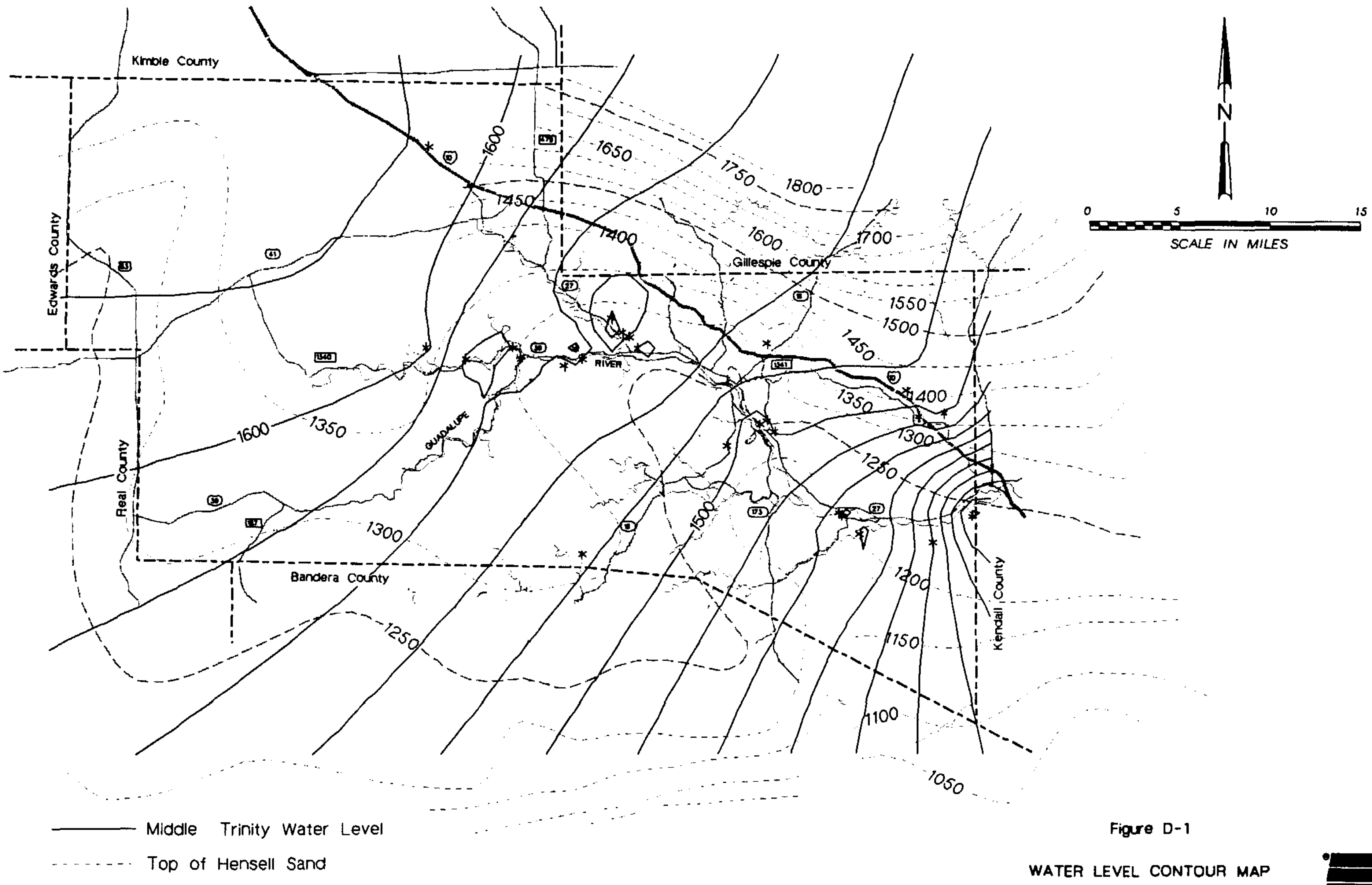


Figure D-1

WATER LEVEL CONTOUR MAP
HENSELL WELLS ONLY

CH2M HILL

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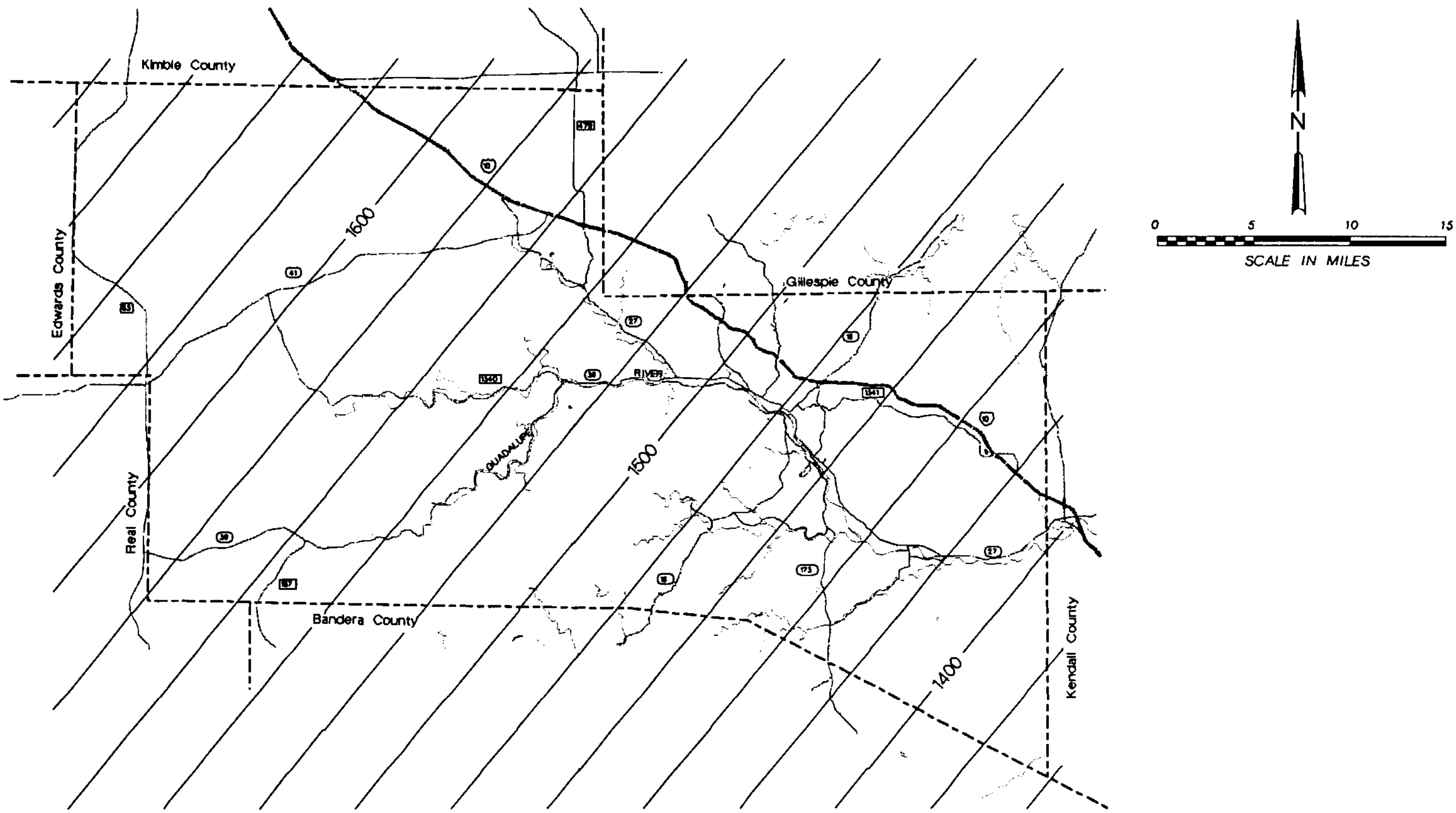


Figure D-2

CALCULATED GROUNDWATER
WATER LEVELS

CH2M HILL

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# APPENDIX E

# Kerr County

# Water Conservation Plan

# Table of Contents

# INTRODUCTION

## PURPOSE

A Water Conservation Plan is required as a part of an application submitted by a political subdivision to the Texas Water Development Board for financial assistance from the Development Fund or the Water Loan Assistance Fund. Furthermore, a successful application is required to have a program in place before loan funds can be released. The origin of these requirements is action taken by the 69th Texas Legislature in 1985. Conservation requirements were established by a House Bill (HB) 2 and House Joint Resolution (HJR) 6. On November 5, 1985, Texas voters approved an Amendment to the Texas Constitution that provided for the implementation of HB-2.

Water used in the residential and commercial sector involves the day to day activities of all cities of the State and includes water used for bathing, cooking, toilet flushing, fire protection, lawn watering, swimming pools, laundry, dishwashing, car washing and sanitation. Since the early 1960's per capital water usage in the States has increased about four (4) gallons per person, per decade. More important, per capital/water use during droughts is usually about one-third greater than during periods of average precipitation.

The objective of a conservation program is to reduce the quantity required for each water using activity, in so far as is practical to the implementation of efficient water use practices. The program are tools that water purveyors should have available to operate effectively in all situations.

The purpose of this report is to present the data collected, alternatives, and elements selected for the Kerr County Water Conservation Plan and to provide procedures and information for the implementation of the plan.

## PLANNING AREA

The planning area is the area served by the UGRA. The boundaries of the UGRA are conterminous with the boundaries of Kerr County. Facilities include:

- Upper Guadalupe Dam
- 105 Acre Pumpout Reservoir
- 5.0 mgd Water Treatment Plant
- Regional Environmental Laboratory

UGRA Activities:

- Water supply to City of Kerrville as a wholesale customer.
- Regional water testing.
- River flow and climatological data collection.
- Flood sensing and alert program.
- Investigations of future water supply.

Kerrville is the UGRA's only water customer with treated water supplied at $0.83 per 1,000 gal. The City of Kerrville adopted a water conservation and drought contingency plan in 1990 which is included as Appendix E of the Kerr County Regional Water Plan (Phase I).

Most of the areas outside of Kerrville are served with on-site septic systems for waste-water disposal. Kerr County now limits septic systems to a minimum of 1 acre per residence.

Not all of the water systems in Kerr County are metered, and most systems have a uniform rate structure (i.e., a base rate or minimum for the first increment and a uniform rate for all use above the minimum).

UGRA has already begun gathering data on water use and ground water levels in Kerr County. They will continue this effort and expand it to gather as much water use information as is available.

## PUBLIC INVOLVEMENT IN PLANNING PROCESS

The UGRA holds board meetings on the second Tuesday of each month at 2:00 p.m. Meetings are open to the public, and citizens are free to speak on any subject during the portion of the meeting designated for this purpose.

Special interest groups located in Kerr County include:

- Kerrville Chamber of Commerce
- Kerr County Economic Development Foundation
- Headwaters Underground Water Conservation District

## SYSTEM AUDIT/PROBLEMS

The UGRA has contact with most water systems through the water testing services of the UGRA Laboratory. This contact will facilitate further data collection efforts.

The major water system problems are:

- Metering is not universal
- Condition of supply systems is unknown
- Water use and unaccounted water volumes cannot be determined
- Some systems are inadequate to meet demand and treatment requirements
- Ground water sources may be limiting.

## ALTERNATIVES

Water conservation methods are typically divided into two (2) categories, Demand Management Methods and Supply Management Methods. Demand Management

# WATER CONSERVATION PLAN

## INTRODUCTION

The purpose of a Water Conservation Plan is to reduce the quantity required for each water using activity, insofar as is economically feasible and physically practical, through the implementation of efficient water use practices. Many communities throughout the United States have used conservation measures to successfully cope with various water and wastewater problems. Reduction in water use of as much as 25% or more have been achieved, but the normal range is from 5 to 15%. As a result of reduced water use, wastewater flows have also been reduced by 5 to 10%.

Nine (9) principal water conservation methods to be considered in preparing a water conservation are as follows:

- Education and Information
- Plumbing codes for new construction
- Retrofit programs
- Conservation oriented water rate structures
- Universal metering and meter repair and replacement
- Water conserving landscaping
- Leak detection and repair
- Recycling and reuse
- Means of implementation and enforcement

## UTILITY EVALUATION

The UGRA presently serves only the City of Kerrville with treated surface water. The UGRA's jurisdiction covers all of Kerr County. Therefore, the UGRA can implement water conservation education and awareness programs county-wide. The Texas Department of Health (TDH) currently has records listing 101 water suppliers in Kerr County not including UGRA and City of Kerrville. The Texas Water Commission has certificated 31 water supply utility areas in Kerr County. The UGRA is not presently contractually associated with any of these systems and cannot require conservation efforts, but goal No. 5 of UGRA goals is "To develop and promote programs which encourage water conservation and wise use of this limited resource in Kerr County."

Water use records for all of the systems in Kerr County are not available, but it is estimated that 5,900 ac-ft/yr is used by 36,304 people, resulting in 145 gpcd. More detailed information on water use is unavailable. Since many of the systems rely on wells, the yield or well capacity often limits supply.

methods deal with water use on the downstream side of a customer meter. Demand management provides for education or incentives to reduce the water use by the consumer. This method of conservation generally results in a decrease in water revenues because less water is purchased from the City.

Supply Management Methods deals with the utility's water system upstream of the customer's meter. The goal of supply management is to improve efficiency and reduce waste within the production, treatment, and distribution system. Supply management usually results in decreased costs to the utility as water losses in the system are reduced.

## DEMAND MANAGEMENT ALTERNATIVES

### *Education and Information:*

The most readily available and lowest cost method of promoting water conservation is to inform water users about ways to save water inside homes and other buildings, in landscaping and lawn uses, and in recreational uses. An effective education and information program can be easily and inexpensively administered by the Upper Guadalupe River Authority. Materials available from the American Water Works Association, Texas Water Development Fund, and other similar associations can easily be made available to the four (4) entities involved with the UGRA for distribution to their customers, through hand outs, mail outs, and other sources. All four (4) entities have adopted the Kerrville Times as their official newspaper. This publication can be used to print articles concerning water conservation. The use of various radio stations in the area, together with public and cable television systems, can also be utilized for this purpose.

### *Plumbing Codes:*

Water saving plumbing codes for new construction and for replacement of plumbing in existing structures may be adopted. The standards recommended by the Texas Water Development Fund represent readily available technologies and do not involve additional costs when compared with "standard" fixtures. Water conserving plumbing codes can be specially tailored to be adopted by each individual entity, in addition to the Standard Plumbing Code 1985 edition with Appendix J. The UGRA will work with Kerr County to promote the use of the Standard Plumbing Code on a county-wide basis in conjunction with their septic tank program. The state-wide water-conserving fixture standards will also aid in this effort.

### *Retrofit Programs:*

The UGRA should make information available through its education program for plumbers and customers to use when purchasing and installing plumbing fixtures, lawn watering equipment, or water devices such as low-flow shower heads or toilet damns that reduce water use by replacing or modifying existing fixtures or appliances should also be provided.

### *Water Rate Structures:*

A water conservation oriented rate structure usually takes the form of an increasing block rate, although continuously increasing rate structures, peak or seasonal load rates, excess use fees, and other rate forms can be used. The increasing block rate structure is the most commonly used water conservation rate structure. Separate rate structures are usually used for commercial, institutional, and industrial customers. UGRA will work with the various utilities to encourage adoption of water conservation rate structures.

### *Water Conserving Landscaping:*

In order to reduce the demands placed on a water system by landscape watering, the city or utility should consider methods that either encourage, by education and information, or require, by code or ordinance, water conserving landscaping by residential customers and commercial establishments engaged in the sale or installation of landscape plants or watering equipment. Because Kerr County is located in the Hill Country, it has a moderate annual average rainfall. The need for outdoor watering is higher than for wetter climates. Some agricultural land in the area is irrigated. Although not made a specific section of the Conservation Plan, water conserving landscaping information will be made available through the Information/Education Section.

## SUPPLY MANAGEMENT ALTERNATIVES:

### *Universal Metering*

All public water supply utilities should master meter their water source. In addition, all users, including the utility itself, should be metered. A regularly scheduled maintenance program of meter repair and replacement also needs to be established to ensure that proper metering is taking place. Metering and meter repair and replacement, can be used in conjunction with other programs such as leak detection and repair and, thereby, save significant quantities of water. Nearly all sales by the various entities in Kerr County are metered, with the exception of a few utility owned facilities. Currently, only the City of Kerrville has a regular meter repair replacement program. The UGRA will work with utilities to encourage installation of master and individual meters to account for all water use.

### *Leak Detection and Repair:*

A continuous leak detection, location, and repair program can be an important part of a water conservation plan. An annual water accounting or audit should be part of the program. Sources of unaccounted for water, once located, should be immediately corrected. Utility employees for the various entities periodically check for leaks when reading meters and when driving around the city during regular maintenance. Major leaks are usually quickly detected by either city employees or customers and are repaired immediately. Soil in the area is generally shallow and, therefore, leaks show up at the ground surface quite readily. Leak detection technology is also available in the form of electronic sonic devices. UGRA can purchase leak detection equipment for loan to various utilities.

### *Recycling and Reuse:*

A city or utility should evaluate the potential of recycling and reuse because these methods may be used to increase water supplies in the utility's service area. Reuse can be especially important where the use of treated effluent from industry, a municipal system, or agricultural return flows replace existing uses that currently require fresh water from a city or utility supply. Recycling in-plant process or cooling water can reduce the amount of fresh water required by many industrial operations. Currently, no entity in Kerr County has a water reuse program. Because of its size and daily flows, the reuse of treated effluent for irrigation could prove to be economical for the City of Kerrville. In addition, the City of Kerrville has a municipal golf course. The use of treated effluent for irrigation for this facility is possible. UGRA will encourage reuse and recycling where it is appropriate and economical.

### *Aquifer Storage and Recovery*

The UGRA is investigating using its recently completed aquifer storage and recovery project as a water supply management tool. Storage underground would potentially reduce storage loss by eliminating the evaporative loss that occurs in a surface storage reservoir.

## PLAN DESCRIPTION

Based on the evaluation of alternatives available to Kerr County for conserving water, the following elements have been selected as those best suited to the needs of the County for water conservation:

### *Demand Management*

Public education and information
Water conserving plumbing code for new construction
Retrofit programs
Water rate structures

### *Supply Management*

Universal metering
Meter repair and replacement
Leak detection and repair
Recycling/reuse

The goal of this water conservation plan is a reduction of 15% in the consumption of water per connection to the various systems by 2040.

### *Public Education and Information.*

A program of public education and information to promote water conservation by the public will be instituted. The program will include the following:

Educational materials will be made available twice a year. The semi-annual distribution will be timed to correspond with the peak summer and winter demand periods. The initial pamphlet will explain the purpose of the Conservation Plan, and will coincide with a published article in educational materials will present various water conserving methods, including plumbing fixtures and devices available for retrofit or addition, water conserving methods in landscaping and irrigation, and good water use practices to conserve water. UGRA will develop and acquire sufficient educational materials for county-wide distribution. The materials will be made available on request by cities and utilities.

Regular Articles will be published in the Kerrville Times at times corresponding to the distribution mentioned above, and more often as conditions warrant. As mentioned earlier, the Kerrville Times is the official newspaper for all four (4) entities.

The program will cover the water saving methods listed in Attachment B of Appendix E. The UGRA will put special emphasis on the need to insulate pipes to prevent freezing in cold weather, retrofitting of plumbing fixtures and devices, and landscaping conservation methods. The energy savings associated with a water conservation program will also be emphasized.

Assistance in obtaining publications and materials for the program will be obtained from:

> Texas Water Development Board
> American Water Works Association
> American Public Works Association

During the first year of the program, individual pamphlets and flyers will be developed, tailored to the specialized needs and goals of the County.

### *Water Conserving Plumbing Code*

The entities in Kerr County will adopt appropriate plumbing codes for new construction and for replacement of plumbing in existing structures, and will be water conserving by nature. The UGRA will encourage all utilities in Kerr County to adopt and promote the use of the Standard Plumbing Code with Appendix J.

### *Retrofit Programs*

The UGRA will make information available through its education program for plumbers and customers to use when purchasing and installing plumbing fixtures, lawn watering equipment, or water using appliances. Information regarding retrofit devices such as low-flow shower heads or toilet dams that reduce water use by replacing or modifying existing fixtures or appliances will also be provided. Kits containing retrofit devices can be budgeted and made available to member entities for distribution to customers.

### *Universal Metering and Meter Repair and Replacement*

The UGRA will encourage installation of master meters and individual meters on all utility systems in the County. These meters should be tested and replaced on a regular basis. The UGRA will consider providing a test and repair shop for the meters, providing a central shop for all of the public water systems.

### *Water Rate Structures*

In order to meet the requirements set out by the Texas Water Development Fund for conservation oriented rate structures, UGRA will encourage each entity in Kerr County to implement conservation oriented water rate structures as soon as possible.

### *Leak Detection and Repair*

The entities in Kerr County currently have no leak detection programs. UGRA will encourage each entity to participate in a leak detection program. The program should include the following elements:

a. Monthly water use accounting by the Billing Department which identifies high water used after the service meters indicate leaks.

b. Visual inspection by utility employees who keep a constant watch out for abnormal conditions indicating leaks.

c. An adequate maintenance staff which is available to repair any leaks.

d. The UGRA and/or each entity will purchase leak detection equipment, and incorporate this device as a regular part of the leak detection program.

*Recycling/Reuse*

As previously noted, the City of Kerrville is the only entity within Kerr County with the capability of reuse and recycling of treated effluent. No recycling or reuse is anticipated by Ingram or Kerr County. The UGRA will encourage recycling and reuse in those instances where it is economically feasible and physically practical.

## IMPLEMENTATION/ENFORCEMENT

The UGRA will administer the Kerr County Water Conservation Program. In this function, the UGRA will oversee the execution and implementation of all elements of the program. The UGRA will also be responsible to oversee the keeping of adequate records for program verification. Each entity will be responsible for furnishing all information needed and requested by the Authority.

In addition to the above, the UGRA will be responsible for the submission of an annual report to the Texas Water Development Board on the Water Conservation Plan. The report will include the following elements:

1. Progress made in the implementation of the program
2. Response to the program by the public
3. Quantitative effectiveness of the program
4. Proposed administration and goals of plan for following year

The program will be initiated through adoption of the Water Conservation Plan by resolution by all of the sponsors of the Kerr County Regional Water Plan. In addition, the entities of Kerr County will adopt a water conserving plumbing code.

Each entity upon adoption will provide certified copies of all ordinances and resolutions concerning water rates, plumbing codes, and other regulatory documents necessary for the administration of this plan, including all updates.

The initial budget for implementing the water conservation plan should be approximately $5,000 to be funded by UGRA.

# DROUGHT CONTINGENCY PLAN

## INTRODUCTION

Drought and other uncontrollable circumstances can disrupt the normal availability of a community or utility water supply. Kerr County is fortunate to have access to surface water and ground water. The UGRA and the City of Kerrville will be able to utilize Aquifer Storage Recovery (ASR) to augment ground water levels and conjunctively use ground and surface water. Since ASR has proven to be successful, it provides the possibility of recovering stored ground water at increased pumping rates for a limited duration (when surface water is unavailable due to drought) without dewatering the Lower Trinity aquifer.

The City of Kerrville has not had to enact a water conservation/emergency since the Summer of 1980, when Ordinance 80-21 was passed because of the drop in the aquifer and lack of summer rains. Other areas of the County were equally affected even through the water conservation/emergency ordinance did not extend to them.

A triggering criteria during a drought period has been established to include the flow of water from the Guadalupe River as well as the water level in the Lower and Middle Trinity aquifers. Below is a three-step curtailment plan which will be enacted depending on the river flow and the water level of the aquifers.

## TRIGGER CONDITIONS

1. **Mild Drought.** When the flow of the Guadalupe River falls below 25 cfs which passes through at the UGRA dam.

2. **Moderate Drought.** When the flow of the Guadalupe River falls below 15 cfs which passes through at the UGRA dam.

3. **Severe Drought.** When water cannot be pumped from the Guadalupe River and the level in the aquifer supplying the City of Kerrville's wells drops to 1,260 feet NGVD (Lower Trinity), and the level in the Middle Trinity aquifer supplying the area around the Kerrville airport drops below 1,000 NGVD.

## DROUGHT CONTINGENCY MEASURES

1. **Mild Drought Measures:**

   - Inform public by giving notice of mild drought to customers.

   - Voluntary curtailment of water use will be encouraged.

- The UGRA staff will contact all major users and request their cooperation in curtailing water use.

2. **Moderate Drought Contingency Measures:**

    - Inform public by giving notice of moderate drought to customers; the notice will be posted as well as notifying the news media of the moderate drought.

    - The UGRA will request cooperation in the curtailment of water use.

3. **Severe Drought Contingency Measures:**

    - Public will be informed as mentioned above.

    - There will be mandatory water curtailment issued to all City of Kerrville water users as described below.

    - Ordinance 80-21 (Attachment C) will be enacted by the Kerrville City Council.

    - All utilities will be requested to implement mandatory water curtailment.

## SEVERE CONDITIONS CURTAILMENT PROGRAM

- Continue all relevant actions defined in the preceding phase.
- Request banning all outdoor water use
- Develop and provide suggested limits on water use by both commercial and residential users

## INFORMATION/EDUCATION

As a component of the Information/Education section in the Water Conservation Plan, the purpose and effect of the Drought Contingency Plan will be communicated to the public through articles in the local newspapers.

When trigger conditions appear to be approaching, the public will be notified through publication of articles in the local newspapers.

When trigger conditions have passed, the local newspapers will publish notification that the drought contingency measures are abated for that condition, and if applicable, will outline measures necessary for the reduced condition.

Throughout the period of a trigger condition, regular articles will appear to explain and educate the public on the purpose, cause, and methods of conservation for that condition. Also, a graph (Attachment D, page 29 of Appendix E) will be used daily in the local newspapers to show how much water was used the previous day.

## IMPLEMENTATION/ENFORCEMENT

It will be the responsibility of the UGRA to monitor the status of the water levels in designated monitor wells and the flow in the main stem and tributaries of the Guadalupe River. When a trigger condition is reached, the UGRA will notify each entity to begin implementation of the Drought Contingency Plan.

The UGRA will continue to monitor the water emergency until it is determined that a trigger condition no longer exists and then advise all entities of the change in condition.

## UPDATE OF TRIGGER CONDITIONS

Annually, the UGRA will examine the production requirements and ability to maintain these requirements to determine if trigger conditions need to be re-established.

# APPENDIX F

# CITY OF KERRVILLE
# WATER CONSERVATION
# AND
# DROUGHT CONTINGENCY PLAN

Submitted By: City of Kerrville Staff
January 4, 1991

TABLE OF CONTENTS

Title

# CITY OF KERRVILLE
# WATER CONSERVATION AND
# DROUGHT CONTINGENCY PLAN

## Introduction

### A. Purpose

The Texas Water Development Board has promulgated Financial Assistance Rules which require water conservation planning for the City of Kerrville. The origin of these requirements is action taken by the 65th Texas Legislature in 1985. The conservation requirements were established by House Bill (HB) 2 and House Joint Resolution (HJR) 6. On November 5, 1985, Texas voters approved an amendment to the Texas Constitution that provided for the implementation of HB 2. This document provides specific guidelines for developing conservation and drought contingency plans and programs that will meet the regulatory requirements of the Texas Water Development Board.

Since the early 1960's, per capita water use in the state has increased approximately four (4) gallons per capita per decade. More important, per capita water use during droughts is typically about one-third greater during periods of average precipitation.

Water used in residential and commercial sectors involve day-to-day activities of all citizens of the state and includes water used for drinking, bathing, cooking, toilet flushing, fire protection, lawn watering, swimming pools, laundry, dish washing, car washing, and sanitation. The objective of a conservation program is to reduce the quantity required for each water activity, where practical, through implementation of efficient water use practices. The drought contingency program provides procedures for both voluntary and mandatory actions placed in effect to temporarily reduce usage demand occurring during a water shortage crisis. Drought contingency procedures include water conservation and prohibition of certain uses. Both are tools that city officials will have available to effectively operate in all situations.

### B. Planning Area

The City of Kerrville water system is dual in nature. The City has nine (9) operational wells which take water from the Lower Trinity or the Hosston, Silago, Cow Creek formations. These nine (9) wells are capable of producing 6.5 mgd for a period of approximately 1 1/2 to 2 months, and are used as a secondary water source. The primary source is the Upper Guadalupe River Authority (UGRA) which can produce a maximum of slightly over 5.0 mgd. The City of

Kerrville is the U.G.R.A.'s only customer. The maximum daily all time high was 7.8 mgd, reached in August 1985. The U.G.R.A. is in the process of developing an Aquifer Storage Recovery program, and if successful, will enable us to recharge our aquifer giving us more flexibility in drought periods and the possibility of Kerrville becoming a regional water source for the area.

C. Goal I

Many communities throughout the United States have used conservation measures to successfully cope with various water and wastewater problems. Reductions of 25 percent have been achieved in some communities.

The City of Kerrville's average daily usage is relatively high, 166 gallons per capita per day. It is the goal of the water conservation program to reduce water consumption by 15 percent (465,000 gallons per day) which equals 169,725,000 gallons per year. Kerrville's average daily consumption for 1989 was 3.1 million gallons per day.

Goal II

It is the goal of the drought contingency plan to reduce water use, during an emergency situation or prolonged drought, by 35 percent or dropping between 5.0 mgd and 4.5 mgd. The drought contingency program includes those measures that can cause the city to significantly reduce water use on a temporary basis. These measures involve voluntary reductions, restriction and/or elimination of certain types of water use, and water rationing. Because the onset of an emergency condition is often rapid, it is important that the city be prepared in advance. Further, the citizen or customer must know that certain measures not used in the water conservation program may be necessary if a drought or other emergency condition occurs.
Nine principal water conservation methods to be considered in preparing the water conservation plan are considered herein as follows:

1. Education and Information
2. Plumbing Codes
3. Retrofit Programs
4. Conservation Oriented Water Rate Structure
5. Universal Meter and Meter Repair
6. Water Conservation Landscaping
7. Leak Detection and Repair
8. Recycling and Reuse
9. Means of Implementation and Enforcement

D. Utility Evaluation Data

1. Population of Service Area 18,700

2. Area of Service 15.84 Square Miles

3. Number of Water Connections in Service Area

| | | |
|---|---|---|
| a. | Residential | 6096 |
| b. | Commercial | 881 |
| c. | Industrial | .01 |

4. Net Rate of New Connection Additions in 1989 (less disconnects)

| | | |
|---|---|---|
| a. | Residential | 49 |
| b. | Commercial | 14 |
| c. | Industrial | 0 |

5. Water Use Information

a. Water Production 1,116,165,000 (1989)
b. Average Water Production 1,052,789,500 (1988-89)
c. Average Monthly Production 87,732,458 (1988-89)
d. Estimated Monthly Water Sales by Category (gallons)

| Month | Residential | Commercial | Industrial | Total |
|---|---|---|---|---|
| Jan. | 35,357,800 | 26,512,100 | 267,800 | 62,137,700 |
| Feb. | 31,418,100 | 20,561,600 | 253,100 | 52,232,800 |
| Mar. | 35,694,500 | 27,407,700 | 276,800 | 63,379,000 |
| Apr. | 41,392,500 | 27,453,400 | 277,300 | 69,123,200 |
| May | 42,683,700 | 29,934,400 | 302,300 | 72,920,400 |
| June | 64,543,900 | 41,770,300 | 421,900 | 106,736,100 |
| July | 89,132,900 | 51,914,800 | 524,400 | 141,572,100 |
| Aug. | 82,079,700 | 49,956,300 | 504,600 | 132,540,600 |
| Sep. | 64,491,000 | 40,093,400 | 405,000 | 104,989,400 |
| Oct. | 49,385,400 | 38,797,300 | 391,900 | 88,574,600 |
| Nov. | 35,370,900 | 28,244,700 | 285,300 | 63,900,900 |
| Dec. | 37,528,600 | 26,673,500 | 269,400 | 64,471,500 |
| Total | 609,079,000 | 409,319,500 | 4,179,800 | 1,022,578,300 |

| | | | |
|---|---|---|---|
| e. | Average Daily Water Use | 3,440,000 | gallons (1989) |
| f. | Peak Daily Water Use | 7,652,000 | gallons (1989) |
| g. | Peak to Average Use Ratio | 2.22 | |
| h. | Unaccounted Water | 15 | (percent) |

6. Wastewater Information

a. Percent of potable water customers served by wastewater system 89.5 (percent)

b. Percent of potable water customers who have septic tanks or other private disposal systems 10.5 (percent)

c. Percent of potable water customers served by another wastewater treatment facility 0 (percent)

d. Average daily wastewater treated 2,170,000 (gallons)

e. Peak daily wastewater flows 2,430,000 (gallons)

f. Estimated percent of wastewater flows to the city's wastewater facilities that originate from the following:

1. Residential 99 (percent)
2. Industrial 0.1 (percent)
3. Commercial 0.9 (percent)
4. Stormwater 0 (percent)
5. Other 0 percent)

7. Save Annual Yield of Current Supply as of 1989 1,519,769,064 (gallons)

8. Peak Daily Design Capacity of Water System (Supply) City- 6,000,000 (gallons)
UGRA- 5,000,000 (gallons)

9. Major Water Customers

| | Users | Gallons Per Month (Avg) |
|---|---|---|
| 1. | Kerrville Independent School District | 3,198,300 |
| 2. | Kerrville State Hospital | 1,901,674 |
| 3. | Three Hills Mobile Home Park | 842,800 |
| 4. | Y.O. Hilton | 831,110 |
| 5. | Sid Peterson Hospital | 806,305 |
| 6. | Inn of the Hills Motel | 586,100 |
| 7. | Take-It-Easy Trailer Park | 543,094 |
| 8. | Mooney Aircraft Corporation | 500,000 |
| 9. | Birkdale Apartments | 460,947 |
| 10. | Lakeside Apartments | 409,405 |
| 11. | N.C.H.P. Property Management | 376,624 |
| 12. | Lime Creek Apartments | 355,578 |

10. Percent of Water Supply Connections in System Which are Metered 100 (percent)

11. Water Rate Structure

Minimum (Inside City Limits) 5.96 first 3000 gallons
1.78 per 1000 over minimum

Outside City Ratés are double the above

12. Average Annual Revenues from Water Sales

a. Water Sales $2,050,000.00
b. Sewer Sales $1,610,000.00

13. Average Annual Revenues from non Rate Derived Sources $232,681.00

14. Average Annual Cost of Operation

5-year average (1984-1989) $2,767,090.00

WATER CONSERVATION PLAN

A. Plan Elements

1. Education and Information

The City of Kerrville will promote water conservation by informing water users about the ways to save water inside of homes and other buildings, in landscaping and lawn uses, and in recreational uses. Information will be distributed to water users as follows:

a. Initial Year

(1) The initial year shall include all the activities outlined in the Maintenance Program Section A.1.b

(2) Distribution of a fact sheet explaining the newly adopted Water Conservation Program and the elements of the Drought Contingency Plan. The initial fact sheet shall be included with the first distributions of educational material.

b. Maintenance Program

(1) The approximate cost for educational material and postage is $3,000.00 per year. There are free water conservation materials available from the Texas Water Development Board, in quantities of less than 500. There is also enough space on the City's water bill, that could be used for one water conservation tip per billing. Distribution of educational material will be made annually, timed to correspond with peak summer demand periods. The City currently practices this program and will incorporate material available from the American Water Works Association (AWWA), Texas Water Development Board (TWDB), and other similar associations to expand the scope of this project. A list of current materials available is contained in Attachment A (pg. 15-20 ) to this plan and may be obtained from:

Texas Water Development Board
P.O. Box 13231, Capitol Station
Austin, Texas 78711-3231

(2) Regular articles will be published bi-monthly in the area newspapers during a seven (7) month period, March to September. If conditions warrant, daily graphs will notify water user how close they are to reaching critical conditions.

This method has been used successfully in past drought conditions.

(3) New customers will be provided with general conservation literature when applying for service

Information for "Water Savings Method that can be Practiced by the Individual Water User" is contained herein as Attachment B (pg.21 -25).

2. Plumbing Codes

The City of Kerrville has adopted Appendix J of the 1985 version of the Southern Standard Building Code, which requires water saving devices on all new construction. The Code has been in effect for some time now. The Code will be amended to include new swimming pools, which will have appropriate filtration equipment.

3. Retrofit Program

The City of Kerrville will make available, through its education and information programs, information for water customer's use when purchasing and installing plumbing fixtures, lawn watering equipment, or using appliances. The advertising program will inform existing users of the advantages of installing water saving devices. The City will contact local plumbing and hardware stores and encourage them to stock water conserving fixtures including retrofit devices.

4. Water Rate Structure

The City of Kerrville has a rate structure that discourages wasting water. During the drought years of the mid-fifties, the maximum daily usage was 6.7 mgd. Again in the mid-sixties drought period, the maximum daily usage was 6.8 mgd. The population during this period was approximately 7,500 in the fifties and 9,500 in the sixties. The population has more than doubled since the fifties. The current population is 18,700, yet the maximum daily usage of 7.8 mgd was reached in August 1985. This means that over a 30 year period, the maximum daily consumption has risen only 1.0 million gallons, with a population increase of 2.5 times.

Part of this may be attributed to a new meter change out program which entailed changing every meter in the City over a six year period. This certainly made an impact, coupled with increased rates to help pay the bond debt on the Upper Guadalupe River Authority's (UGRA) 5.25 mgd surface water treatment plant and a generally depressed economy has made the wasting of water unattractive in Kerrville.

If at a point in time the citizens of Kerrville approach the maximum (11.25 mgd), which is fairly unlikely in the near future if the Aquifer Storage Recovery (ASR) program we are involved in is successful, the City will design a continuously increasing rate structure, whereby every 1,000 gallons will cost more per unit.

At this time, our combined water availability, the UGRA 5.25 mgd and the City of Kerrville's well fields 6.0 mgd, are capable of producing 11.25 mgd in peak periods. If we reach 8.8 mgd during peak demand periods this will be the triggering amount for a continuously increasing rate structure implementation. Hopefully with our conservation plan in place, we might not reach this peak demand until approximately the year 2005 or later.

5. Universal Metering

All water users, including utility, City of Kerrville offices and public facilities are metered. The City has a four-meter test bench which is used for meter testing. No meter is installed in the field without being tested for accuracy, this includes new meters. We are capable of testing 1/2" through 3" meters in-house and the Water Production Department has two-meter testing devices for in-field testing of residential and commercial meters. Kerrville is in the process of purchasing a large field testing unit capable of testing 3" through 6" meters in the field, which will give us the ability to test all commercial and industrial meters once a year. Meters 2 " and larger have tees installed for field testing. By testing five meters per day with our field test units, the entire City can be checked on a 5-year cycle. These tests will give us an idea when we are due for a meter change out program.

To change out meters that have an accuracy of 96% to 100% is not financially sound. It would take $337,500 for a complete change out. As meters are found that fall below 96%, they will be replaced by one with 100% accuracy. This will encourage water conservation and ensure that we don't give water away.

6. Leak Detection and Repair

The City will utilize modern leak detection techniques in locating and reducing leaks. A continuous leak detection and repair program is vital to the City's conservation effort. A monthly accounting of water delivery efficiencies is made by the City. Once located, all leaks are immediately repaired. Through its computerized billing program, the City can readily identify when excessive leakage occurs and takes immediate action to remedy the problem. The City is confident that the program will more than pay for itself.

The City will propose in its 1991-92 Capital Improvement Program, a state of the art leak detection device called an Aqua Scope and start a systematic leak detection program to help us keep our 85% water accountability rate intact and strive to reach between 90% and 95% accountability.

7. Water Conserving Landscape

In order to reduce the demands placed on the water system, the City of Kerrville through an information and education program, will encourage citizens, professionals, contractors, and nurseries to utilize water saving practices in design, planning, installation, and maintenance of all landscaping. Some of the methods to be promoted by the information and education program are as follows:

a. Encourage landscape architects and designers to use native and low water use plants and grasses, ground cover, permeable paving and decks in lieu of turf areas, and efficient irrigation systems.

b. Encourage licensed irrigation contractors to design all irrigation systems with water conservation features such as low volume, low angle spray heads which deliver large drops of water close to the ground rather than a fine mist high in the air and/or pressure compensating heads, bubblers, soaker hoses and/or drip irrigation where appropriate. Automatic timers/electronic controllers, rain shut off devices or soil moisture sensors, and a layout which accommodates prevailing wind patterns.

c. Encourage existing and new establishments to consult professionals on design, installation and maintenance of water conservative/drought tolerant landscapes; efficient irrigation systems, permeable paving and runoff reduction, and fountains that recycle and use minimal quantities of water.

d. Encourage local nurseries to offer a wide variety of native and low water use plants and grasses, mulches, fertilizers, efficient water devices, and related literature.

e. Encourage citizens to consult professionals on design, installation and maintenance of water conservative/drought tolerant landscapes and efficient irrigation systems, group plants with similar water needs, limit turf areas, mulch beds, and reduce runoff; and water in the early morning or evening deeply and infrequently and avoid over-watering.

8. Recycle and Reuse
The City of Kerrville owns and operates its own wastewater treatment facility, southeast of the city on Loop 534. The City would like to see this area developed for commercial purposes. Since this Loop could develop into a major business artery, the City has proposed that 12" water mains be laid to accommodate any eventuality. This Loop also goes past the Scott Schreiner Municipal Golf Course which is approximately 2.4 miles from the treatment plant in a northerly direction, and the Riverhill Golf Course approximately 1.7 miles to the southwest. Portions of this 12" line are already in our Capital Improvement Program.

The City would like to explore the possibility of obtaining funds from the Texas Water Development Board (TWDB) to lay a 12" water line to parallel our 12" potable water line as we develop this area, with the city paying for the construction cost and the 12" main including valves, fittings, engineering, etc. The cost of the 12" line and two variable speed booster pumps capable of pumping 4 mgd, plus yard piping to be borne by the TWDB.

This project would let us use our wastewater in a constructive manner. All businesses along the Loop would have access to this wastewater irrigation, including a large concentration of motels near the golf course and our football practice fields.

9. Implementation/Enforcement
The Director of Water and Wastewater Utilities for the City of Kerrville will act as the Administrator of the Water Conservation Program. The Administrator will oversee the execution and implementation of all elements of the program. He will be responsible for supervision of keeping adequate records for program verification.

The City will adopt the final approved plan and commit to maintain the program for the duration of the City's financial obligation to the State of Texas.

10. Annual Report
In addition to the above outlined responsibilities, the Administrator will submit an annual report to the Texas Water Development Board on the Water Conservation Plan. The report will include the following:

a. Public information which has been issued
b. Public response to plan
c. Effectiveness of water conservation plan in replacing water consumption by providing production and sales records
d. Implementation progress and status of plan

The plan will be enforced through adoption of the Water Conservation Plan by ordinance of the City Council of Kerrville in the following manner:

a. Service tap will not be provided to customers not meeting the plan requirements.
b. Customers who do not pay their water bills will have service disconnected.
c. The building inspection department will not certify new construction which fails to meet the requirements.

11. <u>Contracts With Other Political Subdivisions</u>
The City will, as part of the contract for sale of water to any other political subdivision, require that entity to adopt applicable provisions to the City's water conservation and drought contingency plan or have a plan in effect previously approved by the TWDB. These provisions will be through contractual agreement prior to the sale of any water to the political subdivision.

DROUGHT CONTINGENCY PLAN

A. Introduction

Drought and other uncontrollable circumstances can disrupt the normal availability of a community or utility water supply. The City of Kerrville is fortunate to have a dual source of water. That is, ground water from the City wells provide a secondary source of water and may be pumped in the amount of 6.0 mgd. Another 5.25 mgd may be obtained from the Upper Guadalupe River Authority (UGRA), the City's primary water supply source. Hopefully, in the near future, UGRA and the City of Kerrville will be able to utilize an Aquifer Storage Recovery (ASR). If the ASR is successful, it could represent the possibility of recovering as much as 10 mgd from the city well field for a short period of time.

The City of Kerrville has not had to enact a water conservation/emergency since the Summer of 1980, when Ordinance 80-21 was passed because of the drop in the aquifer and lack of summer rains.

The triggering criteria during the drought period has been changed to include the flow of water from the Guadalupe River as well as the water level in the aquifer. Below is a three step curtailment plan which will be enacted depending on the river flow and the water level of the aquifer.

B. Trigger Conditions

1. Mild Drought

When the flow of the Guadalupe River Falls below 25 cfs which passes through at the UGRA dam.

2. Moderate Drought

When the flow of the Guadalupe River falls below 15 cfs which passes through at the UGRA dam.

3. Severe Drought

When water cannot be pumped from the Guadalupe River and the mean sea level (msl) in the aquifer supplying the City's wells drops to 1260 feet msl.

C. Drought Contingency Measures

1. Mild Drought Measures:

(a) Inform public by giving notice of mild drought to customers;

(b) Voluntary curtailment of water use will be encouraged;

(c) The City of Kerrville staff will contact all major users and request their cooperation in curtailing water use.

2. Moderate Drought Contingency Measures:

(a) Inform public by giving notice of moderate drought to customers; the notice will be posted as well as notifying the news media of the moderate drought;

(b) the City will request cooperation with the City's effort to curtail water use;

3. Severe Drought Contingency Measures:

(a) Public will be informed as mentioned above;

(b) There will be a mandatory water curtailment issued to all city water users as described below;

(c) Ordinance 80-21 (Attachment C) will be enacted by the City Council.

D. <u>Severe Conditions Curtailment Program</u>

(a) Continue all relevant actions defined in the preceding phase,

(b) Ban all outdoor water use,

(c) Set limits on water use by both commercial and residential users.

E. <u>Information/Education</u>

As a component of the Information/Education section in the Water Conservation Plan, the purpose and effect of the Drought Contingency Plan will be communicated to the public through articles in the local newspapers.

When trigger conditions appear to be approaching, the public will be notified through publication of articles in the local newspapers.

When trigger conditions have passed, the local newspapers will publish notification that the drought contingency measures are abated for that condition, and if applicable, will outline measures necessary for the reduced condition.

Throughout the period of a trigger condition, regular articles will appear to explain and educate the public on the the purpose, cause, and methods of conservation for that condition. Also, a graph (Attachment D pg. 29) will be used daily in the local newspapers to show how much water was used the previous day.

F. Implementation/Enforcement
It will be the responsibility of the City of Kerrville Director of Water and Wastewater Utilities to monitor the status of the water supply and distribution systems. When a trigger condition is reached, the Director will notify each entity through its chief executive officer, to begin implementation of the Drought Contingency Plan.

The Director of Water and Wastewater Utilities will continue to monitor the water emergency until it is determined that a trigger condition no longer exists. When this takes place, the Director will notify each entity of such and the Drought Contingency Abatement procedures will be implemented.

G. Update of Trigger Conditions
Annually, the City of Kerrville will examine the production requirements and ability to maintain these requirements to determine if trigger conditions need to be re-established.

## SUMMARY

The City of Kerrville is proud to submit our Water Conservation/ Drought Contingency Plan to the Texas Water Development Board for approval. Each city in Texas has its own unique character and water availability needs. Kerrville is fortunate to have ground water available from our own well fields and surface water from the Upper Guadalupe River Authority, and if our joint Aquifer Storage Recovery Project goes as planned, we'll have water to meet our needs far into the future. But, we can never become complacent over the stewardship of our city's water supply. It is the life blood of all communities large and small and the resource that determines a healthy business community. It will also determine how long future generations will enjoy this beautiful hill country community. It is with this purpose in mind that this project was accomplished.

ATTACHMENT A

Contents of the Municipal Water Conservation Workshop Notebook

The notebook is distributed to participants at board-sponsored Municipal Water Conservation Workshops. In addition, single copies of the notebook can be provided to cities and utilities. Single copies of selected materials from the notebook can also be provided.

| TITLE | Published By | Description | Length |
|---|---|---|---|
| Section 1: The Need for Conservation | | | |
| Texas Water Resources and Conservation | TWDB | Paper | 38 pg. |
| Section 2: Water Conservation Techniques | | | |
| Efficient Use of Water in the Garden and Landscape (B-1496) | TAEX | Booklet | 20 pg. |
| Xeriscape | City of Austin | Booklet | 20 pg. |
| Water Pressure Reducing Valves | Watts Regulator | Booklet | 21 pg. |
| Texas Native Tree and Plant Director, 1986 | TDA | Book | 162 pg. |
| Sources of Leak Detection Equipment and Services | TWDB | List | 2 pg. |
| Sources of Water Saving Devices | TWDB | List | 21 pg. |
| Locating and Reducing Unaccounted for Water Through the Use Of the Water Audit and Leak Detection | TWDB | Guide-book | 30 pg. |
| Water Rate Design Emphasizing Conservation Rate Structures | TWDB | Guide-book | 30 pg. |
| Model Water Ordinances | TWDB | Guide-book | 25 pg. |
| The Authority of Cities, Water Utilities, and Water Districts to Regulate and Enforce Water Conservation Measures | TWDB | Guide-book | 25 pg. |
| Section 3. Alternate Sources | | | |
| The Cost of Conventional Water Supply Development and Treatment | TWDB | Paper | 9 pg. |

| | | | |
|---|---|---|---|
| Potential for Utilization of Brackish Ground Water | TWDB | Paper | 21 pg. |
| Guidelines for Water Reuse EPA-600/8-80-036 | EPA | Book | 105 pg. |

<u>Section 4: Workshop Exercise</u>

| | | | |
|---|---|---|---|
| Example Problem | TWDB | Loose-leaf | 15 pg. |

<u>Section 5: Plan Elements</u>

| | | | |
|---|---|---|---|
| Guidelines for Municipal Water Conservation and Drought Contingency Planning and Program Development | TWDB | Loose-leaf | 36 pg. |

<u>Section 6: Plan Development</u>

| | | | |
|---|---|---|---|
| Water Conservation and Drought Contingency Plan Development Procedures | TWDB | Loose-leaf | 58 pg. |

TEXAS WATER DEVELOPMENT BOARD
WATER CONSERVATION LITERATURE

Single copies of all of the following publications and materials can be obtained at no charge. The * includes those publications that are available free to political subdivisions in small quantities. Larger quantities can be obtained through special arrangements or at the cost of printing. To make a request, write: Conservation, Texas Water Development Board, Capitol Station, Austin, Texas 78711-3231

## Agricultural Conservation Literature

| Title | Published By | Description | Length |
|---|---|---|---|
| Agricultural Water Conservation in Texas* | TWDB | Pamphlet with tear-out | 8 pg. |
| Have Your Irrigation System Evaluated Free* | TWDB | Pamphlet | 4 pg. |
| LEPA Irrigation* | TWDB | Pamphlet | 6 pg. |
| Drip Irrigation* | TWDB | Pamphlet | 6 pg. |
| Plastic Ruler* | TWDB | 6" x 1 1/4" | - |
| Furrow Dikes* | HPUWCD #1 | Pamphlet | 4 pg. |
| Soil Moisture Monitoring* | HPUWCD #1 | Pamphlet | 4 pg. |
| Center Pivot Irrigation Systems L-2219* | TAEX | Pamphlet | 4 pg. |
| Surge Flow Irrigation L-2220* | TAEX | Pamphlet | 4 pg. |
| Surge Irrigation* | SCS | Pamphlet | 6 pg. |
| Coloring Poster for Children | TWDB | Coloring Poster | 1 pg. |
| Water Conservation Coloring Book (No.1) | TWDB | Booklet | 4 pg. |
| Water Half-A-Hundred Ways To Save It* | TWDB | Pamphlet | 8 pg. |
| Water Saving Ideas for Business and Industry* | TWDB | Pamphlet | 8 pg. |
| How to Save Water Outside the Home* | TWDB | Pamphlet | 8 pg. |

| | | | |
|---|---|---|---|
| How to Save Water Inside The Home* | TWDB | Pamphlet | 8 pg. |
| Toilet Tank Leak Detector Tablets* | TWDB | 2 tablets | - |
| Municipal and Commercial Water Conservation Services | TWDB | Pamphlet with tear-out | 8 pg. |
| A Homeowner's Guide to Water Use and Water Conservation | TWDB | Booklet | 22 pg. |
| Guidelines for Municipal Water Conservation and Drought Contingency Planning and Program Development | TWDB | Loose-leaf | 36 pg. |
| How to Xeriscape | NXC | Pamphlet | 10 pg. |
| Texas Sesquicentennial Native Plant Landscape | TDA/ TWDB | Pamphlet | 8 pg. |
| Municipal Water Conservation Workshop Notebook (See Attachment "A" for a Description of Contents) | TWDB | Notebook | 6 sect. |
| Water Conservation Coloring Book* (No.2) | TWDB | Booklet | 4 pg. |
| TWDB Report 294 - Surveys of Irrigation in Texas | TWDB | Book | 243 pg. |
| Summary of Water for Texas (c-20) | TDWR | Pamphlet | 8 pg. |
| Water Planning in Texas | TDWR | Booklet | 27 pg. |
| Texas Water Development Board (Funding Programs) | TWDB | Pamphlet | 4 pg. |
| Water for Texas (GP-4-1) | TDWR | Books | |
| Volume 1(Comprehensive Plan) | Available for purchase only from the Texas Water Commission, P.O. Box 13087 Austin, Texas 78711) | | 72 pg. |
| Volume 2(Technical Appendix | | | 530 pg. |
| Texas Water Facts | TDWR | Booklet | 12 pg. |

<u>Abbreviations</u>:

| | |
|---|---|
| HPUWCD #1 | High Plains Underground Water Conservation District No. 1 |
| NXC | National Xeriscape Council, Inc. |
| SCS | USDA - Soil Conservation Service |
| TAEX | Texas Agricultural Extension Service |

| | |
|---|---|
| TDA | Texas Department of Agriculture |
| TDWR | Texas Department of Water Resources |
| TWDB | Texas Water Development Board |

# PUBLICATIONS AND AUDIOVISUAL MATERIALS AVAILABLE FOR LOAN FROM TEXAS WATER DEVELOPMENT BOARD (TWDB) (a)

The following water conservation publications and audiovisual materials are available for a loan of up to two weeks from TWDB. To borrow any of these, write to: Conservation, Texas Water Development Board, Capitol Station, Austin, Texas 78711-3231.

## Publications

| Title | Published By | Description | Length |
|---|---|---|---|
| Water Audit and Leak Detection Guidebook | California Dept. of Wtr. Res. | Book | 142 pg. |
| Example Brochures and Promotional Material | Compiled by TWDB | Ring-binder | 32 pg. |
| Regional Teachers Guide Supplements | California Dept. of Wtr.Res. | Books | Nos 1-7 |

## Audiovisual Materials

| | | | |
|---|---|---|---|
| The Alternative is Conservation | Water films | 16mm film VCR/VHS format | 28 min. |
| Water Follies | American Wtr Wks.Assoc.(AWWA) | 16mm film VCR/VHS format | 7.5 min. |
| Orangutans (Public Service Announcement) | AWWA | 16mm film VCR/VHS format | 30 sec. |
| Gooney Birds (Public Service Announcement) | AWWA | 16mm film VCR/VHS format | 30 sec. |
| Tanks (Public Service Announcement) | AWWA | 16mm film VCR/VHS format | 30 sec. |
| Spot Announcements | Lower Colorado River Authority | Audio Cassette | 30 sec. |

(a) The films, video cassettes, and publications are provided for review purposes only. Permission to use any of this material for print or broadcast must be obtained from the producer or publisher of the material.

ATTACHMENT B

WATER SAVING METHODS THAT CAN BE PRACTICED BY THE INDIVIDUAL WATER USER

In-home water use accounts for an average of 65 percent of total residential use, while the remaining 35 percent is used for exterior residential purposes such as lawn watering and car washing. Average residential in-home water use data indicate that about 40 percent is used for toilet flushing, 35 percent for bathing, 11 percent for kitchen use, and 14 percent for clothes washing. Water saving methods that can be practiced by the individual water user are listed below.

A. Bathroom

1. Take a shower instead of filling the tub and taking a bath. Showers usually use less water than tub baths.

2. Install a low-flow head which restricts the quantity of flow at 60 psi to no more than 3.0 gallons per minute.

3. Take short showers and install a cutoff valve or turn the water off while soaping and back on again only to rinse.

4. Do not use hot water when cold will do. Water and energy can be saved by washing hands with soap and cold water; hot water should only be added when hands are especially dirty.

5. Reduce the level of the water being used in a bath tub by one or two inches if a shower is not available.

6. Turn water off when brushing teeth until it is time to rinse.

7. Do not let water run when washing hands. Instead, hands should be wet and water should be turned off while soaping and scrubbing and turned on again to rinse. A cutoff valve may also be installed on the faucet.

8. Shampoo hair in the shower. Shampooing in the shower takes only a little more water than is used to shampoo hair during a bath, and much less than shampooing and bathing separately.

9. Hold hot water in the basin when shaving instead of letting the faucet continue to run.

10. Test toilets for leaks. To test for a leak, a few drops of food coloring can be added to the water in the tank. The toilet should not be flushed. The customer can then watch to see if the coloring appears in the bowl within a few minutes. If it does, the fixture needs adjustment or repair.

11. Use a toilet tank displacement device. A one-gallon plastic milk bottle can be filled with stones or with water, recapped, and placed in the toilet tank. This will reduce the amount of water in the tank but still provide enough for flushing. (Bricks which some people use for this purpose are not recommended since they crumble eventually and could damage the working mechanism, necessitating a call to the plumber).

12. Install faucet aerators to reduce water consumption.

13. Never use the toilet to dispose of cleaning tissues, cigarette butts, or other trash. This can waste a great deal of water and also places an unnecessary load on the sewage treatment plant or septic tank.

14. Install a new low-volume flush toilet that uses 3.5 gallons or less per flush when building a new home or remodeling a bathroom.

B. <u>Kitchen</u>

1. Use a pan of water (or place a stopper in the sink) for rinsing pots and pans and cooking implements when cooking rather, than turning on the water faucet each time a rinse is needed.

2. Never run the dishwasher without a full load. In addition to saving water, expensive detergent will last longer and a significant energy saving will appear on the utility bill.

3. Use the sink disposal sparingly, and never use it for just a few scraps.

4. Keep a container of drinking water in the refrigerator. Running water from the tap until cool is wasteful. Better still, both water and energy can be saved by keeping cold water in a picnic jug on a kitchen counter to avoid opening the refrigerator door frequently.

5. Use a small pan of cold water when cleaning

vegetables rather than letting the faucet run.

6. Use only a little water in the pot and put a lid on it for cooking most food. Not only does this method save water, but food is more nutritious since vitamins and minerals are not poured down the drain with the extra cooking water.

7. Use a pan of water for rinsing when hand washing dishes rather than a running faucet.

8. Always keep water conservation in mind, and think of other ways to save in the kitchen. Small kitchen savings from not making too much coffee or letting ice cubes melt in a sink can add up in a year's time.

C. <u>Laundry</u>

1. Wash only a full load when using an automatic washing machine (32 to 59 gallons are required per load).

2. Use the lowest water level setting on the washing machine for light loads whenever possible.

3. Use cold water as often as possible to save energy and to conserve the hot water for uses which cold water cannot serve. (This is also better for clothing made of today's synthetic fabrics).

D. <u>Appliances and Plumbing</u>

1. Check water requirements of various models and brands when considering purchasing any new appliances that use water. Some use less water than others.

2. Check all water line connections and faucets for leaks. If the cost of water is $1.00 per 1,000 gallons, one could be paying a large bill for water that simply goes down the drain because of leakage. A slow drip can waste as much as 170 gallons of water each day, or 5,000 gallons per month, and can add as much as $10.00 per month to the water bill.

3. Learn to replace faucet washers so that drips can be corrected promptly. It is easy to do, costs very little, and can represent a substantial amount saved in plumbing and water bills.

4. Check for water leakage that the customer may be entirely unaware of, such as a leak between the water meter and the house. To check, all indoor and outdoor faucets should be turned off, and the water meter should be checked. If it continues to run or turn, a leak probably exists and needs to be located.

5. Insulate all hot water pipes to avoid the delays and wasted water experienced while waiting for the water to "run hot".

6. Be sure the hot water heater thermostat is not set too high. Extremely hot settings waste water and energy, because the water often has to be cooled with cold water before it can be used.

7. Use a moisture meter to determine when house plants need water. More plants die from over watering than from being too dry.

E. Out of Door Uses

1. Water lawns early in the morning during the hotter summer months. Much of the water used on the lawn can simply evaporate between the sprinkler and the grass.

2. Use a sprinkler that produces large drops of water, rather than a fine mist, to avoid evaporation.

3. Turn soaker hoses so the holes are on the bottom to avoid evaporation.

4. Water slowly for better absorption, and never water on windy days.

5. Forget about watering the street or walks or driveways. They will never grow a thing.

6. Condition the soil with compost before planting grass or flower beds, so that water will soak in rather than run off.

7. Fertilize lawns at least twice a year for root stimulation. Grass with a good root system makes better use of less water.

8. Learn to know when grass needs watering. If it has turned a dull gray-green or if footprints remain visible, it is time to water.

9. Do not water too frequently. Too much water can overload the soil so that air cannot get to the roots and can encourage plant diseases.

10. Do not over water. Soil can absorb only so much moisture and the rest simply runs off. A timer will help, and either a kitchen timer or an alarm clock will do. An inch and one-half of water applied once a week will keep most Texas grasses alive and healthy.

11. Operate automatic sprinkler systems only when the demand on the town's water supply is lowest. Set the system to operate between 4:00 and 6:00 a.m.

12. Do not scalp lawns when mowing during hot weather. Taller grass holds moisture better. Rather, grass should be cut fairly often, so that only 1/2 to 3/4 inch is trimmed off. A better looking lawn will result.

13. Use a watering can or hand water with the hose in small areas of the lawn that need more frequent watering (those near walks or driveways or in especially hot, sunny spots).

14. Learn what types of grass, shrubbery, and plants do best in the area and in which parts of the lawn, and then plant accordingly. If one has a heavily shaded yard, no amount of water will make roses bloom. In especially dry sections of the state, attractive arrangements of plants that are adapted to arid or semi-arid climates should be chosen.

15. Consider decorating areas of the lawn with rocks, gravel, wood chips, or other materials now available that require no water at all.

16. Do not sweep walks and driveways with the hose. Use a broom or rake instead.

17. Use a bucket of soapy water when washing the car and the hose only for rinsing.

## ATTACHMENT "C"

CITY OF KERRVILLE, TEXAS

ORDINANCE 80-21

An Ordinance declaring a water emergency and providing for certain curtailments of water usage.

BE IT ORDAINED BY THE CITY COUNCIL OF THE CITY OF KERRVILLE, KERR COUNTY, TEXAS:

Pursuant to the provisions of Ordinance 80-17, also being Article 3-II-24(A) "Water Emergency," it is hereby declared that a water emergency exists. A state of water emergency shall be in effect until provided otherwise by the Council.

During the period of water emergency declared hereby, use of water for non-domestic purposes is hereby prohibited for both residential and commercial customers except on the following days;

For odd numbered addresses - Fridays;

For even numbered addresses - Wednesdays;

For Municipal Golf Course and Tivy High School Stadium - Mondays.

All use of water for non-domestic purposes on Tuesdays, Thursdays, Saturdays, and Sundays are prohibited.

Non-domestic water usage includes any watering of plants, including yards, gardens, shrubs, trees and ornamentals; automobile and vehicle washing, and filling of swimming pools. The enumeration of uses constituting non-domestic use shall not limit the generality of the term "non-domestic." Except, however, this Ordinance shall not apply to commercial uses where water usage is an essential part of the primary commercial, manufacturing or business enterprise of a commercial customer.

The penalty for violation of this Ordinance shall be punished by a fine of not less than $25.00, nor more than $75.00. Each day of violation shall constitute a separate offense.

In the event that users at one connection violate the provisions herein, so at to constitute two or more offenses hereunder, then the City, upon direction of the City Manager, may discontinue service to that user.

All persons using water in violation hereof, and all those in control of premises where water usage, in violation hereof, occurs, are guilty of an offense. There shall be a prima facie presumption that a person in whose name water service is registered, or, a person who is physically present upon the premises at or near the time of violation, is in control of the premises.

An emergency exists for the immediate passage of this Ordinance, and therefore this Ordinance shall be effective upon first and final reading thereof.

Ordinance 80-19 declaring a water emergency and providing for penalties is hereby repealed upon passage hereof.

PASSED AND APPROVED ON FIRST AND FINAL READING, this the 4th day of August, 1980.

Manly W. Cooper, Jr., Mayor
City of Kerrville, Texas

ATTEST:

Sheila L. Brand, City Clerk
City of Kerrville, Texas

CITY OF KERRVILLE, TEXAS
ORDINANCE NO. 80-30

AN ORDINANCE OF THE CITY OF KERRVILLE, TEXAS, REPEALING ORDINANCE 80-18, ORDINANCE 80-19, AND ORDINANCE 80-21, AND DECLARING THE TIME OF WATER EMERGENCY IS HEREBY TERMINATED.

WHEREAS, the City Council by Ordinance 80-18, Ordinance 80-19, and Ordinance 80-21, declared a water emergency and provided for certain restrictions on water usage and provided for penalities for violation thereof; and

WHEREAS, the Council finds there is no longer an existing water emergency; Now, therefore,

BE IT ORDAINED BY THE CITY COUNCIL OF THE CITY OF KERRVILLE, KERR COUNTY, TEXAS:

SECTION 1: It is declared that the time of water emergency is hereby terminated.

SECTION 2: The foregoing ordinances are hereby repealed as of October 1, 1980.

PASSED AND APPROVED ON FIRST READING, this the 7th day of October, 1980.

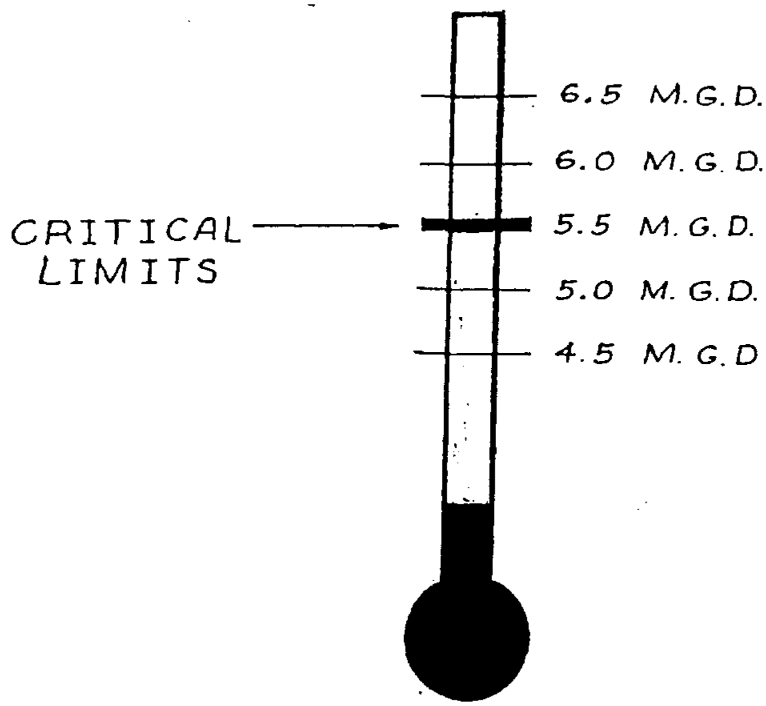
PASSED AND APPROVED ON SECOND AND FINAL READING, this the 14th day of October, 1980.

Manly W. Cooper, Jr., Mayor
City of Kerrville, Texas

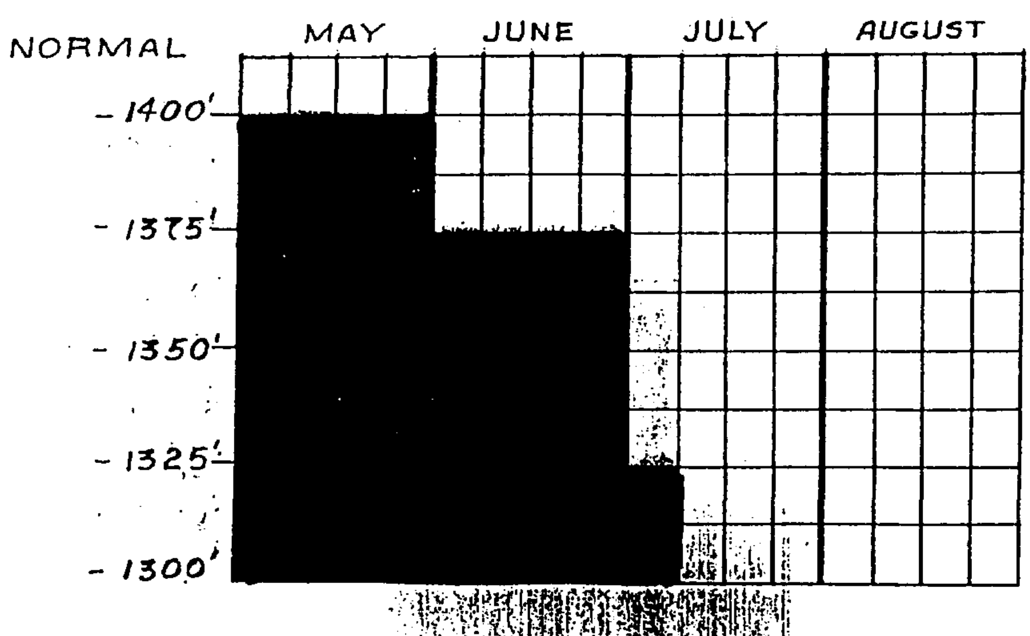
ATTEST:

Sheila L. Brand, City Clerk
City of Kerrville, Texas

ATTACHMENT "D"




MILLION GALLONS PER DAY




GROUND WATER TABLE
(ELEVATION IN FEET)