EDWARDS UNDERGROUND
WATER DISTRICT

Report 95-01

EDWARDS AQUIFER
GROUND-WATER DIVIDES ASSESSMENT
SAN ANTONIO REGION, TEXAS

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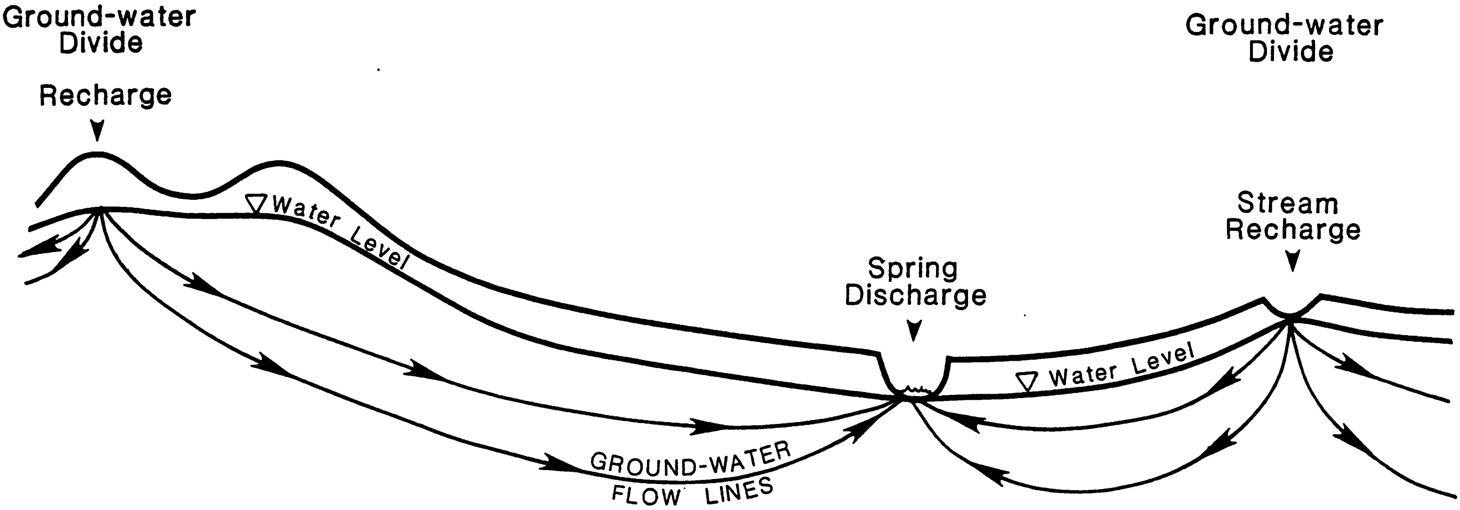
GROUND-WATER DIVIDES ASSESSMENT, SAN ANTONIO REGION, TEXAS



Prepared for the

EDWARDS UNDERGROUND WATER DISTRICT

December 1994

Prepared by

LBG-GUYTON ASSOCIATES

PROFESSIONAL GROUND-WATER AND ENVIRONMENTAL SERVICES

Austin, Texas

EDWARDS AQUIFER
GROUND-WATER DIVIDES ASSESSMENT, SAN ANTONIO REGION, TEXAS

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Edwards Underground Water District
San Antonio, Texas

December 1994

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December 23, 1994

Mr. Rick Illgner
General Manager
Edwards Underground Water District
1615 N. St. Mary's
San Antonio, Texas 78212

Dear Mr. Illgner:

Transmitted herewith is our report, "Edwards Aquifer Ground-Water Divides Assessment, San Antonio Region, Texas." This study was conducted and the report prepared by Mr. William G. Stein, with some assistance from others of our firm. We have enjoyed working with the Edwards Underground Water District in making this study of the Edwards aquifer.

If you have any questions regarding the report or the results of the study, please let us know.

With best regards,

Sincerely yours,

LBG-GUYTON ASSOCIATES

Charles W. Kreitler

Charles W. Kreitler
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Frank H. Crum
Principal

A Division of Leggette, Brashears & Graham, Inc.

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SUMMARY

The Edwards aquifer in the San Antonio region extends approximately 180 miles from the ground-water divide in Kinney County on the western end to the ground-water divide in Hays County on the northeastern end. The exact delineation of the divides has not been clearly defined and has not been located in the same place through the history of hydrogeologic studies of the Edwards aquifer. The areas on the western and eastern ends of the Edwards aquifer in the San Antonio region were studied to evaluate and better delineate the ground-water divides, with the results discussed in this report.

In Hays County, a mound in the water table of the recharge zone results from recharge being focused in an area located along Onion Creek. This area has extensive exposures of Kirschberg evaporite member and numerous faults, which are favorable for the development of secondary porosity and permeability. In the artesian part of the aquifer, the water-level high may be associated with a preferred flowpath that is directed from the Onion Creek recharge area into the artesian part of the aquifer, possibly being modified by an unknown subsurface geologic structure. The water-level high in the artesian part of the aquifer is formed in part by the effects of pumpage in the vicinities of the Cities of Kyle and Buda located on either side of the high and the relative lack of pumping in the area between the two cities. Water levels measured toward the end of summer 1994 in the artesian part of the aquifer appear to be below the level of San Marcos Springs Lake. This suggests that, during times of lower water levels, the artesian part of the aquifer in this area may not supply water to San Marcos Springs but instead to pumpage near Kyle and Buda and to Barton Springs. A water-level high between Kyle and Buda that is shown by the summer 1994 measurements indicates that flow during this period does not move past San Marcos Springs to Barton Springs. Based on the data from this report, the ground-water divide in Hays County should be located generally between the Cities of Buda and Kyle in the artesian part of the aquifer and along Onion Creek in the Edwards aquifer recharge zone.

In Kinney County, several anticline and syncline folds that plunge to the southwest channel water like a large sheet of corrugated tin toward Las Moras and Pinto Springs. Intrusions of essentially impermeable igneous rocks that generally occur along the axes of the anticlines, which are folded upward, help to magnify the constraining effect of the folds. The intrusions act as a "grout curtain" where the igneous material has been intruded into the Edwards limestone. Water levels have shown some minor changes through time, but no effects from the filling of Lake Amistad have been detected in the vicinity of the ground-water divide in Kinney County. Two noses appear on the water-level contour maps for Kinney County, both reflective of the underlying anticlines and synclines. However, water-level measurements indicate that a component of flow comes past Las Moras Springs from west to east toward the City of Uvalde. As a result, the divide should be placed to the west of Las Moras Springs. It probably runs to the north toward Pinto Mountain and then along a topographic high in the unnamed escarpment north of Pinto Mountain. Because stream losses in the West Nueces River are presently used for recharge calculations for the San Antonio region of the Edwards aquifer and water-level contours indicate that a portion of this recharge is moving toward Pinto and Las Moras Springs, discharge of both these springs should be considered as part of any water-balance calculations for the Edwards aquifer in this area.

INTRODUCTION

This report presents the results from a study made by LBG-Guyton Associates with assistance from the Edwards Underground Water District to evaluate and better delineate the ground-water divides that form the western and eastern limits of the Edwards aquifer. This portion of the aquifer between the two divides (Figure 1) often is referred to as the Edwards aquifer in the San Antonio region.

The Edwards aquifer is one of the most permeable and productive limestone aquifers in the United States. In the San Antonio region, the aquifer supplies drinking water to more than 1.3 million people. The Edwards aquifer varies in width from 5 to 40 miles from the northern limit of the recharge zone to the southern limit of fresh water, which is a gradational zone of increasing salinity from 350 parts per million to over 300,000 parts per million total dissolved solids (TDS). Locally, the point at which TDS reaches 1,000 parts per million is referred to as the "bad-water line" and is the approximate southern extent of potable water. The length of the Edwards aquifer in the San Antonio region extends approximately 180 miles from the ground-water divide near Brackettville in the west to the ground-water divide north of Kyle in the northeast.

The basic concept for ground-water flow in an aquifer is water flowing from topographically higher to lower areas, with the water table following the land surface in a subdued fashion. A ground-water divide delineates the line that theoretically separates ground-water flow in one direction from ground-water flow in another direction, and according to the basic concept, would probably occur along topographic highs. This basic concept assumes a homogeneous and isotropic aquifer and recharge being evenly distributed across the aquifer.

Actual ground-water flow and the occurrence of ground-water divides are more complex, especially in karst limestone such as the Edwards aquifer, because the recharge processes and the permeability distributions are also more complicated. Some of the potential controlling mechanisms for ground-water divides can be related to structure (such as fractures and faults), depositional geology (such as facies changes that cause varying permeabilities), hydraulics, types of recharge (stream losses versus infiltration of rainfall over the land surface), presence of perched zones, and locations of recharge and discharge points.

In the Edwards aquifer, the western ground-water divide near Brackettville in Kinney County and the eastern divide near Kyle in Hays County have been delineated previously from historic water-level data. The divide near Brackettville that separates ground-water flow toward Del Rio from ground-water flow toward San Antonio is generally prominent. However, available historic water-level maps show the position of the ground-water divide becomes less obvious at different times and appears to be at slightly different locations. Similarly, the ground-water divide located in Hays County between the Cities of Kyle and Buda that theoretically isolates flow toward Austin from flow toward San Marcos Springs has always been considered nebulous, probably in large part because water levels in only a few wells have been used to previously define the presence and location of this ground-water divide. As a result, the main objectives of this study are to evaluate the geology and hydrology in the vicinity of the Edwards aquifer ground-water divides in Hays and Kinney Counties in order to define and document the divides' position and to explain the associated hydrogeologic controls.

Previous Investigations

Numerous investigations of the geology and water resources of the Edwards aquifer have been made by federal, state and local agencies such as the U. S. Geological Survey (USGS), International Boundary and Water Commission (IBWC), Texas Water Development Board (TWDB), Texas Natural Resource Conservation Commission (TNRCC) and its predecessor agencies—the Texas Water Commission (TWC), Texas Department of Water Resources (TDWR) and Texas Board of Water Engineers (TBWE)—the University of Texas Bureau of Economic Geology (BEG), Barton Springs/Edwards Aquifer Conservation District (BSEACD) in Austin, and the Edwards Underground Water District (EUWD) in San Antonio. Some of these investigations are listed in the Selected References section at the end of this report.

Many additional references including studies conducted by private consultants can be found in the reports that are listed. Some of the pertinent information from these reports is reviewed below.

Sayre and Bennett (1941) described how water flows in the Edwards aquifer from Kinney County, both eastward and westward. This report also pointed out that ground water in the Edwards fed springs from west of Del Rio to Austin, Texas. A high in the water table in the general vicinity of Brackettville was recognized, but it was not identified as a ground-water divide.

In a 1955 report to the San Antonio City Water Board, William F. Guyton & Associates described the two ground-water divides in an attempt to define the lateral extent of the Edwards aquifer of the San Antonio region to develop a water budget. A report by Petitt and George (1956) similarly defined the Edwards aquifer in the San Antonio region. Both reports expounded upon the complexity of the hydrogeology associated with the Edwards aquifer.

Las Moras Springs at Brackettville was essentially on the so-called ground-water divide, but it was not known whether the ground water supplying the springs came from the east or the west side or both sides. William F. Guyton & Associates decided not to include Las Moras Springs in the San Antonio portion and located the divide northeast of Brackettville. It was assumed that Las Moras Springs received recharge from a local "pie-shaped" area located between the flow systems to the east and the west.

In order to calculate the water budget for the San Antonio portion of the Edwards aquifer, William F. Guyton & Associates (1955) placed the eastern limit along a small potentiometric ridge near Kyle which they considered as the ground-water divide. The results from a later study of the northern segment of the Edwards aquifer by William F. Guyton & Associates (1958) concluded that any underflow past Kyle would have to be relatively small.

Since these early studies established the two divides, the locations of these divides have become entrenched in people's understanding of the aquifer. Through the years, the calculations of recharge and discharge have balanced over periods of time when the water levels came back to the same point gave people a sense of security that the right area had been chosen for the San Antonio portion of the Edwards aquifer. Most people have not taken into consideration that both recharge and discharge estimates have potential errors in them, perhaps as much as 25 percent or more. Based on a review of previous investigations of these divides, it appears that their existence and the hydrogeologic controls with which the divides are associated are not well understood. Thus, a better understanding of the ground-water divides may contribute to more refined estimates of the water budget, and more accurate modeling of the Edwards aquifer.

Methods of Investigation

Previous studies of the Edwards aquifer in the San Antonio area were evaluated and information in the ground-water divide areas was brought up to date where possible by the acquisition of new data. Details from previous records regarding well construction were evaluated to determine what the water levels actually represent with respect to the more transmissive units that occur within the aquifer and the possible presence of perched water in unconfined parts of the aquifer. Wells were inventoried and water levels in the wells were measured within an area that extends laterally from the previously delineated ground-water divides to identify their current position.

The water-level measurements shown on the maps in this report are generally reflective of the hydrostatic head of the Edwards aquifer at the time of the measurement. These water levels generally illustrate the potentiometric surface, or height to which water levels will rise in wells constructed in the Edwards aquifer. The direction of ground-water flow is generally at right angles to the water-level contours and in the direction of decreasing altitude. However, within a karst limestone aquifer such as the Edwards aquifer, specific flowpaths may be channeled through caves or fractures that are not at right angles to the drawn contours, but the end result is that overall flow will be downgradient and under the influence of gravity. Also, in evaluating water-level measurements, consideration was given to how the measurements might be influenced by the following: (a) prior pumping from the well for which a water level is shown, or current or prior pumping from wells which may be close by; (b) depth at which the well is completed in the hydrologic unit; (c) method of completion, which in many cases allows a well to draw water from more than one water-bearing unit; and (d) accuracy in estimating the altitude of the land surface at the well from land-surface contours on topographic maps. Generally, the conditions indicated by these measurements were considered approximate, and minor inconsistencies between adjacent data points need to be evaluated on a regional basis.

Water levels in Hays County were measured at relatively higher and lower aquifer stages corresponding to the winter and summer of 1994, respectively, to determine how water-level changes might impact the location and extent of the ground-water divide. Recent hydrogeologic mapping of the recharge zone in Hays County by the USGS was evaluated in the context of probable hydrologic effects in the vicinity of the ground-water divide in Hays County.

While no major problems in data collection were experienced in Hays County, data collection efforts in Kinney County were limited. The intended approach for studying current ground-water conditions in Kinney County was to inventory 30 to 60 Edwards aquifer water wells in the northern part of the county. Wells were to be measured early in the year during relatively higher water-level conditions and again at the end of the summer during relatively lower water-level conditions.

The plans for well inventory and water-level measurements in Kinney County were for LBG-Guyton Associates personnel to work jointly with EUWD personnel initially to ensure that both groups were collecting data similarly, and then the EUWD personnel would complete the data acquisition in Kinney County. The joint inventory effort in Kinney County went well. In an attempt to contact as many local citizens as possible in the Kinney County study area, the EUWD placed two articles regarding the study in the Brackett News, the first on March 31, 1994 and the second on April 7, 1994. The unexpected reaction by many of the local landowners was to refuse access to their wells for making water-level measurements. As a result, the efforts to collect data soon became unproductive.

Personnel of LBG-Guyton Associates subsequently attempted to contact the well owners to obtain permission to measure water levels in their wells, but this effort encountered similar resistance. Fortunately, a very extensive hydrogeologic study of Kinney County had been conducted by the USGS in cooperation with TBWE with most of the field work for the study occurring from 1938 to 1940 (Bennett and Sayre, 1962). Much of the hydrogeologic information used in evaluating the Kinney County ground-water divide is from this earlier study.

A total of 63 water wells in Hays County and 23 water wells in Kinney County were inventoried by LBG-Guyton Associates and/or EUWD personnel during the course of this investigation. Seven additional wells that are monitored by the IBWC were used to help evaluate water-level conditions in Kinney County. The inventoried wells are identified in accordance with the numbering system described in the following section.

Well-Numbering System

The numbering system that is used in this report is based on subdivisions of latitude and longitude as shown by the diagram of Figure 2. The TWDB, TNRCC and the USGS use a similar well identification system in Texas with the exception of the last few digits of the well identification which are unique to this study. The first two letters identify the county in Texas, which for this report are LR for Hays County and RP for Kinney County.

Next, each one-degree by one-degree section of the state has been assigned a two-digit number from 01 to 89 and this becomes the first set of numbers in the well identification. Each one-degree section is divided further into sixty-four 7-1/2-minute topographic quadrangles, numbered from 01-64, and this two-digit number becomes the second set of numbers in the well identification. Each 7-1/2-minute quadrangle is divided into 2-1/2 minute blocks, which are numbered from 1 to 9. This is the first digit in the third set of numbers (the fifth number) in the well identification.

At this point the state system and the system used for this study differ. Within the 2-1/2-minute sections, the state system then assigns numbers sequentially as needed regardless of location within the section. However, the numbering system used for this study subdivides each 2-1/2-minute section into the following series of progressively smaller sections of nine quadrangles each, as shown by the diagram on Figure 2. The first two series of subdivisions, 50-second- and 16-2/3-second quadrangles, use letters "a" through "i" to avoid possible confusion with the state identification system. The third and last subdivision, which is a 5-1/2-second quadrangle, is given a number from 1 to 9 to locate the well within an area approximately 500 feet by 500 feet. As an example, Well RP-70-39-9ic7 would be located in Kinney County within the one-degree section 70 and in the sequentially subdivided quadrangles as illustrated in Figure 2.

REGIONAL GEOLOGY

The Edwards limestone was deposited in a shoaling lagoonal environment on the Comanche Shelf during the Fredericksburg and Washita Ages of the Lower Cretaceous, more than 100 million years ago. The Comanche Shelf is subdivided into smaller depositional regions. The two of interest for this study are the San Marcos Platform encompassing the Hays County divide and the Maverick Basin encompassing the Kinney County divide, shown in Figure 3. During the Fredericksburg and early Washita Age, the Comanche Shelf (Rose, 1972) was dominated by nine major types of depositional environments, each having specific characteristics. The environments depended on several key factors: degree of circulation, wave and current energy, and sediment suspension and load. These environments are described in detail by Rose (1972).

Changes within the lagoon resulted in discrete depositional environments and corresponding variations in lithology. The stratigraphic units for the Edwards limestone on the San Marcos Platform (Figure 3) are the Kainer, Person and Georgetown Formations (Rose, 1972) and in the Maverick Basin are the West Nueces, McKnight and Salmon Peak Formations (Lozo and Smith, 1964). The San Marcos Platform formations are subdivided into members and are summarized with the Maverick Basin stratigraphy in Table 1.

Stratigraphy

In the San Marcos Platform, the Edwards consists of approximately 400 to 500 feet of limestone, with lesser quantities of chert and remnant dolomite and evaporite deposits. The thickness of the Kainer Formation ranges from about 250 to 350 feet, and consists of marine sediments with fossiliferous (most commonly rudistids) mud-stones and wackestones. The formation grades upward into intertidal and supratidal dolomitic mudstones with evaporites and ends in a shallow marine miliolid grainstone (Rose, 1972).

The Person Formation is about 100 to 200 feet thick over the San Marcos Platform. The lowermost unit of the Person Formation is a thin veneer of mudstone known as the regional dense member deposited in relatively higher seas during the early Washita. Deposition continued with dolomitic biomicrite which contains layers of breccias, burrowed mudstones and stromatolitic zones. Uplift of the San Marcos Platform then caused the seas to regress and resulted in subaerial weathering, leaching and collapsing of the limestone.

A depositional hiatus occurred before the open marine, biomicritic Georgetown Formation (Rose, 1972) was deposited. The Georgetown is generally a marly bio-micrite with common fossils of Waconella wacoensis (The Audubon Society, 1981, p. 686) (previously called Kingena wacoensis), pectens and other pelecypods.

To the west in the Maverick Basin, the Edwards limestone is approximately 670 feet thick and is composed of the West Nueces, McKnight and Salmon Peak For-mations (Lozo and Smith, 1964). The West Nueces Formation is about 140 feet thick and consists of nodular, shaly limestone in the lower 60 feet similar to the basal nodular member of the Kainer Formation in the San Marcos Platform. The upper part of the West Nueces grades from a shell-fragment wackestone to a grainstone with some honeycomb-type leaching in some places, which may be a possible Kirschberg evaporite equivalent unit. The McKnight Formation is about 150 feet thick and consists of an upper and lower thin-bedded limestone separated by a dark-colored lime mudstone. The upper section consists of mostly thin-bedded mudstone with some evaporite deposits. Some of the McKnight Formation is probably equivalent to the regional dense bed of the San Marcos Platform. The Salmon Peak Formation consists of about 300 feet of dense, massive limestone containing chert with about 75 feet of shell-fragment, permeable grainstone at the top (Maclay and Small, 1984).

Near the end of the Washita, the sea level rose and deposition of relatively impermeable terrigenous clays occurred in a brackish-water environment, forming the Del Rio Clay over most of both study areas. The Del Rio Clay that outcrops within the study area is a weathered, poorly compacted, friable, greenish-yellow clay with some very fossiliferous accumulations of Ilymatogyra arietina (Moore, 1971, p. N1119-N1121) (previously called Exogyra arietina).

Structure

Cretaceous sedimentary rocks in central Texas strike northeast and dip to the southeast toward the Gulf of Mexico. All faults in both study areas are located within the Balcones fault zone. The Balcones fault zone is the dominant structure that forms the Balcones Escarpment at the edge of the Edwards Plateau which is depicted generally on Figure 1. The last major episode of movement in the Balcones fault zone occurred during the late Early Miocene, approximately 15 million years ago (Young, 1972).

Although most of the faults in the area trend northeast, a smaller set of cross-faults trend northwest. Most of the faults are nearly vertical, normal faults. Generally, the faults are *en echelon*, with the down-dropped blocks toward the southeast. Many faults are not a single sharp break, as suggested by a line drawn on a geologic map, but are usually a narrow zone of shattered rocks. Because rocks on both sides of a fault are sometimes equally resistant to weathering, some of these faults do not result in sharp topographic relief.

Igneous intrusions occurred along the Balcones fault zone during the Late Cretaceous. These intrusions are called the Balcones Igneous Province, with fields located to the north in Travis County and to the west in Uvalde and Kinney Counties. Uplift of Lower Cretaceous strata occurred as a result of intense igneous activity (Ewing, 1989). The edge of the uplift area in the west is known as the Uvalde Salient (Welder and Reeves, 1964).

REGIONAL HYDROLOGY

Historically, calculated recharge to the Edwards aquifer in the San Antonio region as determined by the USGS has averaged 682,800 acre-feet per year (ac-ft/yr) since data collection began in 1934 (Bader and others, 1993). Most of the streamflow available for recharge originates from drainage off the Edwards Plateau located generally to the north of the Edwards aquifer recharge zone. Runoff from this catchment area is channeled through streams to the recharge zone. Additional recharge occurs from direct infiltration of precipitation on the land surface of the recharge zone. In the recharge zone, the water infiltrates through fractures, faults and solution openings into the subsurface. Once underground, the water moves downgradient into the confined part of the aquifer.

In the subsurface, the ground water generally travels from west to east, and eventually discharges naturally from Comal Springs near New Braunfels and San Marcos Springs in San Marcos (Figure 1). Discharge from the aquifer is primarily by well withdrawals and springflow. Discharge by springs has averaged 362,000 ac-ft/yr from 1934 to 1992 (Bader and others, 1993). Annual withdrawals from the aquifer by wells have been gradually increasing, from 101,900 ac-ft/yr in 1934 to a high of 542,400 ac-ft/yr in 1989, with the average being 459,600 ac-ft/yr for the last 10 years (1983 to 1992) (Bader and others, 1993).

Transmission of water through the Edwards aquifer is dependent mostly on size, shape and connection of the pores (effective porosity) through the presence of fractures and solution openings. Transmissivities may be as high as 2 million square feet per day (ft^2/day) (Maclay and Small, 1984) in the most permeable parts of the artesian zone of the Edwards aquifer where enhanced secondary porosity has allowed for very large well yields. Hydraulic conductivity of the recharge zone may be similar to the artesian zone, but because of less saturated thickness, recharge-zone transmissivities are relatively lower than artesian-zone transmissivities. The recharge-zone transmissivities are relatively lower at about 200,000 ft^2/day (Maclay and Small, 1984). High transmissivity values of the aquifer result in rapid recharge when water is available, a relatively flat potentiometric surface and relatively high flow velocities.

The Edwards aquifer is anisotropic with discontinuous heterogeneity at fault zones and gradations or trending heterogeneity through changing lithology. Porosity within the Edwards aquifer is primarily the result of diagenesis along bedding planes, joints and fractures after deposition. Some porosity was formed by subaerial weathering during the Cretaceous, but the bulk of the porosity is due to more recent removal by solutioning from aggressive percolating waters. The Edwards aquifer also exhibits layered heterogeneity because the aquifer subdivisions have different hydraulic conductivities.

In the San Marcos Platform, where the Hays County area is located, aquifer subdivisions 3, 5 and 6 of the eight Edwards aquifer subdivisions (Table 1) are the most permeable. Aquifer subdivisions 1, 4 and 8 are relatively impermeable, and the remaining aquifer subdivisions are somewhat variable in permeability and porosity based on core observations, geophysical logs and packer tests of test holes (Maclay and Small, 1984). The Kirschberg evaporite member (aquifer subdivision 6) generally is the most productive, and excluding fracturing or faulting, the regional dense bed (aquifer subdivision 4) is the most impermeable unit. However, in the outcrop of the recharge zone, aquifer subdivision 8 (basal nodular member) has gone through extensive karstification, generating secondary porosity in the form of large lateral caves (Stein, 1993), which result in this unit being able to receive and transmit substantial amounts of ground water.

In the Maverick Basin to the west where the Kinney County area is located, the best porosity and permeability generally occur at the top of the Salmon Peak Formation. Some porosity also occurs near the top of the West Nueces Formation (Maclay and Small, 1984). Porosity and permeability often are modified by local fracturing or karstification, which usually is more common and intense near creeks or streams.

HAYS COUNTY GROUND-WATER DIVIDE

Hays County is located on the very northeastern end of the Edwards (Balcones fault zone) aquifer in the San Antonio region. The portion of the Edwards aquifer to the north of the Hays County ground-water divide is known as the Austin region of the Edwards aquifer. The area between these two portions of the aquifer has been referred to as the Hays County ground-water divide.

Water levels in the Edwards aquifer are affected by the amount of water the aquifer receives from recharge as a result of precipitation, infiltration of streamflow and the amount of water taken from the aquifer as result of pumping from wells and springflow. Precipitation at San Marcos, Texas has averaged 33.79 inches per year for the 91-year period of record through 1992 (Bader and others, 1993).

The major sources of discharge to the aquifer in this area are San Marcos Springs and Barton Springs, located south and north of the study area, respectively. Annual mean discharge from San Marcos Springs is 170 cubic feet per second (cfs) (about 123,000 ac-ft/yr) for the period of record, 1957 to 1993 (USGS, 1994). For Barton Springs, the annual mean discharge is 63.4 cfs (about 46,000 ac-ft/yr) for the period of record, 1978 to 1993 (USGS, 1994). Daily mean discharges from these springs over the past 10 years are shown in Figure 4.

Pumping centers exist near the Cities of Buda and Kyle where public supply wells and a higher density of domestic wells are located. The public supply pumpage for the City of Buda has increased from 43 ac-ft/yr in 1955 to over 230 ac-ft/yr in 1993. Additionally, Goforth Water Supply Corporation, in close proximity to the City of Buda, has a well field that has been producing up to 400 ac-ft/yr since the mid-1980's (BSEACD, written communication, 1994). In Kyle, the pumpage has increased from 84 ac-ft/yr to over 582 ac-ft/yr from 1955 to 1993. Monthly pumpage totals for both cities are shown in Figure 4 (TWDB, written communication, 1994).

Analysis of Water-Level Data

Previous delineations of the ground-water divide in Hays County appear to have varied. Hearings before the Texas Water Commission (now TNRCC) for the creation of the Barton Springs/Edwards Aquifer Conservation District (BSEACD) demonstrated that, based on previous work, the ground-water divide in Hays County appeared to have shifted over time generally between the Cities of Kyle and Buda. In earlier studies, the Hays County ground-water divide was determined from potentiometric-surface maps with as few as three measured water-level control points within the area of interest. The approximate locations of the ground-water divide from previous studies are shown in Figure 5. The dates of the water-level measurements and the authors of the respective reports are referenced in the figure. The shift in the location of the divide may be caused by the lack of data control for drawing the potentiometric contours, because only a few data points were used, or by different wells being used for water-level data points for different maps. In order to confirm the location of the divide, water levels in a larger number of wells needed to be measured "simultaneously." This was done by reevaluating the data collected by EUWD and TWDB in 1985, as well as measuring water levels in wells in the winter and summer of 1994.

Water-level data collected by the EUWD and TWDB in 1985 for the delineation of the BSEACD was reevaluated, and the results are presented in Table 2 and Figure 6. Based on the recent surface hydrogeologic mapping, some wells on the western end of the selected well set are believed to be completed in the Glen Rose. Therefore, these wells were not used in reevaluating and plotting the 1985 water levels. Near average precipitation of 33.54 inches (Bader and others, 1993) occurred at San Marcos during 1985, indicating that water-level conditions in this area were also probably under average conditions.

LBG-Guyton Associates measured water levels in the winter (January and February) and water levels in late summer (August and September) of 1994. Data are shown in Table 3 and plotted on Figures 7 and 8. Prominent water-level highs can be seen on both winter and late summer 1994 water-level maps in the vicinity of Onion

Creek. The rainfall conditions during the period before the water-level measurements taken in late August and early September were initially very dry, but several heavy rains occurred a few weeks just prior to the time the measurements were made. In Austin, the month of August was one of the wettest Augusts on record. What exactly might happen to the water-level high along Onion Creek over extended dry periods is not clearly understood.

Water levels in the artesian part of the aquifer were relatively flat in February 1994, but there was a high between the Cities of Buda and Kyle. Other than possible hydrogeologic factors, the location of this high in water levels may be associated with relatively high pumping centers in the vicinities of Kyle and Buda on either side of the high and the relative lack of pumping in the area between the two cities. The pumpage in the cities would cause cones of depression during heavy pumping and a corresponding high between the two pumping centers.

The elevation of water levels throughout the study area in early 1994 was higher than the elevation of San Marcos Springs Lake at 575 feet above mean sea level. However, during the second set of 1994 water-level measurements, levels for much of the artesian part of the aquifer from just south of Kyle through Buda dropped below the San Marcos Springs Lake level. The late summer water levels may indicate that ground water is not flowing toward San Marcos Springs during lower water-level conditions, but supplying pumpage at Kyle, Buda and areas toward Barton Springs instead. The elevation of Barton Springs, 432 feet above mean sea level, is much lower than water-level elevations in the Buda/Kyle area. A water-level high still remains during the summer measurements, which indicates that ground-water flow does not move from San Marcos Springs toward Barton Springs at this time.

Water levels in this artesian area are subject to declines caused by pumping as evidenced by water levels fluctuating up to 40 feet in magnitude during a single day, which can be seen in the BSEACD observation well in Buda (LR-58-58-101) (S. Vickers, oral communication, 1994). Long-term water levels measured periodically in the area and recorded by TWDB are shown in Figure 9a. Daily water-level highs for observation wells maintained by the BSEACD and EUWD near the Hays County ground-water divide are shown in Figure 9b. During the period of record, daily water-level highs have fluctuated over 80 feet in Well LR-58-58-101 and over 60 feet in Wells LR-58-57-9bi4 and LR-67-01-303. For the period of record provided by continuous water-level recorders, generally from late 1991 to the present, the highest water levels in these wells occurred in June 1992 and the lowest occurred in late July to early August 1994.

Changes in water levels from winter to summer 1994 in the north-northeast Hays County area are shown on Figure 10. A lowering of water levels is shown for all the wells except two. The two wells that showed rises in water levels are believed to be associated with the effect of local pumpage at the time of the winter water-level measurements. The greatest declines generally are in the artesian section and may be focused on the Cities of Buda and Kyle in association with relatively higher pumpage. The other area that experienced large water-level declines between winter and summer of 1994 is along the east end of the recharge zone along Onion Creek.

Geologic and Hydrologic Features

The study area in Hays County is composed predominantly of Cretaceous strata as discussed earlier in the Regional Geology section. The Glen Rose Limestone and the Austin Chalk also form aquifers in the Hays County area, but the Edwards limestone is the principal aquifer of interest to this study. The area also has minor deposits of more recent alluvium found mostly within the floodplains of the Blanco River and smaller creeks.

The dip of the Cretaceous rocks in the study area is between 10 and 15 feet per mile to the southeast in the downdip direction (Arnow, 1959). This creates a hydrogeologic setting that permits ground water to flow toward the southeast, generally toward San Marcos Springs from the area northwest of the springs. In contrast, faults in Hays County primarily trend N40° to 50°E. The fault zones have associated fracturing that causes locally increased porosity and permeability. Conduits developed as a result of this may direct flow generally along the fault trends toward Barton Springs from the north-central Hays County area rather than to the southeast with the dip of the rocks.

A recent series of USGS mapping projects in the Edwards aquifer recharge zone, starting in Bexar County (Stein and Ozuna, unpub.), moving northward through Comal County (Small and Hanson, unpub.) and Hays County (Hanson and Small, unpub.) and currently underway in southern Travis County, have given a more detailed hydrogeologic picture of the recharge zone. A part of the mapping in Hays County (Hanson and Small, written communication, 1994) generally north of Onion Creek to south of Blanco River is shown in Figure 11. West of Mustang Branch Fault is the Edwards aquifer recharge zone (Figure 11), and east of the fault the surface geology generally consists of the sequence of Del Rio Clay, Buda Limestone, Eagle Ford Shale (upper confining unit) and Austin Chalk, with some minor recent alluvial deposits veneering the creek areas not being depicted on the map.

Several interesting geologic conditions can be inferred from this mapping. A series of faults with generally the basal nodular member on the south side of the faults and the leached/collapsed members on the north side of the faults are present north of the Blanco River in the southwest corner of quadrangle 58-57. These faults, which have approximately 250 feet of displacement, possibly act as barrier faults that isolate flow within the respective blocks. South of the fault, such a small remnant of the Edwards section remains that only the basal nodular member and some of the dolomitic member crown the tops of hills. Thus, any water recharged over Edwards outcrop, south of the fault, probably would not stay in Edwards strata but have a water table near the contact with or even within the upper member of the Glen Rose Limestone.

Only a limited reach of the Blanco River is actually on Edwards limestone. Most of the reach of the river is on upper Glen Rose. Downstream the river crosses predominantly the basal nodular member and some of the dolomitic member (lower Kainer Formation), and finally two smaller fault blocks of upper Person Formation. The upper confining unit (Eagle Ford Shale, Buda Limestone and Del Rio Clay) is exposed predominantly in the Blanco River bed between the two fault block areas, where upper Person Formation is exposed, and again further downstream. As a result of the limited number of river miles with Edwards exposure, the Blanco River has a diminished potential for recharging the Edwards aquifer.

On the other hand, Onion Creek, which is located to the north of the Blanco River, has optimal hydrogeologic conditions for recharging the aquifer even though the quantity of base flow is much less than the base flow for the Blanco River. North of FM Road 150, Onion Creek flows over a long stretch of the exposed Kirschberg evaporite member, which hydrostratigraphically has the highest potential for development of secondary porosity and the resulting increased transmissivity (Stein, 1993). Also, toward the lower end of this stretch, Onion Creek crosses several faults including one that trends parallel to the creek at about N35°E. The focused recharge of surface water undersaturated with respect to calcium carbonate within Onion Creek would accelerate dissolving of the faulted rock and Kirschberg evaporite to form extensive secondary porosity. This enhanced recharge potential along Onion Creek appears to cause the ground-water high that delineates the ground-water divide in the Edwards aquifer recharge zone in Hays County.

Fairly constant inflow from upstream into a small reservoir located at the north end of this stretch of Onion Creek within the Edwards outcrop provides a source of relatively continuous recharge to the Edwards aquifer. Discharge records are available for Onion Creek near Driftwood and downstream of the Edwards aquifer recharge zone near the City of Buda (Figure 12a). The difference between the two gages, shown by the bottom graph of Figure 12a, indicates the potential recharge to the aquifer. On occasion, rainfall and runoff occur between the gages resulting in discharges at Buda being higher than discharges at Driftwood, which results in a negative number for the potential recharge. Additionally, some of the negative values in the upstream minus downstream are associated with storm runoff pulses arriving at the downstream gage the day after the pulse passes the upper gage. For comparison, the difference between the upstream gaging station on the Blanco River near Wimberley, Texas and the downstream gaging station near Kyle, Texas (Figure 12b) suggests that only minor recharge occurred within that reach. The major negative discharge differences on the Blanco River probably are associated with the time-delay of runoff, as mentioned above for Onion Creek, and not from recharge. This supports the geologic observations that much of the Blanco River exhibits limited recharge potential.

Large water-level declines occurred between winter and summer 1994 (Figure 10) along the east end of the recharge zone along Onion Creek. The aquifer is confined in some of this area where outcrops of Del Rio Clay occur, but the aquifer is generally under water-table conditions with the water level being below the contact between the Edwards limestone and the Del Rio Clay. The areas along Onion Creek probably have the best enhanced secondary porosity as compared to areas further away from the creek. As a result, this area along the creek has the highest relative permeability and is capable of transmitting water away the quickest. The large fluctuations in water level in this area may result from this. The continuous recharge source located upstream along Onion Creek cannot supply as much water to this area as can be transmitted away during drier times. Another possible reason for the drop in water level in this area is that a cone of depression associated with pumpage near the City of Buda may spread up into this more transmissive area along Onion Creek first before moving into the surrounding tighter limestone.

In the updip limits of the recharge zone, the hydrostratigraphy plays a very important role in controlling the depth of the water levels. According to well owners and a review of available data, the water levels in many wells located near the updip limit of the recharge zone would drop to a particular level during dry times and then stop declining. By comparing the recent hydrogeologic mapping and known thickness of aquifer units to the depth of the well, many of the wells in the western part of the recharge zone in Hays County appear to bottom in or below the basal nodular member; that is, near the contact between the Edwards limestone and the upper member of the Glen Rose Limestone. In the recharge zone, the basal nodular member often exhibits large secondary porosity development and numerous caves, which may be associated with dissolution occurring above the perching of the underlying upper Glen Rose Limestone (Stein, 1993). In this area of the recharge zone where the Person

Formation has been stripped off, the basal nodular member may be the most reliable and ultimate water-producing unit because of the perching effects of the less transmissive underlying upper Glen Rose Limestone. During lower water-level conditions, the depth and location of the basal nodular member from land surface may dictate the water levels in the recharge zone.

The ground-water divide in the confined section of the aquifer could be controlled by the structural setting or the hydrologic setting. The water-level high in the artesian section may result because of a preferred pathway from the mounding of ground water beneath Onion Creek in the recharge zone into the artesian part of the aquifer. Another possibility is that, based on topography, a structural high exists between the Cities of Kyle and Buda.

Austin Chalk is on the surface over much of the artesian part of the aquifer in this area, which is located generally near IH 35 between the Cities of Kyle and Buda. Available electric logs show the Edwards aquifer is about 340 to 410 feet below the land surface in this part of the study area. However, not enough electric logs from wells drilled between the Cities of Kyle and Buda were available to develop a complete detailed geologic picture of the Edwards aquifer in the subsurface. A topographically high ridge between Loop 4 and IH 35, south of the City of Buda, is close to the location of the ground-water divide and may reflect some subsurface structure causing the ground-water divide in the artesian part of the aquifer.

Hays County Conclusions

The ground-water mound that creates the divide generally west of Buda is the result of recharge the Edwards aquifer receives from surface water in Onion Creek. Recharge is focused in this area along Onion Creek because of extensive exposures of the Kirschberg evaporite member and numerous faults, which are favorable for the development of secondary porosity and permeability.

The Blanco River, located to the south, crosses primarily the upper Glen Rose and then the upper confining units after a narrow outcrop of Edwards. As a result, the Blanco River has less recharge potential than Onion Creek, even though the

Blanco River has much higher base flows than Onion Creek. The recharge is focused in an area located along Onion Creek that has extensive exposures of Kirschberg evaporite member and numerous faults, which are favorable for the development of secondary porosity and permeability. The focused recharge in this hydrogeologically favorable area results in the mound, or high, in water levels that delineates the divide in the unconfined recharge zone.

In the artesian part of the aquifer, the divide is less defined. The water-level high may result solely from ground water discharging from the recharge zone to the confined section, such as a preferred flowpath that is directed from the Onion Creek area into the artesian part of the aquifer. It could possibly be modified by an unknown subsurface geologic structure. The water-level high in the artesian part of the aquifer between the Cities of Buda and Kyle is modified and possibly magnified by the effects of relatively larger amounts of pumpage in the vicinities of the two cities on either side of the high and the relative lack of pumping in the area between the two cities. Water levels measured toward the end of summer 1994 in the artesian part of the aquifer are below the level of San Marcos Springs Lake. These data may suggest that, during times of lower water levels, the artesian part of the aquifer generally north of the Blanco River may not supply water to San Marcos Springs but instead to pumpage near Kyle and Buda and to Barton Springs. A water-level high between Kyle and Buda that is shown by the summer 1994 measurements indicates that flow during this period does not move past San Marcos Springs to Barton Springs.

Based on the data in this report, the ground-water divide in Hays County should be located generally between the Cities of Buda and Kyle in the artesian part of the aquifer and then along Onion Creek in the Edwards aquifer recharge zone. Given the configuration of the water table and location of the high in water levels over this area, water recharged along Onion Creek would go to both Barton Springs and San Marcos Springs. Even though ground-water divides are drawn along water-level highs, the certainty of the boundary for flow to move only in one direction away from the ground-water high is unknown. This may be especially true given that the

Edwards aquifer is a karst limestone and flowpaths may not always follow the apparent gradient on a contoured water-level map because of the associated caves and fractures. Different conditions may cause different flowpaths within the Edwards aquifer. The BSEACD is planning to conduct a dye tracer test in Antioch Cave located in the stream bed of Onion Creek about 1.6 miles upstream of FM Road 967 near Buda. Hopefully, this dye trace study will more accurately determine specific flowpaths in this part of the Edwards aquifer.

KINNEY COUNTY GROUND-WATER DIVIDE

Kinney County is located on the very western end of the Edwards (Balcones Fault Zone) aquifer. The Edwards aquifer found to the west of the Kinney County ground-water divide is believed to be a part of the Edwards-Trinity Plateau aquifer. To the east of the ground-water divide is the San Antonio region of the Edwards aquifer.

Generally, water levels are controlled by recharge to the aquifer through precipitation and discharge from the aquifer from pumping and springs. Precipitation at Brackettville has averaged 21.19 inches per year for the 94-year period of record through 1992 (Bader and others, 1993) and the yearly precipitation from 1936 to 1992 is shown in Figure 13. The other major source of potential recharge is the West Nueces River to the north-northeast of the study area, with an annual mean discharge of 39.5 cfs for the period 1956 to 1993 (USGS, 1994). Stream losses in this stretch of the West Nueces River are currently used for recharge calculations in the San Antonio region of the Edwards aquifer.

Kinney County is composed primarily of ranch land and some minor dry-land farming. A majority of the pumping located near Brackettville is by domestic and public supply wells. Pumpage by the City of Brackettville is relatively small, reaching almost 90 acre-feet per month, and is shown in Figure 13 as reported to the TWDB in acre-feet per month. Pumpage is usually relatively higher during seasonally drier periods.

Spring discharge from the Edwards aquifer in Kinney County occurs primarily from three main sets of springs, Las Moras, Pinto and Mud Springs. Other springs exist in Kinney County (Brune, 1981) but these three have the largest springflow. Measurements recorded by the IBWC for Las Moras in Brackettville, and Pinto and Mud Springs in Kinney County are shown on graphs in Figure 14. For comparison, total discharge from San Felipe Springs located about 30 miles west of Brackettville near Del Rio in Val Verde County is also shown on the graphs.

Analysis of Water-Level Data

Historic water-level measurements were evaluated for Kinney County. The data originally collected by Bennett and Sayre (1962) from late 1937 through 1940 are the most comprehensive data set. Hundreds of water levels in wells were measured over this period of time. Only a few of the water levels measured were used in their 1937-40 water-level map. At that time, accurate topographic maps were not available and altimeter readings were used to determine the altitude of land surface at the well. These instruments are subject to large variations in readings, sometimes associated with atmospheric changes. An attempt was made to locate these wells on current topographic sheets with the aid of well location maps, information in TBWE Bulletin 6216 (Bennett and Sayre, 1962) and some original field notes kept by the USGS office in San Antonio. Land-surface altitudes were determined for many wells that had no altitudes listed. Altitude readings for some wells were changed by as much as 41 feet. From these data, 64 wells, which are listed in Table 4 with well information and changes made to the land-surface altitude, were used to derive the 1937-40 water-level map. Over this time period, near average rainfall occurred at Brackettville with 19.97 inches, 18.38 inches and 22.43 inches for 1938 through 1940, respectively. Most of the water-level measurements used were taken in nonsummer months with the exceptions occurring in small geographic areas in close proximity to one another; therefore, the measurements are assumed to be relatively consistent for comparison purposes.

The 1937-40 elevations of and depths to water levels in the Edwards aquifer are shown on Figure 15 and generally illustrate the approximate potentiometric surface over this span of time. If it is assumed that the direction of ground-water flow is generally at right angles to the water-level contours and in the direction of decreasing altitude, ground water is generally moving south-southwest toward Las Moras Springs, and then eastward past the springs.

Water-level maps were also plotted from data shown in Tables 5 and 6 for March 1952, July 1976 and July 1992 and are shown in Figures 16, 17 and 18, respectively. The 1952 and 1976 data were taken from water-level measurement field data sheets recorded by the USGS, and the 1992 data were taken from measurements by the EUWD.

Water levels measured in 1994 (Table 7) by personnel of LBG-Guyton Associates, the EUWD, and the IBWC were plotted and contoured to show current water-level conditions (Figure 19). These current water levels are again very similar to the other historic contoured water levels. The water levels directly east of Las Moras Springs seem to indicate a flow component moving past the springs and toward Uvalde to the east. Looking at contoured water levels over the span of record, the elevations and placements of the contour lines appear similar.

Hydrographs spanning a number of years were developed from two sources, the IBWC and the TWDB. Figure 20 shows water levels in wells in Kinney County measured by the IBWC generally from the period just before the filling of Lake Amistad in 1968 to the present. Water levels in most of these wells have fluctuated 10 to 30 feet. Some of the quick drops in the water levels may be associated with local pumping. Many of the rises may be associated with relatively wetter periods from relatively higher rainfall. IBWC Well Number 664-81 (also State Well Number RP-70-36-101) shows some initial increase, especially in the high water levels. This is the only Kinney County well in the IBWC network of observation wells that may show signs of influence from the filling of Lake Amistad starting in 1968. Additional evidence for increased water levels in this well is found in the state records, with a water level of 102.4 feet below land surface on April 23, 1938. This is 20 feet lower than the next measurement, 80.4 feet below land surface taken by the IBWC on July 3, 1968. The lower water level is not believed to be associated with a lack of precipitation because rainfall was near average in 1938, and therefore the higher water level may be associated with the Amistad Lake level rising. This well which is in close proximity to Mud Springs correlates closely with Mud springflow measurements shown in Figure 14.

Water-level measurements shown in Figure 21 are compiled from TWDB records and generally span an area from Lake Amistad through Del Rio and Brackettville generally along Highway 90 moving from west to east. Well YR-70-25-502 is just east of Lake Amistad and shows a dramatic water-level rise of over 120 feet starting in 1968 occurring simultaneously with the filling of Lake Amistad. Well YR-70-41-209 in Del Rio does not show any upward trend. Well YR-70-42-205 at Laughlin AFB may have a slight increase starting in the early 1970's, but the two Kinney County wells (RP-70-45-401 and RP-70-46-901) definitely show no increase in the water-level trend over the period of record. Based on these water-level observations from IBWC and TWDB data, no rises in water levels are being seen much past the Val Verde and Kinney County line in association with the filling of Lake Amistad.

Geologic and Hydrologic Features

Kinney County is underlain predominantly by sedimentary rocks with some igneous intrusives. Many areas are covered with a more recent alluvium, but the rocks of interest are Cretaceous in age. The Cretaceous stratigraphy of interest was mentioned in the earlier Regional Geology section and is listed in Table 1. The surface geology is shown in Figure 22 from the Geologic Atlas, Del Rio sheet (BEG, 1977). The igneous intrusives found in Kinney County are located in the western part of the Uvalde Igneous Field, which is also the southwestern half of the Balcones Igneous Province. The igneous intrusives predominantly form volcanic tuff cones, plugs and laccoliths (an intrusive that domes up the overlying rocks). Numerous dikes and sills (narrow planar intrusions) are also present in the volcanic field.

Mineralogically, the volcanics are ultramafic basalt composed mostly of olivine nephelinites and are dated Late Cretaceous, generally after the deposition of Edwards equivalent rocks (Ewing, 1989). As a result, the Edwards rocks were baked and metamorphosed adjacent to the igneous intrusions. Hydrologically, this metamorphism of the Edwards limestone may have resulted in reduction of secondary porosity. Because of the essentially impermeable nature of the basalt, the hydrologic effects to the aquifer from the intrusives could be thought analogous to a "grout curtain" that is injected into permeable rock to decrease leakage. Flow within the aquifer will be diverted around the igneous intrusions. On the other hand, the intrusions into the host rock could result in increased fracturing in close proximity to the intrusions and therefore may increase permeability adjacent to these intrusions.

An example of this is the intrusion to the northeast of Turkey Mountain. A well identified as R-6 in Bennett and Sayre (1962), located one mile northeast of Turkey Mountain, was drilled through 150 feet of basalt. This indicates the potential thickness of the dikes located in Kinney County. Bennett and Sayre (1962) also identify outcrops of metamorphosed Edwards limestone in the vicinity of Turkey Mountain. An aerial photograph of Turkey Mountain in Bennett and Sayre (1962) shows dark radiating bands which are associated with denser concentrations of vegetation. The vegetation may be caused either by enhanced permeability because of increased fracturing parallel to the intrusion and/or decreased permeability of the basaltic rock that would slow or impede water from traveling through the aquifer allowing the vegetation to take advantage of this ponding-type effect. Whatever the mechanism might be, surface vegetation shows the effects of alterations to the existing shallow hydrology caused by the intrusion into the Edwards limestone.

The sedimentary strata of the area generally dip to the south or southeast at about 80 feet per mile (Bennett and Sayre, 1962). This area is on the western end of the Balcones fault zone with fault trends predominantly in a northeast/southwest direction. Faulting decreases from east to west in the county, and most of the fault extents and displacements are much less than the displacements found for faults further east within the Balcones fault zone. As a result, the faults do not form barriers to flow, but because of the broken nature of rocks within the fault zones, these areas have enhanced porosities and permeabilities, especially in a parallel direction to the faults.

Bennett and Sayre (1962) described synclinal structures along Road 334 between Brackettville and Laguna, Texas and also discuss the Brackett Anticline along Silver Lake Road (Figure 23) that was originally described by F. M. Getzendaner. Bennett and Sayre (1962) also describe smaller flexures superimposed on the larger folds. Based on the surface geology, the folds seem to be plunging toward the southwest and the axes would trend at about N50°E. Based on these descriptions and the surface geology, a three-dimensional geologic schematic diagram was developed and is shown on Figure 23. Of interest is the location of the igneous intrusions, as compared to the folds. The igneous outcrops seem to occur mostly near the apexes of the anticlines. This indicates that either the intrusion locations are extruded along the highs of the folds or that the intrusions themselves have pushed up the overlying strata and caused the folds, depending on the sequencing of the geologic events.

Regardless of the mechanism, the combination of the location of intrusive igneous rocks and folds (specifically synclines) in the strata create a pie-shaped area that helps to funnel water in the aquifer toward Las Moras Springs, much like a sheet of tilted corrugated tin funneling rainwater. In the recharge zone, the water-level highs (Figures 15 through 19) are associated with the anticlines and the water-level lows are associated with the synclines. All of these measurements seem to indicate the convergence of flow first toward the synclines from the higher anticlines, then toward the springs from the north, generally moving south-southwest down the plunge direction of the folds.

Las Moras Springs issue through a small displacement fault located in the City of Brackettville (Bennett and Sayre, 1962). This area probably reaches north to the West Nueces, receiving recharge from the river and precipitation over the outcrop within this pie-shaped area. A similar funnel probably exists between Las Moras Mountain and Pinto Mountain and feeds Pinto Springs. The synclines also structurally help concentrate surface-water runoff generally along their low axes, and as a result increase recharge to the aquifer in these areas within the synclines. The northeast/southwest-trending faults in the area also help to direct flow toward both of these springs from the northeast from their respective synclines.

Another potential geologic control on the regional hydrology is formed by a northwest-trending lineament that runs from Anacacho Mountain, through the igneous intrusion off Highway 90, through Las Moras Mountain and Pinto Mountain and along an escarpment to the northwest of Pinto Mountain. The unnamed escarpment located northwest of Pinto Mountain in the Edwards aquifer recharge zone may allow water to flow southwest off the escarpment but would not allow flow to move to the east back across the escarpment. The cause for this lineament is not known. The lineament may be the western boundary of the previously mentioned Uvalde Igneous Field. Anacacho Mountain is thought to be associated with a central volcanic uplift (Ewing, 1989) and would probably help to form the southern limits of the aquifer with the "bad-water line" occurring to the north of Anacacho Mountain.

Kinney County Conclusions

In Kinney County, geology plays an important role in the potential pathways for water in the Edwards aquifer. Faulting in Kinney County is a less important hydrologic factor than to the east because the displacements are relatively minor. The faults can act as conduits but probably not as barriers. Folding is very important, with several plunging anticlines and synclines channeling water like a large sheet of corrugated tin toward Las Moras and Pinto Springs. Intrusions of essentially impermeable igneous rocks that generally occur along the axes of the anticlines, which are folded upward, help to magnify the constraining effect of the folds by acting like a "grout curtain" where the igneous material has been intruded into the Edwards limestone.

Water levels have shown some minor changes through time, but have remained relatively constant. No effects from the filling of Lake Amistad have been detected in the vicinity of the ground-water divide in Kinney County. In addition to direct recharge from precipitation over the Edwards aquifer recharge zone, stream losses from the West Nueces north-northeast of the study area are the source of recharge to the ground-water system in north-central and northeast Kinney County. Generally, the potentiometric water-level maps reflect a funneling effect of the geologic controls.

Ground-water divides generally are drawn along water-level highs that appear as a protrusion in the water-level contours, sometimes referred to as noses. Two such noses appear on the water-level contour maps, both reflective of the underlying anticlines and synclines. However, water-level measurements, especially 1994, indicate that a component of flow comes past Las Moras Springs from west to east toward the City of Uvalde. As a result, the divide should be placed to the west of Las Moras Springs. It probably extends to the north toward Pinto Mountain and then along a topographic high in the unnamed escarpment north of Pinto Mountain. Because stream losses in the West Nueces River are presently used for recharge calculations for the San Antonio region of the Edwards aquifer and water-level contours indicate that a portion of this recharge is moving toward Pinto and Las Moras Springs, discharge of both these springs should be considered as part of any water-balance calculations for the Edwards aquifer in this area.

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TABLES

TABLE 1
STRATIGRAPHIC UNITS AND THEIR WATER-BEARING PROPERTIES

MAVERICK BASIN

System		Stage/Group		Stratigraphic Unit	Function	Thickness (feet)	Lithology	Hydrostratigraphy
Cretaceous	Upper	Gulf		Igneous rocks	CB	—	Basalt.	Intrusive sills, laccoliths and volcanic necks; negligible permeability.
Cretaceous	Upper	Gulf	Austin Group	Austin Chalk	AQ	600	Chalk and marl; chalk mostly microangular calcite, bentonite seams, glauconitic.	Little to moderate permeability.
Cretaceous	Upper	Gulf	Eagle Ford Group	Eagle Ford Shale	CB	250	Shale, siltstone and limestone; flaggy limestone beds are interbedded with carbonaceous shale.	Little permeability.
Cretaceous	Upper	Washita		Buda Limestone	CB	100	Limestone; fine grained, bioclastic, glauconitic, hard, massive, nodular, argillaceous toward top.	Little permeability.
Cretaceous	Upper	Washita		Del Rio Clay	CB	120	Clay and shale; calcareous and gypsiferous, some thin beds of siltstone.	Negligible permeability.
Cretaceous	Lower	Washita		Salmon Peak Formation	AQ	380	Limestone; upper 80 feet contains reef talus grainstones caprinid boundstones, crossbedding of grainstones; the lower 300 feet is a uniform dense carbonate mudstone.	Deep water deposits except toward the top. Upper part is moderately to very permeable. Lower part is almost impermeable except where fractured.
Cretaceous	Lower	Fredericksburg		McKnight Formation	CB	150	Limestone and shale; upper 55 feet is mudstone containing thin zones of collapse breccias; middle 24 feet is shaly, lime mudstone; lower part is limestone containing collapse breccias in upper part.	Deep basinal euxinic deposits. Little permeability.
Cretaceous	Lower	Fredericksburg		West Nueces Formation	AQ/CB	140	Limestone; upper 80 feet is largely a massive unit of miliolid- and mollusc-bearing grainstone; lower 60 feet is a nodular, dense mudstone.	Upper part is moderately permeable. Lower part is almost impermeable.
Cretaceous	Lower	Trinity		Glen Rose Formation, Upper member	CB	1,000-1,500	Limestone, dolomite and marl; limestone is fine grained, hard to soft, marly; dolomite is porous and finely crystallized.	Little permeability.
Cretaceous	Lower	Trinity		Glen Rose Formation, Lower member	AQ		Limestone and some marl. Massive bedded.	More permeable toward base of unit.

(Modified from Maclay and Small, 1984)

Abbreviations: AQ - aquifer
CB - confining bed
LS - limestone

SAN MARCOS PLATFORM

System		Stage/Group		Stratigraphic Unit		Function	Approximate Thickness (feet)	Lithology	Hydrology/ Porosity Type	Hydrologic Subdivision
Cretaceous	Upper	Gulf	Austin Group	Austin Chalk		AQ	200-350	Chalk, marl and hard LS	Small to moderate permeability/ secondary karst	
Cretaceous	Upper	Gulf	Eagle Ford Group	Eagle Ford Shale		CB	30-50	Flaggy shale and argillaceous LS	Low permeability/ primary porosity lost	Upper confining unit
Cretaceous	Upper	Washita		Buda Limestone		CB	40-50	Buff to gray biomicrite LS	Usually tight/local caves nonextensive	Upper confining unit
Cretaceous	Upper	Washita		Del Rio Clay		CB	40-50	Green to yellow clay	Primary upper confining unit/none	Upper confining unit
Cretaceous	Lower	Washita		Georgetown Formation		Karst - AQ; nonkarst - CB	0-50	Reddish brown friable LS; tannish yellow biomicrite	Some permeability/ some nonfabric; little permeability/relatively none	I
Cretaceous	Lower	Washita	Edwards Group	Person Formation	Cyclic member and marine member	AQ	80-90	Tidal flat LS with collapsed breccias, biosparite and biomicrite	Water-bearing/ laterally extensive, both fabric and nonfabric	II
Cretaceous	Lower	Washita	Edwards Group	Person Formation	Leached member and collapsed member	AQ	70-90	Dense, bioturbated biomicrite; collapsed stromatilitic LS	One of most permeable/majority fabric porosity	III
Cretaceous	Lower	Washita	Edwards Group	Person Formation	Regional dense member	CB	20-24	Dense micrite	Low permeability vertical barrier/only nonfabric	IV
Cretaceous	Lower	Fredericksburg	Edwards Group	Kainer Formation	Grainstone member	AQ	50-60	Well-sorted grainstone to burrowed mudstone	Recrystallization reduces permeability/ more nonfabric porosity	V
Cretaceous	Lower	Fredericksburg	Edwards Group	Kainer Formation	Kirschberg evaporite member	AQ	50-60	Thinly bedded, highly altered LS	One of most permeable/majority fabric porosity	VI
Cretaceous	Lower	Fredericksburg	Edwards Group	Kainer Formation	Dolomitic member	AQ	110-130	Converted to calcite; microcrystalline LS	Water-bearing/mostly nonfabric, some bedding-plane fabric	VII
Cretaceous	Lower	Fredericksburg	Edwards Group	Kainer Formation	Basal nodular member	Karst - AQ; nonkarst - CB	50-60	Clayey mudstone to wackestone	At surface - large conduit flow; subsurface - no permeability/fabric porosity, stratigraphic controlled	VIII
Cretaceous	Lower	Trinity		Glen Rose Formation	Upper member	CB	350-500	Yellowish tan thinly bedded micritic LS	Relatively impermeable, some water evaporite beds/some caves	Lower confining unit
Cretaceous	Lower	Trinity		Glen Rose Formation	Lower member	AQ	300	Massive fossiliferous LS	Good permeability toward bottom/moldic in reef patches	

(Modified from Stein, 1993)

TABLE 2
RECORDS OF WELLS IN HAYS COUNTY
USED IN 1985 WATER-LEVEL MAP

State Well Number	Well Depth (feet)	Casing Depth (feet)	Probable Producing Unit	Land-Surface Elevation (feet above MSL)	Water-Level Data: Date of Measurement	Water-Level Data: Depth to Water (feet)	Water-Level Data: Elevation (feet above MSL)
LR-58-57-102	200	--	upper Glen Rose	1,055	7/17/85	102.11	953
LR-58-57-103	200	--	upper Glen Rose	1,015	7/17/85	102.29	913
LR-58-57-201	320	--	Edwards	929	7/17/85	148.90	780
LR-58-57-302	285	150	Edwards	765	7/17/85	154.53	610
LR-58-57-402	380	--	Edwards	880	7/16/85	83.90	796
LR-58-57-403	350	--	Edwards	982	7/17/85	199.34	783
LR-58-57-502	385	--	Edwards	875	7/17/85	213.26 [1/]	662
LR-58-57-504	--	--	Edwards	821	8/8/85	140.02	681
LR-58-57-505	--	--	Edwards	854	8/8/85	177.85	676
LR-58-57-602	150	--	Edwards	795	8/8/85	123.89	671
LR-58-57-701	--	--	Edwards	931	7/18/85	176.97	754
LR-58-57-804	--	--	Edwards	818	7/15/85	180.22	638
LR-58-57-806	400	--	Edwards	760	7/16/85	127.79	632
LR-58-57-807	300+	--	Edwards	887	7/17/85	189.11	698
LR-58-57-808	220	161	Edwards	738	7/17/85	73.46	665
LR-58-57-809	240	181	Edwards	738	7/15/85	79.63	658
LR-58-57-810	--	--	Edwards	810	8/8/85	133.60	676
LR-58-57-902	450	--	Edwards	818	7/15/85	193.43	625
LR-58-57-904	428	290	Edwards	825	7/15/85	196.81	628
LR-58-57-906	360	265	Edwards	880	7/15/85	236.58	643
LR-58-57-907	325	--	Edwards	850	7/15/85	226.25	624
LR-58-57-908	425	340	Edwards	830	7/16/85	208.20	622
LR-58-58-101	243	230	Edwards	707	7/17/85	90.10	617
LR-58-58-411	510	435	Edwards	735	7/22/85	128.61	606
LR-58-58-504	--	--	Edwards	778	7/17/85	161.77	616
LR-58-58-701	492	--	Edwards	711	7/22/85	100.54	610
LR-58-58-706	520	300	Edwards	695	7/22/85	91.21	604
LR-58-58-801	502	431	Edwards	714	7/22/85	111.98	602
LR-67-01-304	372	340	Edwards	718	7/17/85	126.24	592
LR-67-01-309	658	328	Edwards	753	7/18/85	165.40	588

NOTE: Water-level measurements used in the construction of the water-level map in Figure 6.

FOOTNOTE: [1/] Water level may be affected by recent pumping.

TABLE 3
RECORDS OF WELLS IN HAYS COUNTY USED IN 1994 WATER-LEVEL MAPS

Well Number	State Well Number	Well Owner	Latitude	Longitude	Year Completed	Well Depth (feet)	Casing Data: Depth (feet)	Casing Data: Diameter (inches)	Land-Surface Elevation (feet above MSL)	Water-Level Data: MP above land surfac (feet)	Water-Level Data: Date of Measurement	Water-Level Data: Depth to Water (feet)	Water-Level Data: Elevation (feet above MSL)	Water-Level Data: Difference (feet)
LR-58-57-2ee8	LR-58-57-201	Bruce Mayes	300610	975613	1945	320	--	6	925	--	2/4/94	1/	--	--
LR-58-57-2fa3	LR-58-57-208	Don West	300635	975538	1983	400	300	5	895	1.6	2/6/94	134.12	761	--
LR-58-57-2fc2	LR-58-57-205	Don West	300638	975508	1983	360	300	5	829	2	2/6/94	114.8	714	--
LR-58-57-2if8	--	Jim Ruby	300522	975510	--	--	--	6	835	0.9	1/28/94	176.79	658	7.47
											8/30/94	169.32	666	
LR-58-57-2ii9	LR-58-57-204	Jim Ruby	300501	975505	1950	245	--	6	800	1.3	1/28/94	140.03	660	-3.30
											8/30/94	143.33	657	
LR-58-57-3ch7	--	G.T.E.	300647	975302	1986	--	--	5	805	1.85	2/2/94	222.35	583	--
LR-58-57-3ei4	LR-58-57-305	Jack Dahlstrom	300557	975332	1973	415	158	12	811	1.15	2/8/94	203.28	608	-4.41
											8/31/94	207.69	603	
LR-58-57-3ff9	--	Jack Dahlstrom	300612	975231	--	--	--	6	772	0.7	2/8/94	218.74	553	-4.34
											8/31/94	223.08	549	
LR-58-57-3fh5	LR-58-57-307	Hays C.I.S.D.	300559	975247	1985	470	470	6-5/8	775	2	1/31/94	209.68	565	--
LR-58-57-3hb9	--	Jack Dahlstrom	300535	975338	--	287	--	5	870	0.4	2/8/94	244.75	625	-3.63
											8/31/94	248.38	622	
LR-58-57-5cc6	--	Jim Ruby	300452	975500	--	--	--	8	790	0.9	1/28/94	125.69	664	-2.06
											8/30/94	127.75	662	
LR-58-57-5ci5	--	Jim Ruby	300421	975510	--	~280	--	6	795	1.05	1/28/94	120.67	674	-2.03
											8/30/94	122.70	672	
LR-58-57-5ff4	LR-58-57-504	Jim Ruby	300342	975512	--	--	--	--	821	0.8	1/28/94	141.81	679	-2.11
											8/30/94	143.92	677	
LR-58-57-5gd1	--	Billy Walker	300259	975726	1993	410	410	--	870	1.8	2/11/94	155.77	714	-3.62
											9/2/94	159.39	711	
LR-58-57-5ic7	LR-58-57-505	Jim Ruby	300304	975515	--	--	--	8-3/4	854	1	1/28/94	180.16	674	-0.78
											8/30/94	180.94	673	
LR-58-57-6ag1	LR-58-57-602	Jim Ruby	300426	975456	--	150	--	6-1/2	795	0.3	1/28/94	128.3	667	-2.11
											8/30/94	130.41	665	
LR-58-57-6ba9	LR-58-57-603?	Jack Dahlstrom	300448	975355	--	--	--	--	804	--	2/8/94	1/	--	--
LR-58-57-6bc3	--	Jack Dahlstrom	300458	975321	--	--	--	--	787	1.05	2/8/94	157.9	629	-10.09
											8/31/94	167.99	619	

TABLE 3 (Continued)

Well Number	State Well Number	Well Owner	Lati-tude	Longi-tude	Year Com-pleted	Well Depth (feet)	Casing Data: Depth (feet)	Casing Data: Diam-eter (inches)	Land-Surface Elevation (feet above MSL)	Water-Level Data: MP above land surfac (feet)	Date of Measure-ment	Depth to Water (feet)	Elevation (feet above MSL)	Differ-ence (feet)
LR-58-57-6cd2	LR-58-57-601?	Jack Dahlstrom	300440	975314	1971	390	160	8-1/2	783	1.65	2/8/94	145.78	637	-8.51
											8/31/94	154.29	629	
LR-58-57-6di4	LR-58-57-605	Jack Dahlstrom	300326	975426	--	--	--	--	802	0.8	2/8/94	143.15	659	-2.61
											8/31/94	145.76	656	
LR-58-57-6ea5	--	Jack Dahlstrom	300402	975357	1993	326	--	6	803	1.6	2/8/94	139.89	663	-5.16
											8/31/94	145.05	658	
LR-58-57-6ih4	LR-58-57-607	Kyle Curch of Christ	300242	975303	1987	320	240	5	826	1.95	2/2/94	235.44	591	-0.34
											8/8/94	235.78	590	
LR-58-57-7bb8	LR-58-57-702	Johnson Jr.	300218	975845	--	--	--	--	942	1	2/4/94	193.26	749	--
LR-58-57-7cc1	--	Johnson Jr.	300226	975745	--	--	--	6	939	0.95	2/4/94	218.08	721	1.10
											9/2/94	216.98	722	
LR-58-57-8cc1	LR-58-57-810	Jim Ruby	300227	975513	--	--	--	6	810	1.05	1/28/94	140.44	670	-0.93
											8/30/94	141.37	669	
LR-58-57-8de8	LR-58-57-807	J. M. Johnson	300110	975706	--	300+	--	--	887	--	2/4/94	[1]	--	--
LR-58-57-8fa2	LR-58-57-802	J. M. Johnson	300136	975540	--	242	--	--	838	0.4	2/4/94	190.99	647	--
LR-58-57-8ha4	--	J. M. Johnson	300039	975639	--	200+	--	--	748	1	2/4/94	139.66	608	--
LR-58-57-8ib2	--	A. W. Gregg, Jr.	300048	975523	--	--	--	--	770	0.95	2/11/94	164.84	605	-1.06
											9/2/94	165.90	604	
LR-58-57-8ih5	LR-58-57-806	A. W. Gregg, Jr.	300011	975524	--	400	--	7	760	1	2/11/94	165.85	594	-0.17
											9/2/94	166.02	594	
LR-58-57-8ii2	--	A. W. Gregg, Jr.	300016	975507	--	--	--	6	742	0.7	2/11/94	160.24	582	-0.73
											9/2/94	160.97	581	
LR-58-57-9bi3	LR-58-57-901	Hays C.I.S.D.	300156	975323	1985	575	235	10	835	1.5	1/31/94	249.46 [2]	586	--
LR-58-57-9bi4	--	Leo Miller	300148	975335	--	--	--	--	838	2.3	2/15/94	241.35	597	--
LR-58-57-9ca8	LR-58-57-903	James Kohler	300217	975309	--	~400	--	7	823	1	2/3/94	231.7	591	-4.00
											9/2/94	235.70	587	
LR-58-57-9cg4	--	James Kohler	300146	975317	--	~450	--	--	817	1	2/3/94	222.7	596	-3.28
											9/2/94	225.98	591	
LR-58-57-9fd4	--	James Kohler	300114	975319	--	~450	--	--	779	1.1	2/3/94	186.15	593	-4.34
											9/2/94	190.49	589	
LR-58-57-9gb1	--	A. W. Gregg, Jr.	300047	975440	--	--	--	--	807	0.15	2/11/94	209.14	598	-1.16
											9/2/94	210.30	597	

TABLE 3 (Continued)

Well Number	State Well Number	Well Owner	Latitude	Longitude	Year Completed	Well Depth (feet)	Casing Data: Depth (feet)	Casing Data: Diameter (inches)	Land-Surface Elevation (feet above MSL)	Water-Level Data: MP above land surfac (feet)	Water-Level Data: Date of Measurement	Water-Level Data: Depth to Water (feet)	Water-Level Data: Elevation (feet above MSL)	Water-Level Data: Difference (feet)
LR-58-57-9gf5	--	A. W. Gregg, Jr.	300025	975417	--	--	--	--	772	1.45	2/11/94	182.84	589	-1.20
											9/2/94	184.04	588	
LR-58-57-9hc1	LR-58-57-904	Pedernales Electric Coop.	300048	975332	1975	428	290	5-5/8	825	1.05	1/31/94	246.49 [2/]	579	--
LR-58-57-9hc3	LR-58-57-911	James Kohler	300041	975321	1950	450	--	--	833	0.3	2/3/94	244.38	589	-5.06
											9/2/94	249.44	584	
LR-58-57-9he2	LR-58-57-902	A. W. Gregg, Jr.	300030	975341	--	450	--	6	818	0.9	2/2/94	227.75	594	-4.61
											9/2/94	232.36	586	
LR-58-58-1ce8	LR-58-58-124	John Porter	300702	975027	1985	510	200	9	720	2	2/15/94	179.86	540	--
LR-58-58-1fb4	LR-58-58-123	John Porter	300632	975029	1985	510	230	9	710	2	2/15/94	146.47	564	-13.36
											8/31/94	159.83	550	
LR-58-58-1hg6	--	Rhonda Levine	300508	975122	~1984	~400	--	5-3/4	751	0.4	2/23/94	161.37	590	-8.49
											8/30/94	169.86	581	
LR-58-58-1ia6	LR-58-58-117	Twin Oaks Ranch Church	300539	975035	1970	195	104	7	705	0.6	2/24/94	134.48	571	--
LR-58-58-1ih7	LR-58-58-101	Franklin/BSEACD	300500	975031	1907	243	230	5	707	--	2/20/94	126.4	581	-9.72
											8/31/94	136.12	571	
LR-58-58-2ha5	LR-58-58-217	SW Auto Brokers	300541	974858	1982	600	--	4-1/2	692	1.6	2/24/94	99.42	593	--
LR-58-58-4ab4	LR-58-58-420	Linda Hipolipo	300450	975208	--	--	--	4-3/4	733	1.8	2/23/94	138.74	594	-7.06
											8/30/94	145.80	587	
LR-58-58-4bg8	LR-58-58-418	Texas Lehigh	300415	975130	--	--	--	11	724	0.5	2/21/94	137.96	586	-4.24
		Cement									8/12/94	142.20	582	
LR-58-58-4ed4	--	Texas Lehigh	300342	975119	--	--	--	--	741	0.7	2/23/94	160.86	580	-8.93
		Cement									9/2/94	169.79	571	
LR-58-58-4ge9	LR-58-58-417	Hays Youth	300250	975201	1984	600	400	6-5/8	763	2	2/23/94	170.84	592	-7.04
		Athletic									9/2/94	177.88	585	
LR-58-58-4hb4	LR-58-58-407	Texas Lehigh Cement	300312	975117	1960	634	153	12	756	2.55	2/21/94	171.32	585	--
LR-58-58-5ad2	LR-58-58-501	Goforth W. S. C.	300442	974951	1970	640	500	8	715	1.45	2/24/94	135.66	579	--
LR-58-58-7af3	--	Texas Lehigh Cement	300212	975142	--	--	--	--	720	--	2/21/94	[3/]	--	--
LR-58-58-7bc7	LR-58-58-709	Tilson Custom	300219	975105	--	--	--	6	763	0.8	2/24/94	180.14	583	-12.48
		Homes									8/10/94	192.62	570	
LR-58-58-7bh4	--	Texas Lehigh	300147	975118	--	--	--	--	752	1.1	2/22/94	169.43	583	-11.89
		Cement									8/31/94	181.32	571	

TABLE 3 (Continued)

Well Number	State Well Number	Well Owner	Latitude	Longitude	Year Completed	Well Depth (feet)	Casing Data Depth (feet)	Casing Data Diameter (inches)	Land-Surface Elevation (feet above MSL)	Water-Level Data: MP above land surfac (feet)	Date of Measurement	Depth to Water (feet)	Elevation (feet above MSL)	Difference (feet)
LR-58-58-7eb2	LR-58-58-703	Les Crane	300137	975115	1898	507	507	6	740	0.55	2/22/94	145.33 4/	595	-6.12
											8/31/94	151.45 4/	589	
LR-58-58-7ha4	LR-58-58-707	Leon Bauerle	300043	975134	--	450	--	--	717	1.15	2/23/94	132.49	585	--
LR-58-58-8ad7	LR-58-58-801	Dick Whitten	300200	974959	1942	502	431	7	714	1.3	2/23/94	130.69	583	--
LR-67-01-2ca1	--	A. W. Gregg	295959	975545	--	--	--	--	712	0.55	2/11/94	127.44	585	-0.18
											9/2/94	127.62	584	
LR-67-01-3ci3	LR-67-01-303	Kyle/EUWD	295922	975231	--	--	--	--	715	--	2/27/94	144.98	570	-17.29
											8/31/94	162.27	553	
LR-67-01-3fc6	LR-67-01-304	R. Selbera/EUWD	295903	975233	1934	372	340	5	718	0.5	2/24/94	145.01	573	-14.18
											8/31/94	159.19	559	
LR-67-01-3hh2	LR-67-01-301?	Kyle Cemetery	295747	975347	1950	336	--	8-1/2	685	--	2/24/94	115.34	570	-0.44
											8/31/94	115.78	569	
LR-67-01-4ce9	LR-67-01-401	Charles Mueller	295700	975751	--	--	--	7-1/2	806	0.7	2/18/94	227.59	578	--
LR-67-01-8cd2	LR-67-01-809	Knispel/EUWD	295443	975542	--	32.5	3	4	602	0	2/18/94	26.51	575	-0.22

NOTE: Water-level measurements used in the construction of water-level maps in Figures 7, 8 and 10.

FOOTNOTES: 1/ Unable to measure water level.
2/ Water level affected by recent pumping.
3/ Producing unit determined to be Austin Chalk.
4/ Well LR-58-58-7eb2 may be open to Austin Chalk and Edwards resulting in an erroneously high water level as compared to other Edwards aquifer wells.

TABLE 4
RECORDS OF WELLS IN KINNEY COUNTY USED IN 1937-40 WATER-LEVEL MAP [1/]

Bulletin 6216 [1/] Well Number	Land-Surface Elevation (feet above MSL)		Difference between Elevations (feet)	Water-Level Data		
	From Bulletin 6216 [1/]	From USGS Topo Sheets		Date of Measure-ment	Depth to Water (feet)	Elevation (feet above MSL)
D-2	--	1,590	--	10/18/38	106.6	1,483
D-5	--	1,622	--	1/25/39	187.0	1,435
E-4	--	1,560	--	2/3/39	259.9	1,300
E-5	1,384.4	1,400	-16	3/27/39	33.5	1,367
F-5	--	1,433	--	2/20/39	62.9	1,370
F-6	--	1,479	--	2/4/39	98.9	1,380
G-5	1,245.7	1,246	0	4/23/38	69.0	1,177
H-2	1,269.6	1,271	-1	4/23/38	77.8	1,193
H-3	--	1,245	--	10/4/39	62.6	1,182
H-4	--	1,171	--	4/22/38	31.3	1,140
H-5	--	1,180	--	2/15/39	52.1	1,128
I-1	--	1,458	--	4/14/38	148.2	1,310
I-2	--	1,410	--	4/14/38	166.1	1,244
I-3	1,358.9	1,363	-4	4/14/38	112.6	1,250
I-5	1,408.7	1,411	-2	4/14/38	169.2	1,242
I-6	--	1,318	--	4/14/38	97.9	1,220
I-7	--	1,209	--	2/15/39	55.0	1,154
I-8	--	1,232	--	2/15/39	36.8	1,195
I-9	1,255.2	1,255	0	4/13/38	62.9	1,192
J-1	--	1,610	--	2/15/39	322.2	1,288
J-4	1,347.3	1,347	0	3/27/39	125.6	1,221
J-6	1,312.1	1,300	12	2/22/39	122.0	1,178
K-2	1,470.5	1,495	-25	2/15/39	160.4	1,335
K-3	1,483.5	1,484	0	6/13/38	194.2	1,290
K-4	1,407.3	1,407	0	1/27/40	190.6	1,216
L-2	1,560	1,575	-15	2/9/39	146.6	1,428
L-3	1,370	1,366	4	8/31/39	79.5	1,287
L-5	1,300	1,300	0	1/31/40	103.0	1,197
L-6	1,259.2	1,259	0	2/27/39	41.8	1,217
L-7	1,408.6	1,450	-41	6/14/38	205.2	1,245
L-8	1,408.7	1,409	0	1/27/40	191.2	1,218
L-9	--	1,347	--	6/14/38	167.7	1,179
M-1	1,117.6	1,118	0	4/20/38	49.4	1,069
O-2	--	1,187	--	2/15/39	24.2	1,163
O-10	--	1,183	--	2/15/39	14.1	1,169
P-1	1,401.3	1,401	0	4/13/38	187.1	1,214
P-2	1,342	1,336	6	1/10/40	146.8	1,189
P-3	1,228	1,236	-8	4/13/38	33.7	1,202
P-4	1,297.9	1,298	0	4/11/38	108.0	1,190
P-6	1,269.2	1,272	-3	3/30/38	170.3	1,102
P-7	1,225.7	1,229	-3	2/20/39	113.6	1,115
P-8	--	1,272	--	3/30/38	152.1	1,120
P-9	1,218.7	1,219	0	4/11/38	116.7	1,102

Bulletin 6216 [1/] Well Number	Land-Surface Elevation (feet above MSL)		Difference between Elevations (feet)	Water-Level Data		
	From Bulletin 6216 [1/]	From USGS Topo Sheets		Date of Measure-ment	Depth to Water (feet)	Elevation (feet above MSL)
Q-1	1,415.8	1,416	0	6/15/38	224.8	1,191
Q-2	--	1,440	--	6/15/38	255.8	1,184
Q-3	1,352.4	1,348	4	6/14/38	167.0	1,181
Q-5	1,366.6	1,371	-4	6/13/38	174.9	1,196
Q-6	1,367.3	1,365	2	6/16/38	175.7	1,189
Q-8	1,344.9	1,345	0	6/16/38	227.4	1,118
Q-9	1,344.5	1,345	-1	6/15/38	227.0	1,118
Q-10	1,319.6	1,318	2	6/15/38	177.7	1,140
Q-11	1,238.8	1,230	9	2/20/39	121.4	1,109
Q-12	1,202.2	1,197	5	4/21/38	105.1	1,092
R-5	1,260	1,253	7	2/27/39	111.9	1,141
R-7	1,392.6	1,393	0	6/16/38	230.0	1,163
R-8	1,304.6	1,305	0	6/16/38	182.3	1,123
R-9	1,274	1,289	-15	4/21/38	210.0	1,079
R-10	1,277.9	1,275	3	12/16/37	202.7	1,072
R-12	1,258.4	1,258	0	12/16/37	214.6	1,043
R-13	1,214.1	1,214	0	12/16/37	202.4	1,012
R-14	1,150.8	1,149	2	11/24/37	186.4	963
T-2	1,045.2	1,045	0	1/9/40	21.7	1,023
V-6	1,149.9	1,150	0	11/9/37	51.8	1,098
W-2	1,137.9	1,138	0	1/10/39	42.4	1,096
X-1	1,201.9	1,164	38	2/20/39	49.4	1,115
Y-1	1,218.5	1,219	-1	4/3/40	146.3	1,073
Y-2	1,204.4	1,215	-11	11/23/37	64.1	1,151
Y-4	1,117.8	1,118	0	11/24/37	145.3	973
Y-5	1,109	1,104	5	4/5/40	140.4	964
FF-7	1,066	1,050	16	1/20/40	129.2	921

NOTE: Water-level measurements used in the construction of water-level map in Figure 15.

FOOTNOTE: [1/] From Bennett and Sayre, 1962.

TABLE 5
RECORDS OF WELLS IN KINNEY COUNTY USED IN 1952 AND 1976 WATER-LEVEL MAPS

Recent State Well Number	Bulletin 6216 [1/] ID No.	Old ID	Latitude	Longitude	Date Com-pleted	Well Depth (feet)	Well Diameter (inches)	Land-Surface Elevation (feet above MSL)	Water-Level Data		
									Month/Year of Measure-ment	Depth to Water (feet)	Elevation (feet above MSL)
--	M-14	101	292109	1003717	--	618	8	1,105	3/52	35.43	1,070
--	V-14	120	291910	1002950	1938	--	48	1,114	3/52	45.54	1,068
--	V-10	128	291856	1002825	1907	157	6	1,110	3/52	42.47	1,068
--	W-2	152	291948	1002438	1913	500	8	1,138	3/52	48.29	1,090
--	P-7	171	292026	1002041	1912	500	8	1,226	3/52	114.74	1,111
--	X-1	176	291908	1001956	--	500	6	1,202	3/52	130.90	1,071
--	R-10	185	292123	1001238	1888	266	6	1,278	3/52	219.70	1,058
--	R-11	186	292122	1001225	--	--	8	1,290	3/52	233.28	1,057
--	R-12	200	292149	1001047	--	350	8	1,258	3/52	249.30	1,009
--	R-13	201	292110	1000946	--	--	8	1,214	3/52	233.16	981
--	R-14	202	292037	1000848	1896	220	5	1,151	3/52	173.77	977
--	R-15	203	292028	1000804	--	--	8	1,131	3/52	148.20	982
--	Y-3	204	291914	1001023	1925	435	5	1,285	3/52	294.20	991
--	FF-6	210	291358	1000556	--	104	4	988	3/52	81.10	907
--	R-7	40	292319	1001358	1923	--	6	1,393	3/52	239.90	1,153
--	Q-10	41	292255	1001707	--	475	6	1,320	3/52	176.36	1,143
--	Q-6	42	292341	1001618	1923	350	5	1,367	3/52	202.94	1,164
--	Q-5	43	292419	1001604	1913	380	6	1,367	3/52	183.44	1,183
--	K-4	46	292606	1001341	1913	342	6	1,407	3/52	22.95	1,384
--	K-3	47	292731	1001707	1899	365	6	1,484	3/52	201.50	1,282
--	K-7	49	292602	1001854	1906	395	6	1,468	3/52	243.86	1,224
--	Q-1	52	292423	1001950	1920	480	5	1,416	3/52	237.10	1,179
--	P-2	53	292337	1002212	1939	--	6	1,342	3/52	185.40	1,157
--	P-1	54	292438	1002236	1914	--	6	1,401	3/52	203.15	1,198
--	I-9	62	292507	1002501	--	--	5	1,255	3/52	70.33	1,185
--	I-3	63	292747	1002518	--	--	5	1,359	3/52	141.55	1,217
--	I-5	68	292905	1002717	1916	259	6	1,409	3/52	180.98	1,228
--	M-1	89	292446	1004137	1910	350	6	1,118	3/52	70.12	1,047
--	M-2	90	292350	1004153	1917	430	5	1,104	3/52	64.50	1,039

Recent State Well Number	Bulletin 6216 [1/] ID No.	Old ID	Latitude	Longitude	Date Com-pleted	Well Depth (feet)	Well Diameter (inches)	Land-Surface Elevation (feet above MSL)	Water-Level Data		
									Month/Year of Measure-ment	Depth to Water (feet)	Elevation (feet above MSL)
RP-70-36-101	--	--	292755	1003702	--	--	--	1,220	8/76	70.67	1,149
RP-70-36-203	--	--	292927	1003455	--	--	--	1,286	8/76	33.92	1,252
RP-70-36-601	--	--	--	--	--	--	--	1,216	8/76	12.43	1,204
RP-70-38-701	--	--	292405	1002052	--	--	--	1,342	2/76	184.53	1,157
RP-70-38-701	--	--	292405	1002052	--	--	--	1,342	8/76	85.89	1,256
RP-70-38-902	--	--	292447	1001542	--	--	--	1,360	2/76	189.19	1,171
RP-70-38-902	--	--	292447	1001542	--	--	--	1,360	8/76	177.82	1,182
RP-70-43-302	--	--	--	--	--	--	--	1,085	8/76	40.44	1,044
RP-70-44-801	--	--	291645	1003306	--	--	--	1,065	8/76	55.26	1,010
RP-70-45-401	--	--	291948	1002824	--	--	--	1,130	8/76	19.50	1,111
RP-70-45-502	V-6	137	291900	1002530	1932	600	8	1,150	3/52	50.26	1,100
RP-70-45-603	--	152A	291940	1002445	--	--	--	1,150	2/76	51.92	1,099
RP-70-45-603	--	152A	291940	1002445	--	--	--	1,150	8/76	35.48	1,115
RP-70-46-101	--	--	292030	1002042	--	--	--	1,226	8/76	97.03	1,129
RP-70-46-201	--	--	292042	1001815	--	--	--	1,239	8/76	100.00	1,139
RP-70-46-401	--	W-17	291731	1002135	--	--	--	1,140	2/76	54.54	1,085
RP-70-46-401	--	W-17	291731	1002135	--	--	--	1,140	8/76	54.36	1,086
RP-70-46-801	X-2	177	291640	1001920	--	--	6	1,090	3/52	35.88	1,054
RP-70-46-901	X-5	182	291630	1001603	1932	514	6	1,123	3/52	82.30	1,041
RP-70-46-901	--	X-5	291630	1001603	--	--	--	1,123	2/76	72.03	1,051
RP-70-46-901	--	X-5	291630	1001603	--	--	--	1,123	8/76	71.90	1,051
RP-70-47-501	--	--	291913	1001017	--	--	--	1,286	8/76	248.12	1,037
RP-70-48-302	--	--	--	--	--	--	--	1,202	8/76	94.72	1,107

NOTE: Water-level measurements used in the construction of water-level maps in Figures 16 and 17.

FOOTNOTE: [1/] From Bennett and Sayre, 1962.

TABLE 6
RECORDS OF WELLS IN KINNEY COUNTY USED IN 1992 WATER-LEVEL MAP

Well Number	Other Well ID	Well Owner	Driller	Latitude	Longitude	Well Depth (feet)	Producing Unit	Land-Surface Elevation (feet above MSL)	Water-Level Data		
									Date of Measurement	Depth to Water (feet)	Elevation (feet above MSL)
RP-70-37-2	I-3 (63)	Edward Mey	--	--	--	300	Edwards	1,361	7/2/92	84.15	1,277
RP-70-37-402	--	W.A. Belcher	A.W. Fulkerson	292535	1002937	697	Edwards	1,208	7/2/92	1.95	1,206
RP-70-37-501	I-9	James T. Shannon	--	292520	1002950	162	Edwards	1,247	7/1/92	55.55	1,191
RP-70-38-701	--	Halloway	--	292405	1002052	270	Edwards	1,336	7/1/92	115.18	1,221
RP-70-38-901	--	Pratt Cattle Co.	Cunningham	--	--	380	Edwards	1,367	7/1/92	163.47	1,204
RP-70-38-902	--	State of Texas	TWDB	292447	1001542	775	Edwards	1,370	7/1/92	171.67	1,198
RP-70-39-1	K-4 (46)	Wilson Ranch	--	--	--	--	--	1,451	7/2/92	190.42	1,261
RP-70-39-5	L-6 (34)	--	--	--	--	--	--	1,259	7/2/92	23.19	1,236
RP-70-39-6	--	Elmer Herdon	--	--	--	30	--	1,229	7/1/92	8.73	1,220
RP-70-44-101	M-14	--	--	--	--	--	--	1,103	7/1/92	50.01	1,053
RP-70-45-3	P-8	Evans U-bar Ranch	--	--	--	--	--	1,276	7/1/92	138.40	1,138
RP-70-45-401	--	Trans Wilson	--	291948	1002824	930 [1/]	Edwards	1,129	7/1/92	16.24	1,113
RP-70-45-402	--	James Bader	Chas. Zinsmeister & Co	291912	1002938	157	Ausitn Chalk	1,114	7/1/92	26.11	1,088
RP-70-45-502	--	John Lowrance	--	291900	1002530	600	Edwards	1,150	7/1/92	50.64	1,099
RP-70-45-5	Ranchito "73"	Diane & Tully Pratt	--	--	--	--	--	1,000	7/2/92	25.34	975
RP-70-45-5	City Well #2	--	--	--	--	--	--	1,108	7/2/92	+18 above	1,126
RP-70-45-601	--	City of Brackettville	York & Coats	291900	1002451	947	Edwards	1,125	7/2/92	9.20	1,116
RP-70-45-602	--	E. Webb	Beaucourt	--	--	500	Edwards	1,138	7/1/92	36.38	1,102
RP-70-45-603	--	Pat Rose	Elkins	291940	1002445		Edwards	1,150	7/1/92	38.37	1,112
RP-70-45-6	--	David Sargent	--	--	--	140	Austin Chalk?	1,127	7/2/92	15.75	1,111
RP-70-45-8	--	Indian Scout Cemetery	--	--	--	--	Austin Chalk	1,094	1992	35.07	1,059
RP-70-46-1	P-6 (172)	--	--	--	--	--	--	1,269	7/1/92	149.20	1,120
RP-70-46-401	--	Dr. B.F. Orr	O.W. Folkerson	291731	1002135	435	Edwards	1,141	7/2/92	55.21	1,086
RP-70-46-901	--	A. Harrison	Geo. Crystall	291630	1001603	514	Edwards	1,118	7/2/92	68.73	1,049
RP-70-47-501	--	Geo. Rose	Fath Mills	291913	1001017	435	Edwards	1,285	7/2/92	240.76	1,044

NOTE: Water-level measurements used in the construction of water-level map in Figure 18.

FOOTNOTE: [1/] Bottom of casing is at 40 feet below land surface.

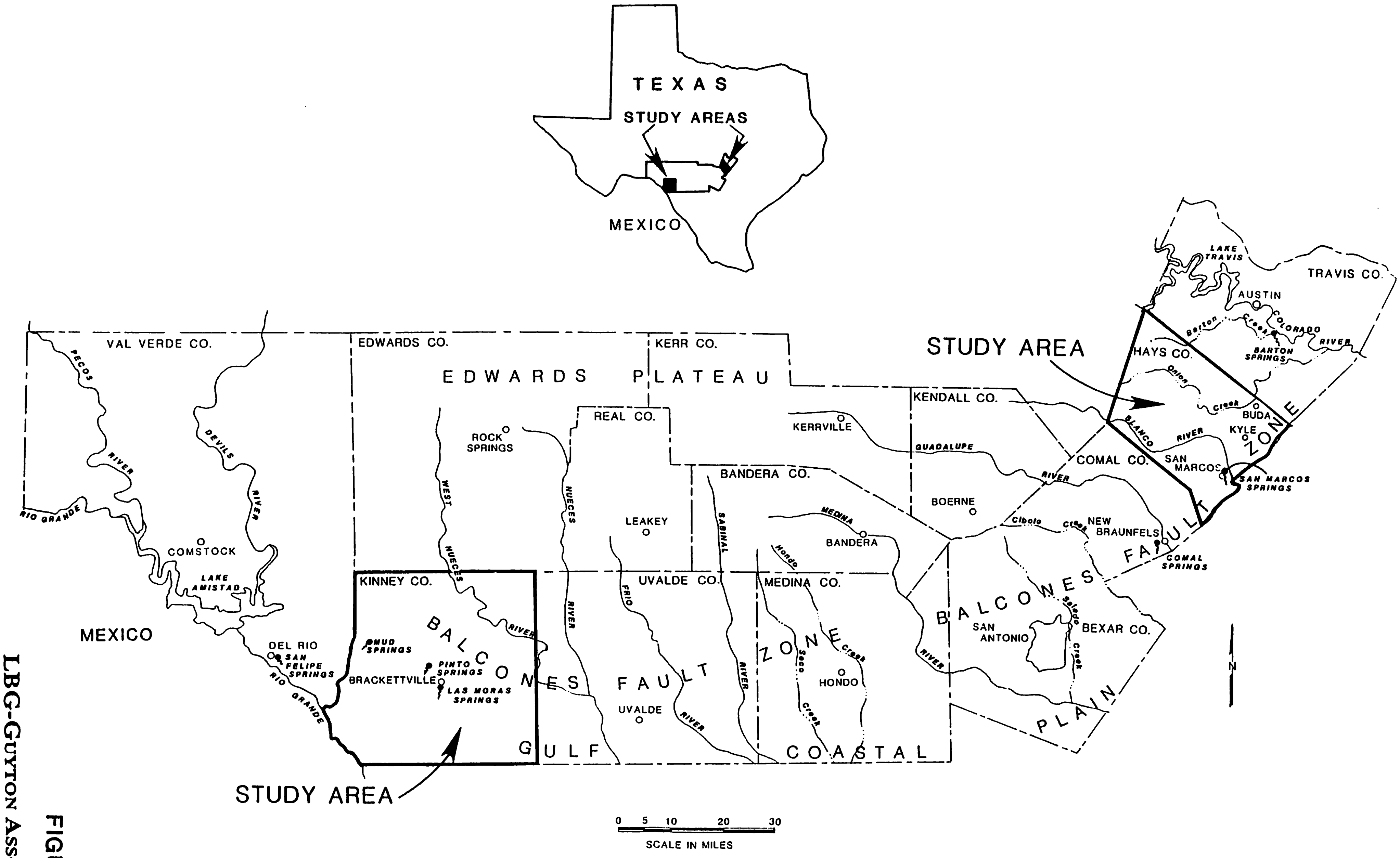
TABLE 7
RECORDS OF IBWC WELLS AND INVENTORIED WELLS USED IN 1994 WATER-LEVEL MAP

Well Number	State or Other Well Number	Well Owner	Latitude	Longitude	Year Completed	Well Depth (feet)	Casing Data: Depth (feet)	Casing Data: Diameter (inches)	Land-Surface Elevation (feet MSL)	Water-Level Data: MP above land surface (feet)	Water-Level Data: Date of Measurement	Water-Level Data: Depth to Water (feet)	Water-Level Data: Elevation (feet above MSL)	Water-Level Data: Water-Level Measurement by [2]
IBWC#668-7	RP-70-29-9	Slater Estate	293152	1002355	--	365	--	--	1,630	--	1/27/94	163.46	1,467	I
IBWC#664-81	RP-70-36-101	Frank Mey	292817	1003707	--	200	--	--	1,246	--	4/13/94	83.68	1,162	I
IBWC#ID-372	RP-70-36-4	G.H. Forester	292559	1003540	--	680	--	--	1,209	--	4/13/94	32.36	1,177	I
IBWC#664-71	RP-70-36-5	Clyde Earwood	292707	1003348	--	~150	--	--	1,283	--	4/13/94	108.28	1,175	I
IBWC#667-5	--	**see RP-70-37-6hi1												
IBWC#668-50	RP-70-38-9	Pratt Cattle Co.	292440	1001539	--	--	--	--	1,371	--	7/27/93	189.53	1,181	I
IBWC#668-32	RP-70-45-3	Buster Dunley	292022	1002317	--	444	--	--	1,272	--	1/27/94	143.05	1,129	I
IBWC#664-85	RP-70-45-504	**see RP-70-45-5fe9												
IBWC#668-29	RP-70-46-401	Mr. Orr	291731	1002151	--	400+	--	--	1,135	--	1/27/94	54.41	1,081	I
RP-70-37-4gb8	RP-70-37-402	Belcher	292535	1002937	--	697	4	6	1,208	0.36	3/21/94	12.70	1,195	E
RP-70-37-6hi1	IBWC#667-5	James T. Shahan	292511	1002334	--	400+	--	--	1,330	0.63	3/15/94	109.49	1,221	L, E
RP-70-37-7eg1	--	Belcher	292332	1002908	1984	93	--	--	1,167	0.41	3/21/94	33.53	1,133	E
RP-70-37-9ba5	RP-70-37-901	James T. Shahan	292459	1002359	--	158+	--	--	1,299	1.1	3/15/94	128.48 [1]	--	L, E
RP-70-37-9di5	--	Slubar	292329	1002420	--	--	--	--	1,236	0.29	3/22/94	47.81	1,188	E
RP-70-37-9fe6	--	Slubar	292347	1002251	--	--	--	--	1,264	0.91	3/22/94	76.71	1,187	E
RP-70-38-4ed9	RP-70-38-401	James T. Shahan	292607	1002126	1940	298	--	--	1,343	1.25	3/15/94	119.86	1,223	L, E
RP-70-38-7eb5	RP-70-38-701	Slubar	292404	1002115	1939	--	--	6	1,336	1.07	3/22/94	130.52	1,205	E
RP-70-38-9ca9	RP-70-38-902	State of Texas	292449	1001538	1973	775	137.5	6 5/8	1,370	2.04	3/23/94	187.56	1,182	E
RP-70-39-5ch7	--	Buch Thompson	292643	1001030	--	--	--	--	1,283	0.87	3/23/94	58.95	1,224	E
YP-70-40-9ff8	YP-70-40-901	USGS	292338	1000007	--	--	--	--	1,125	0.96	3/22/94	43.18	1,082	E
RP-70-45-4ah7	RP-70-45-402	James Bader	291912	1002938	--	157	--	--	1,114	1.5	3/17/94	44.58	[3]	L, E
RP-70-45-4cd7	RP-70-45-401	Clay Hunt	291930	1002815	1953	930	40	8	1,129	0.7	3/17/94	27.41	1,102	L, E
RP-70-45-5fe9	RP-70-45-504	Ft Clark Springs MUD	291836	1002518	1965	844	451	16	1,107	1.7	3/16/94	6.38	1,101	L, E
RP-70-45-5ff8	RP-70-45-503	City of Brackettville	291838	1002507	--	947	--	--	1,107	2.4	3/16/94	6.21	1,101	L, E
RP-70-45-6da5	RP-70-45-601	City of Brackettville	291900	1002451	1964	1,481	424	12 3/4	1,125	1.15	3/16/94	18.99	1,106	L, E
RP-70-45-8ed2	--	Indian Scout Cemetery	291623	1002634	--	72	--	--	1,094	0.5	3/17/94	40.48	[3]	L, E
RP-70-46-8ai4	RP-70-46-802	TX Dept of Hwy	291649	1001920	1980	376	336	6	1,086	1.2	3/15/94	26.85	1,059	L, E
RP-70-47-3dd9	RP-70-47-303	Clint Brown	292110	1000942	--	--	--	8	1,215	0.45	3/18/94	194.24	1,021	L, E
RP-70-47-3he2	RP-70-47-301	Jim Beard	292030	1000846	1896	220	--	5	1,149	0.55	3/18/94	137.81	1,011	L, E
RP-70-47-5ch9	RP-70-47-501	Jim Beard	291913	1001016	--	--	--	5 3/16	1,285	--	3/18/94	--	--	L, E
RP-70-47-6dg5	--	Jim Beard	291828	1000950	--	--	--	6.5	1,234	0.5	3/18/94	258.49 [1]	--	L, E
RP-70-47-8bc1	--	Jim Beard	291728	1001100	--	--	--	8	1,187	0.55	3/18/94	159.59	1,027	L, E
RP-70-47-8ca1	--	Jim Beard	291727	1001045	--	--	--	6.5	1,173	0.55	3/18/94	149.25	1,024	L, E

NOTE: Water-level measurements used in the construction of water-level map in figure 19.

FOOTNOTE: [1] Water level affected by recent pumping.
[2] I = IBWC, E = EUWD, L = LBG-GA
[3] Producing unit determined to be Austin Chalk.

FIGURES



LOCATION OF STUDY AREAS

FIGURE 1

LBG-GUYTON ASSOCIATES

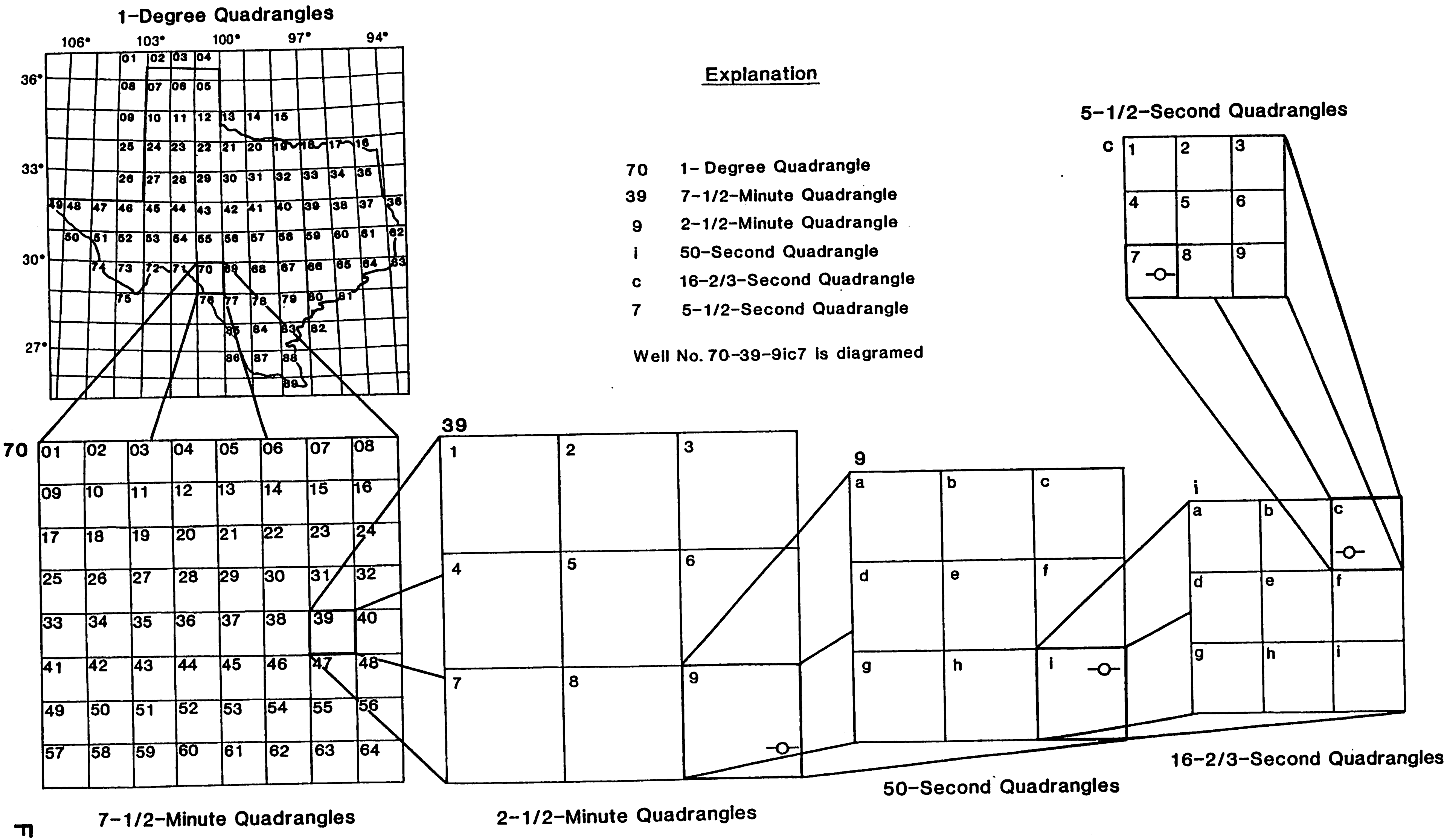
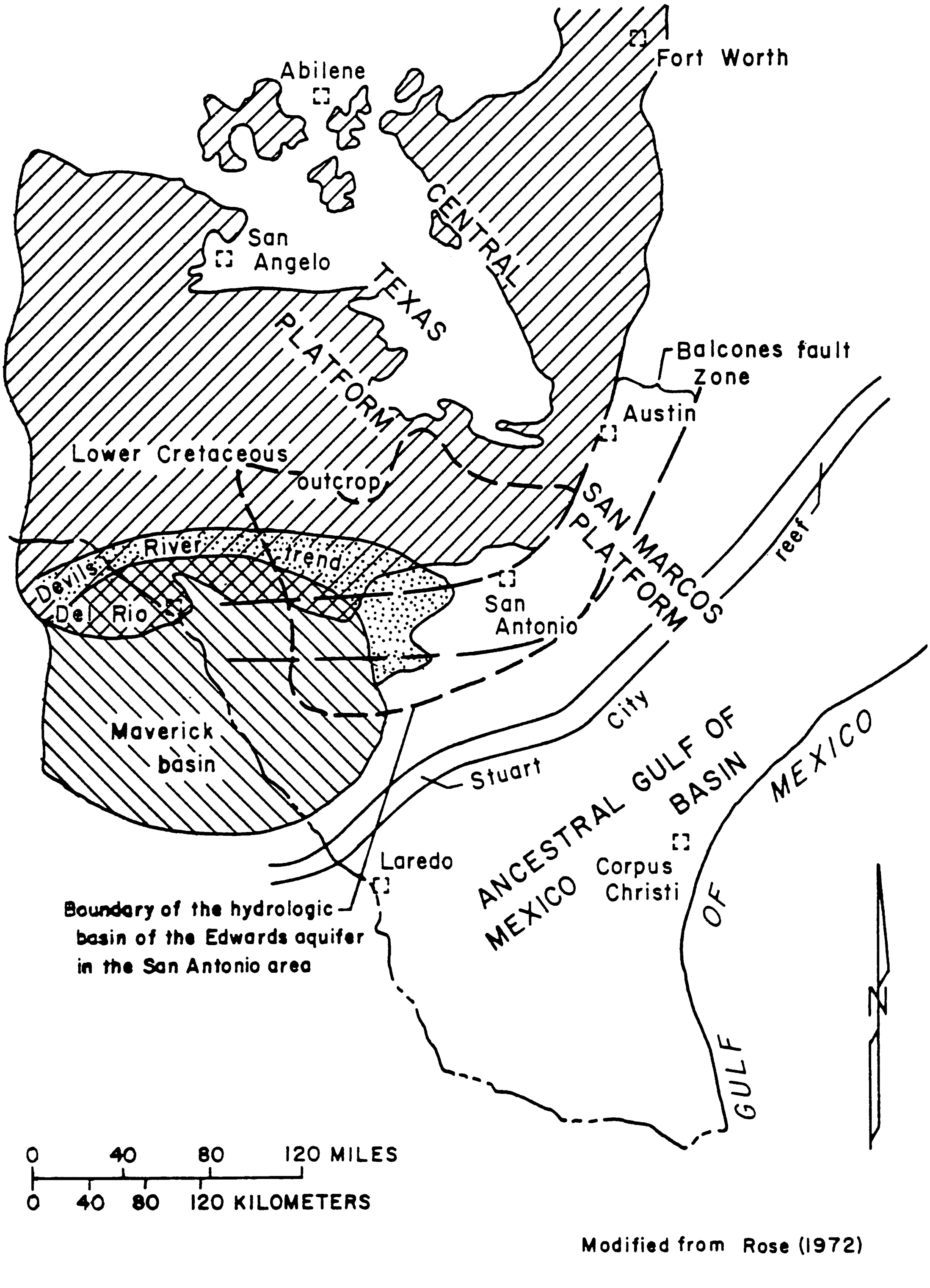


DIAGRAM OF WELL-NUMBERING SYSTEM

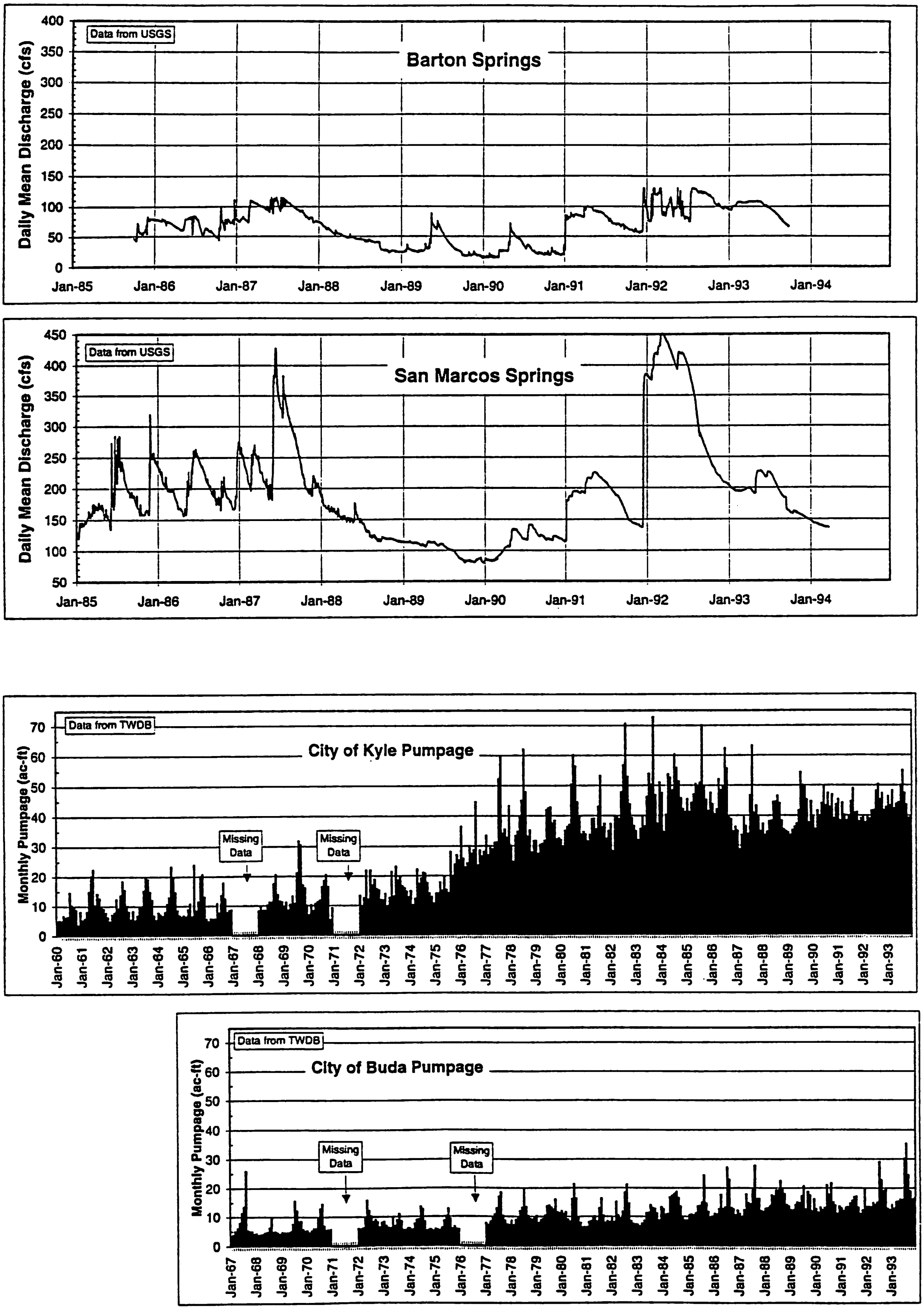
FIGURE 2

LBG-Guyton Associates



LOWER CRETACEOUS DEPOSITIONAL PROVINCES
OF CENTRAL TEXAS

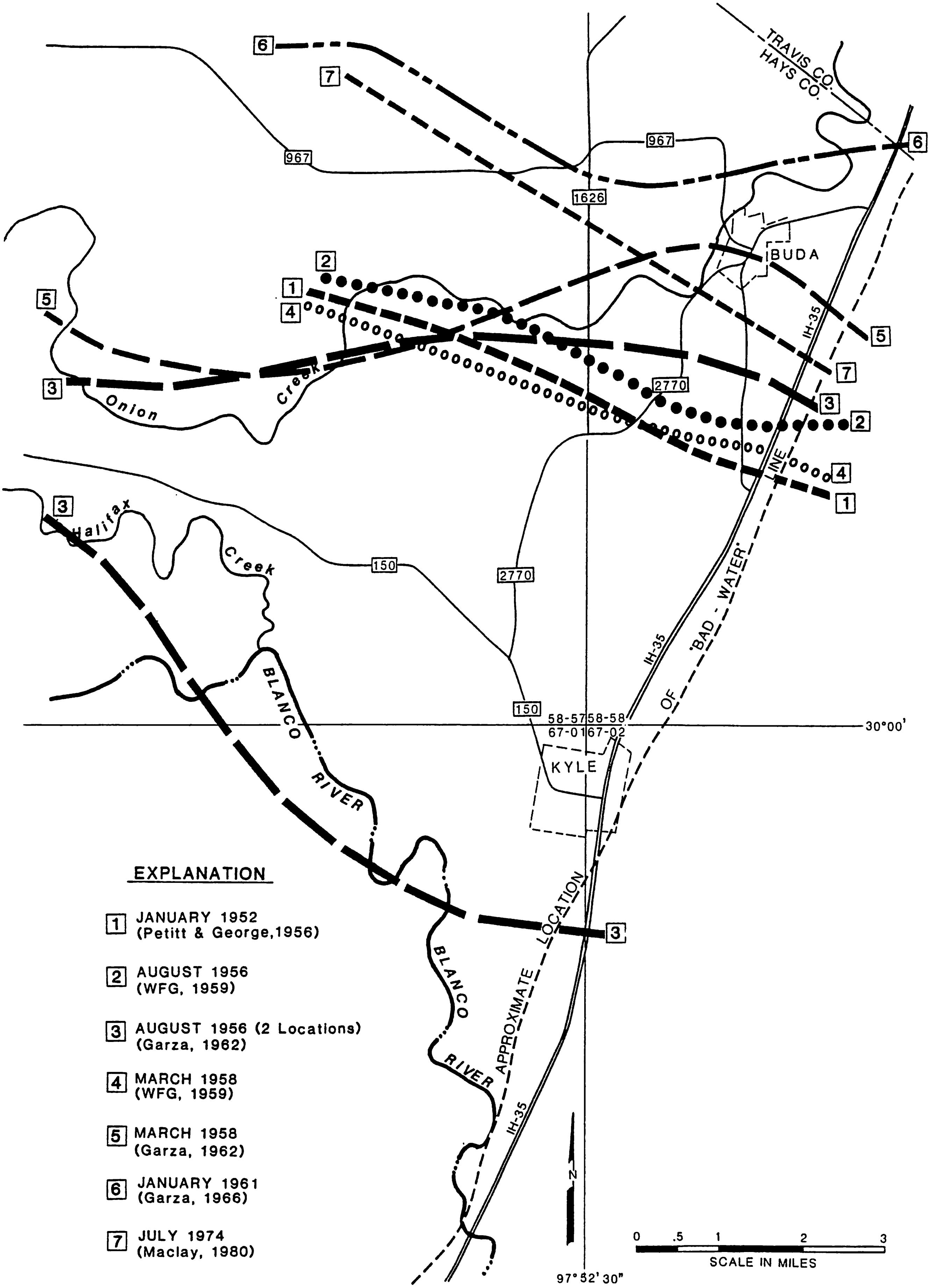
FIGURE 3



DAILY MEAN DISCHARGE AT BARTON SPRINGS AND SAN MARCOS SPRINGS, AND MONTHLY PUMPAGE BY THE CITIES OF KYLE AND BUDA

FIGURE 4

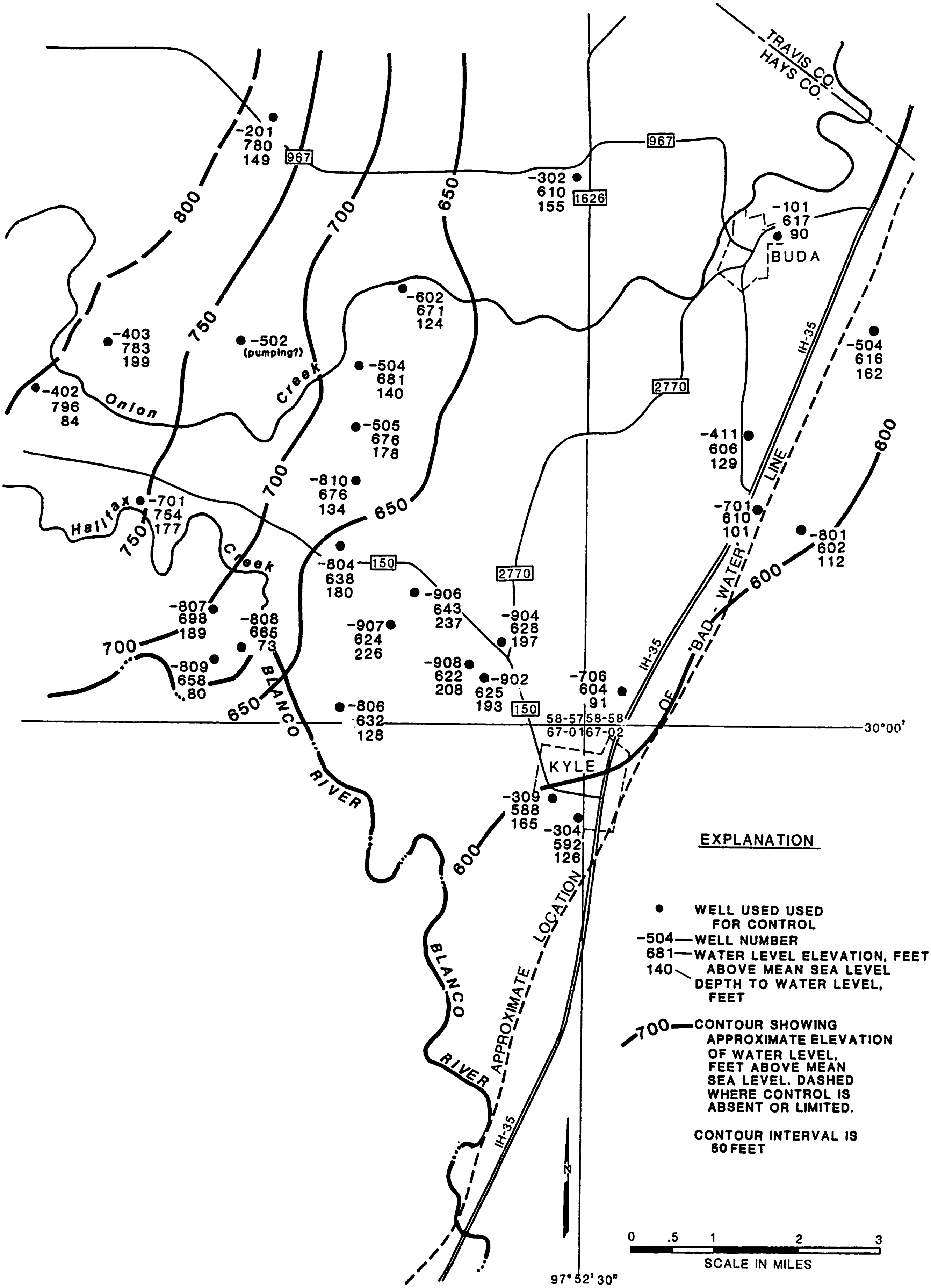
LBG-GUYTON ASSOCIATES



APPROXIMATE LOCATIONS OF PREVIOUSLY DELINEATED GROUND-WATER DIVIDES IN HAYS COUNTY

FIGURE 5

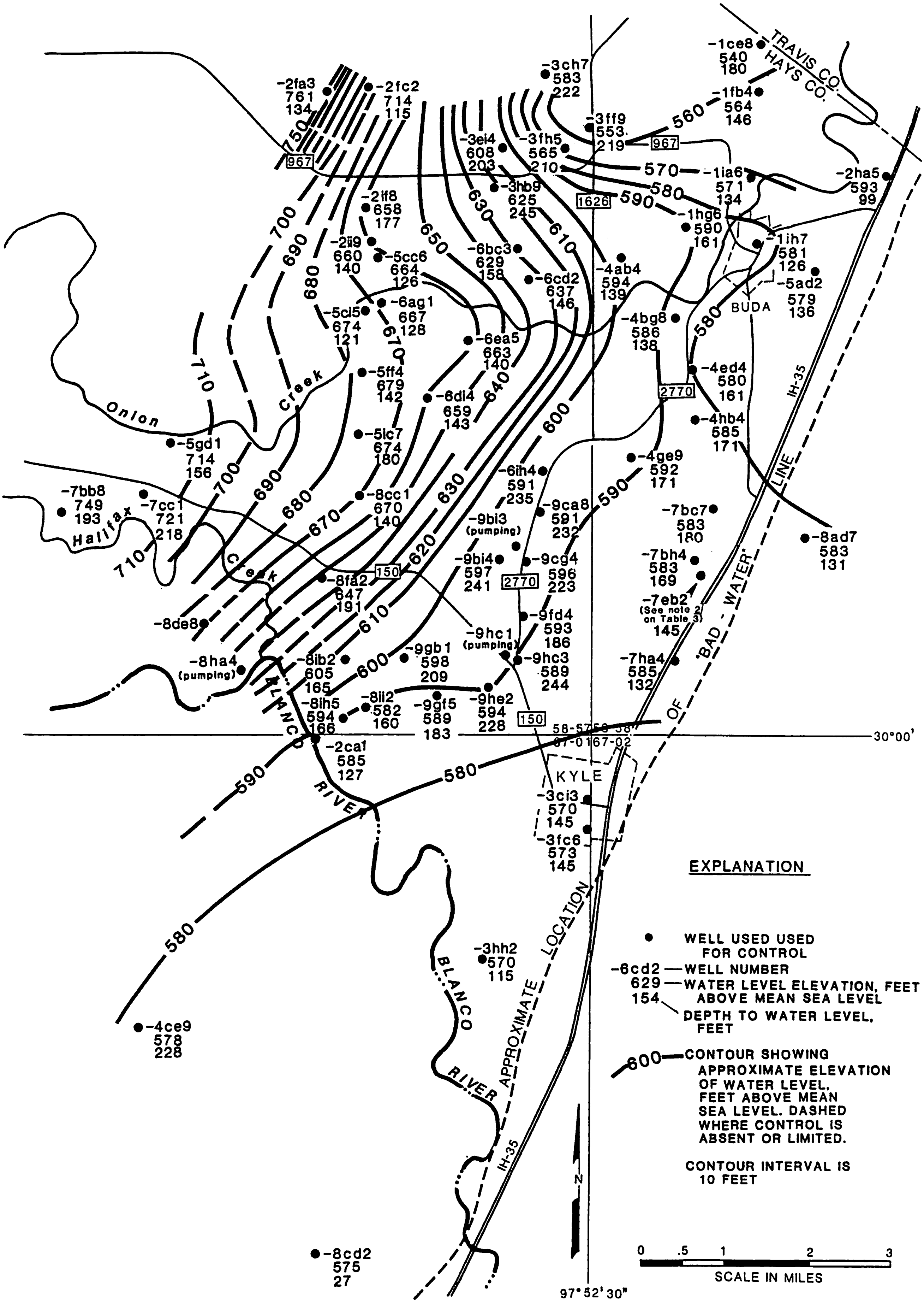
LBG-GUYTON ASSOCIATES



APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, HAYS COUNTY (JULY AND AUGUST, 1985)

FIGURE 6

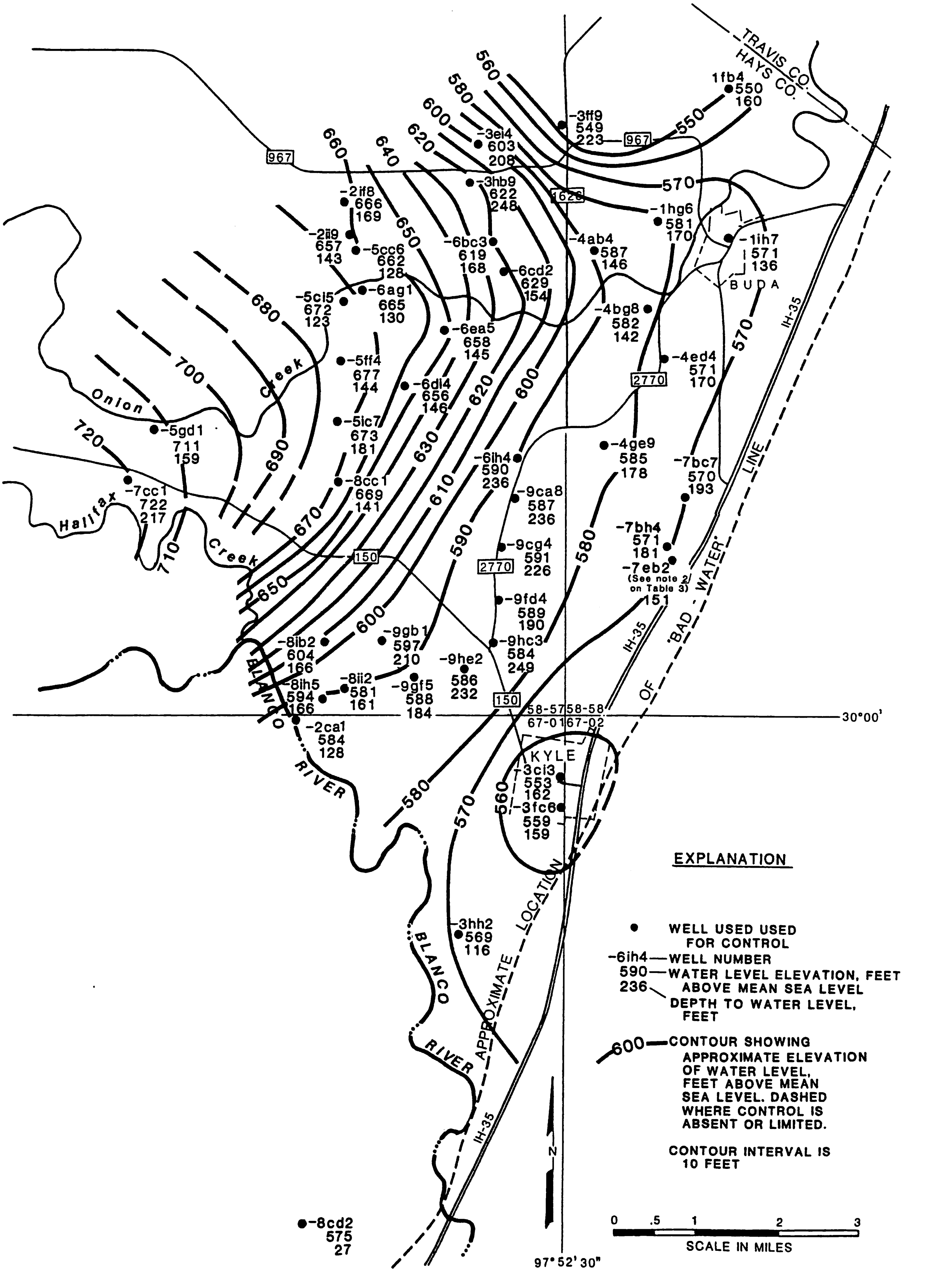
LBG-GUYTON ASSOCIATES



APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, HAYS COUNTY (JANUARY AND FEBRUARY, 1994)

FIGURE 7

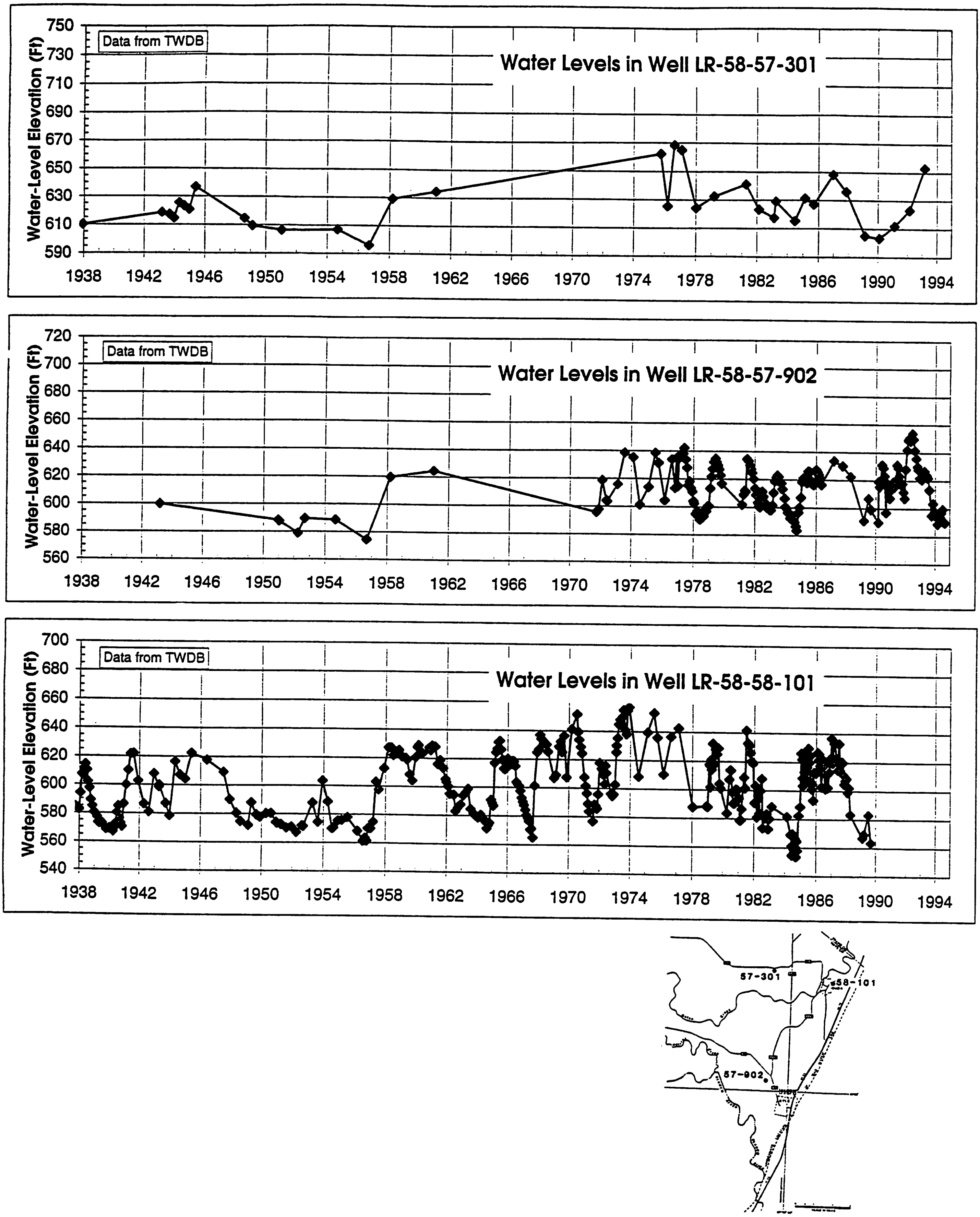
LBG-GUYTON ASSOCIATES



APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, HAYS COUNTY (AUGUST AND SEPTEMBER, 1994)

FIGURE 8

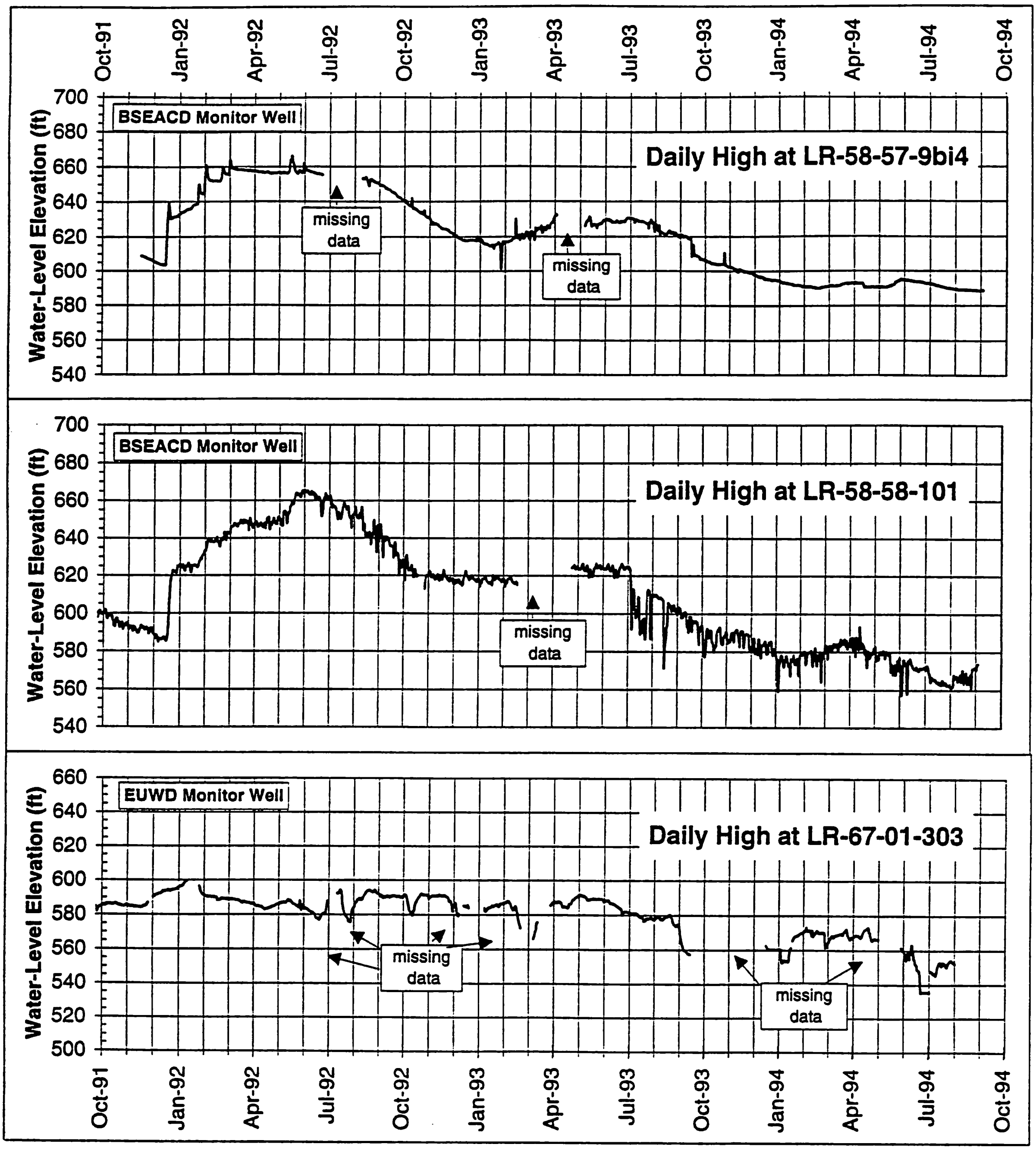
LBG-GUYTON ASSOCIATES

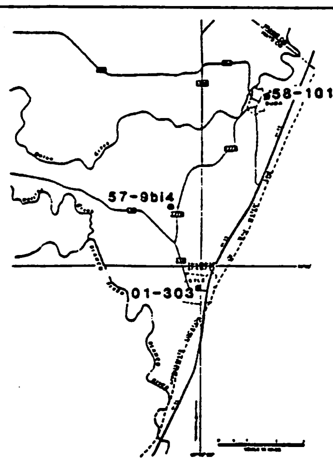


PERIODIC WATER-LEVEL MEASUREMENTS IN SELECTED MONITOR WELLS IN HAYS COUNTY

FIGURE 9a

LBG-GUYTON ASSOCIATES

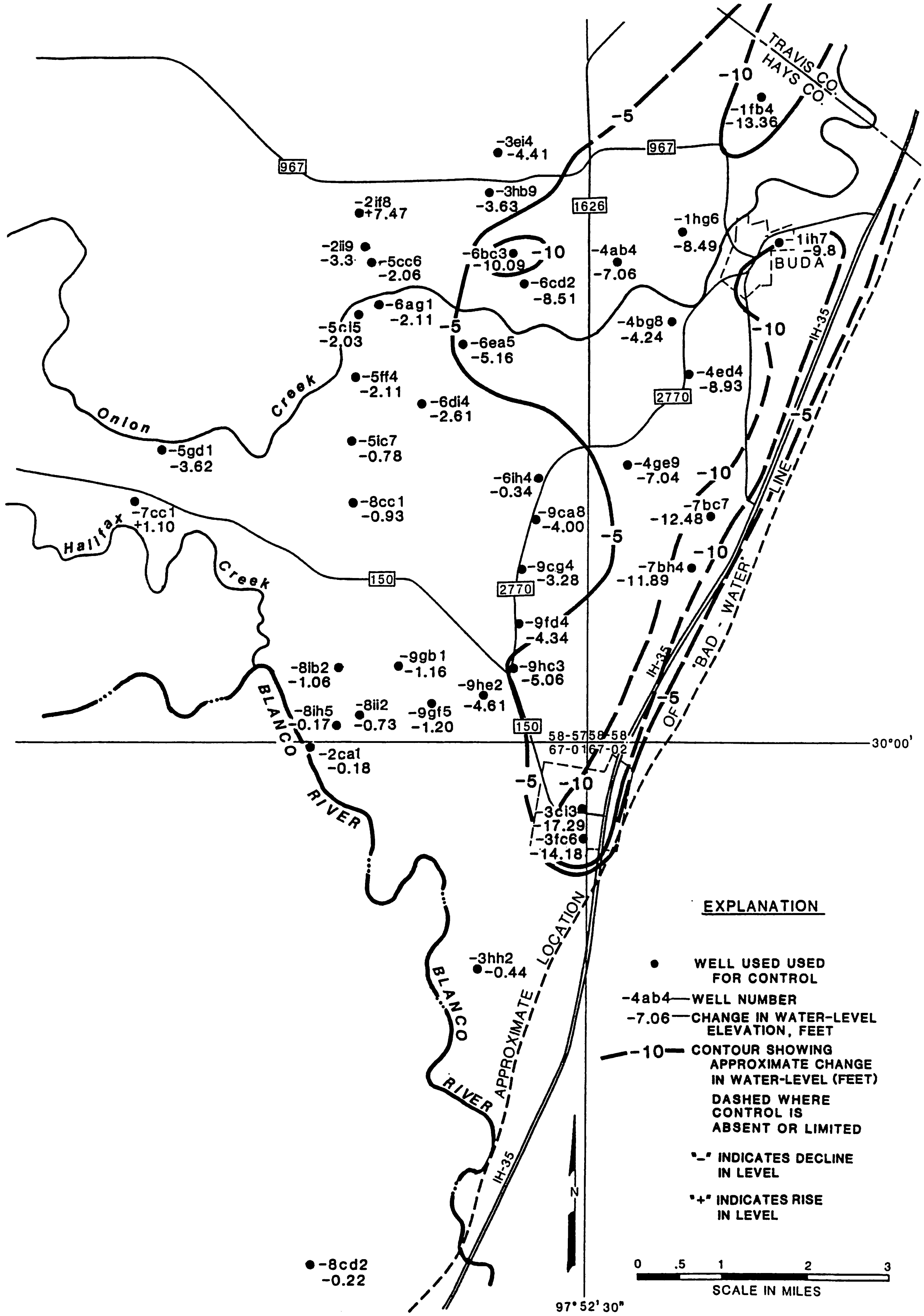




DAILY WATER-LEVEL HIGHS IN SELECTED MONITOR WELLS MAINTAINED BY THE BSEACD AND EUWD IN HAYS COUNTY

FIGURE 9b

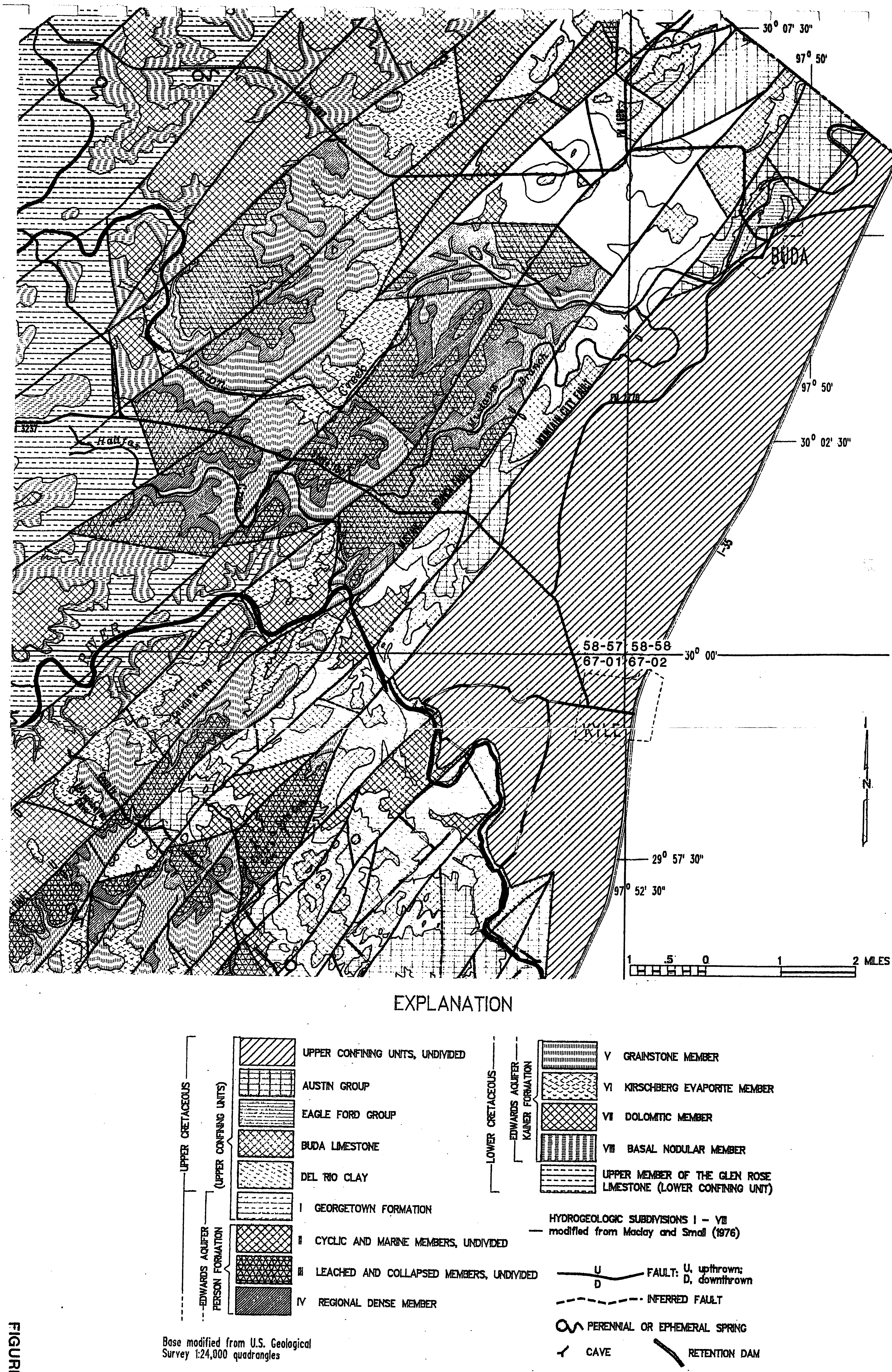
LBG-GUYTON ASSOCIATES



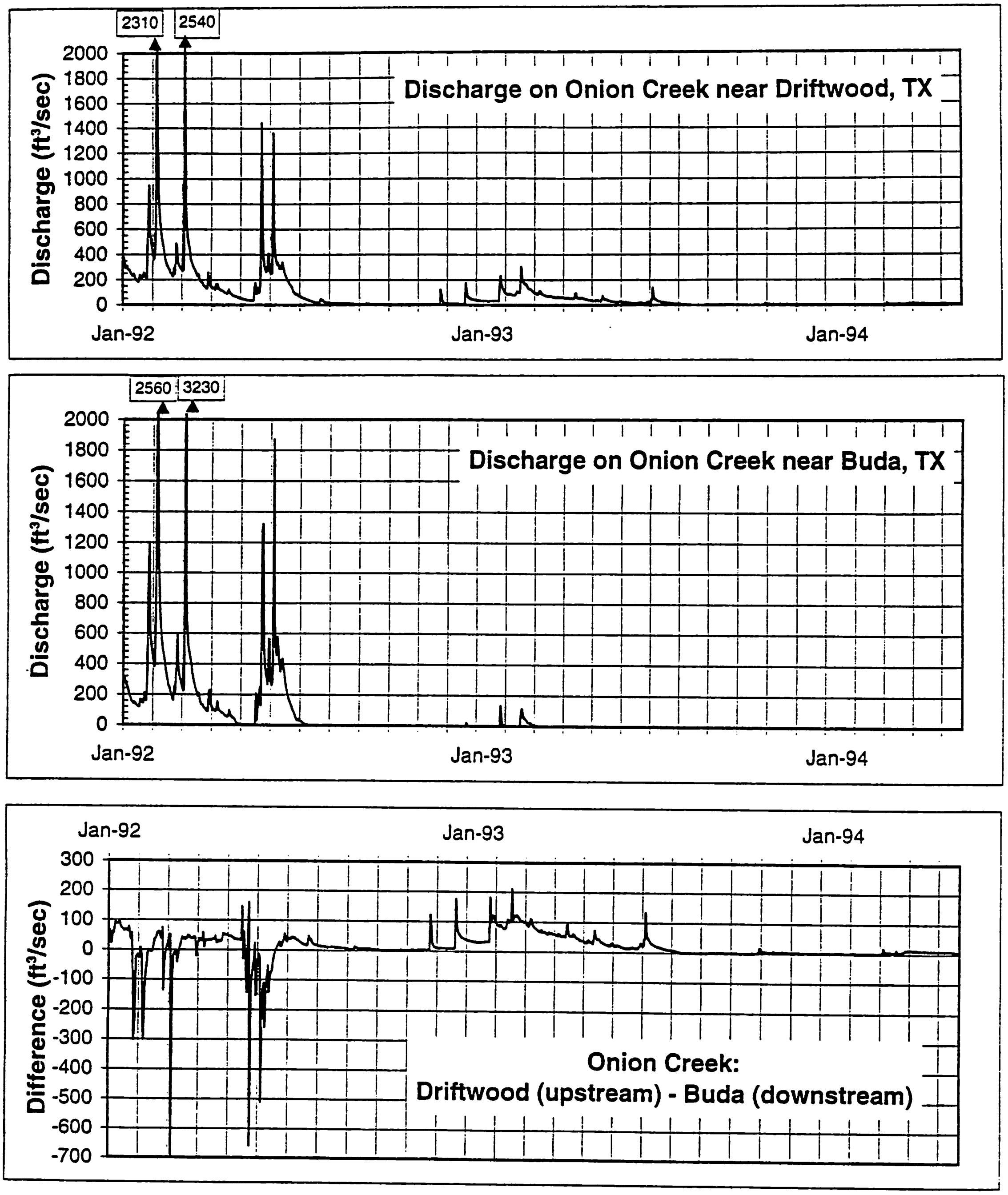
CHANGES IN WATER LEVELS IN HAYS COUNTY WELLS
MEASURED IN EARLY 1994 AND LATE SUMMER 1994

FIGURE 10

LBG-GUYTON ASSOCIATES



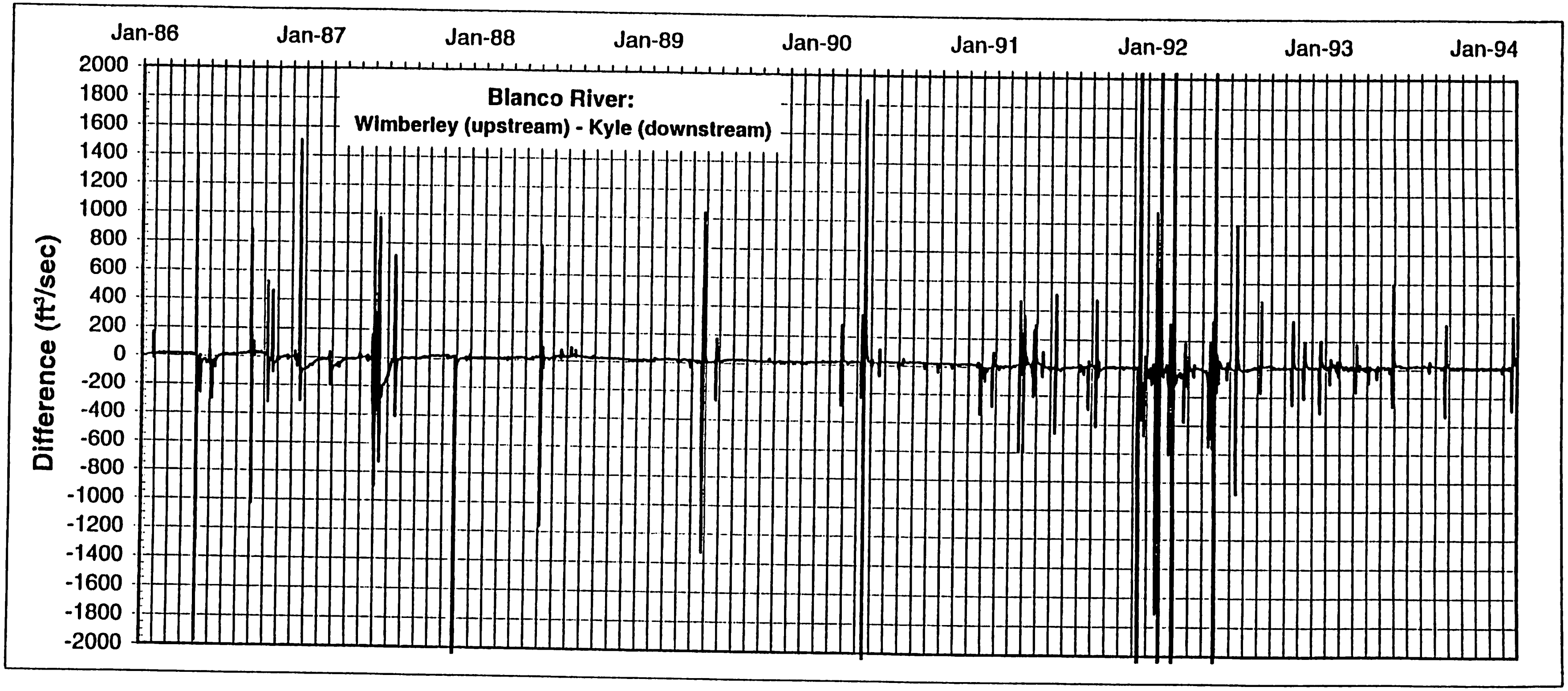
GEOLOGIC MAP OF HAYS COUNTY GROUND-WATER DIVIDE AREA
(HANSON AND SMALL, WRITTEN COMMUNICATION, 1994)



DISCHARGE RECORDS FOR ONION CREEK NEAR DRIFTWOOD (UPSTREAM) AND NEAR BUDA (DOWNSTREAM), DIFFERENCE BETWEEN UPSTREAM AND DOWNSTREAM GAGES ON ONION CREEK

FIGURE 12a

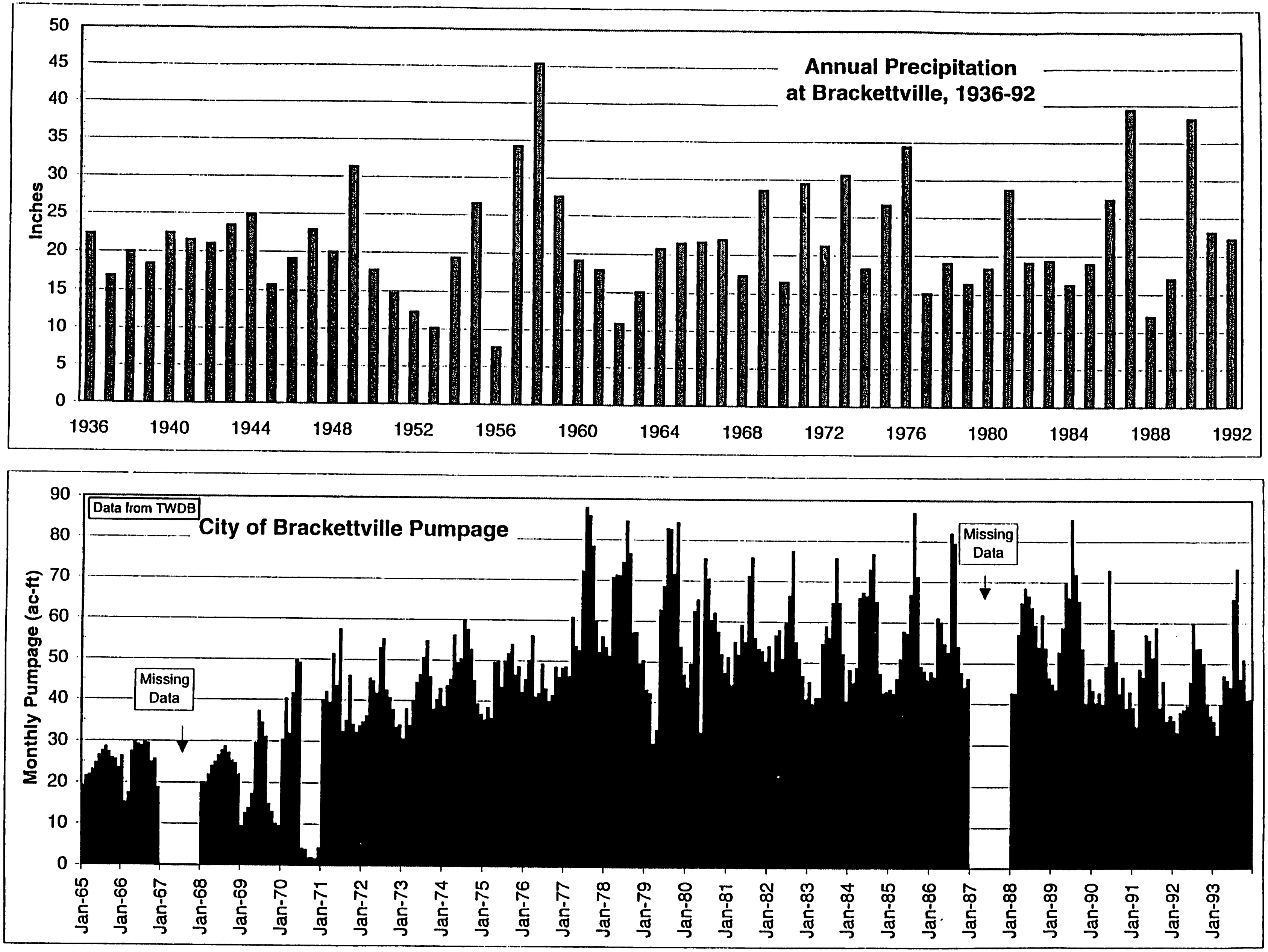
LBG-GUYTON ASSOCIATES



DIFFERENCE BETWEEN UPSTREAM AND DOWNSTREAM
GAGES ON THE BLANCO RIVER

FIGURE 12b

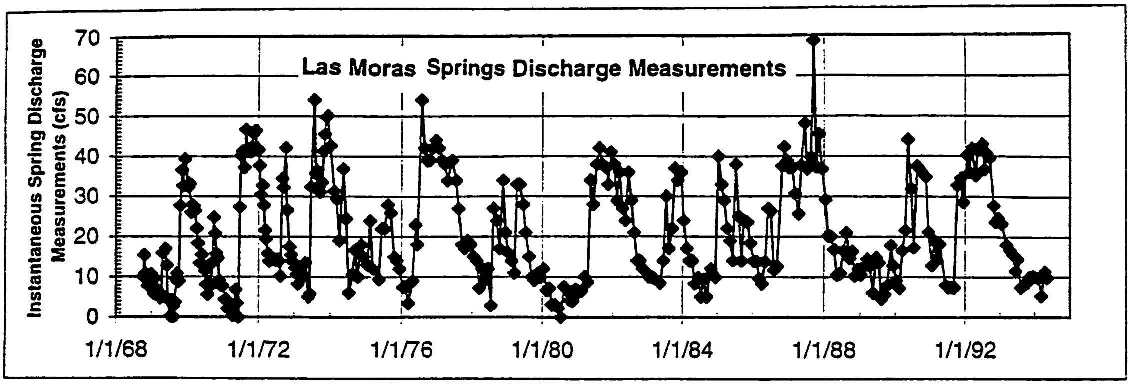
LBG-GUYTON ASSOCIATES

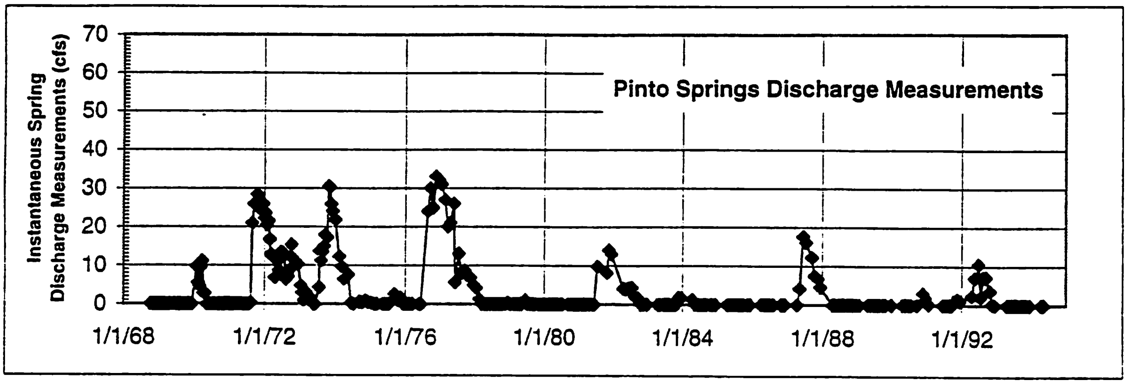


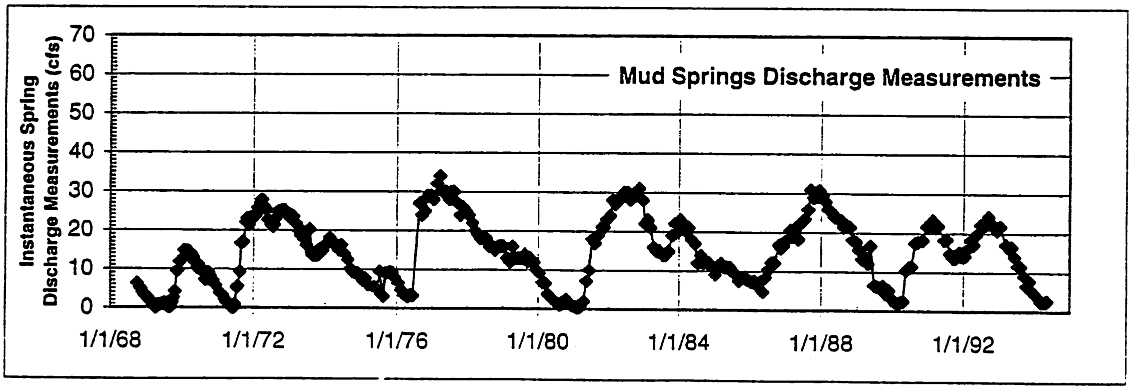
PRECIPITATION AT BRACKETTVILLE AND PUMPAGE BY THE CITY OF BRACKETTVILLE

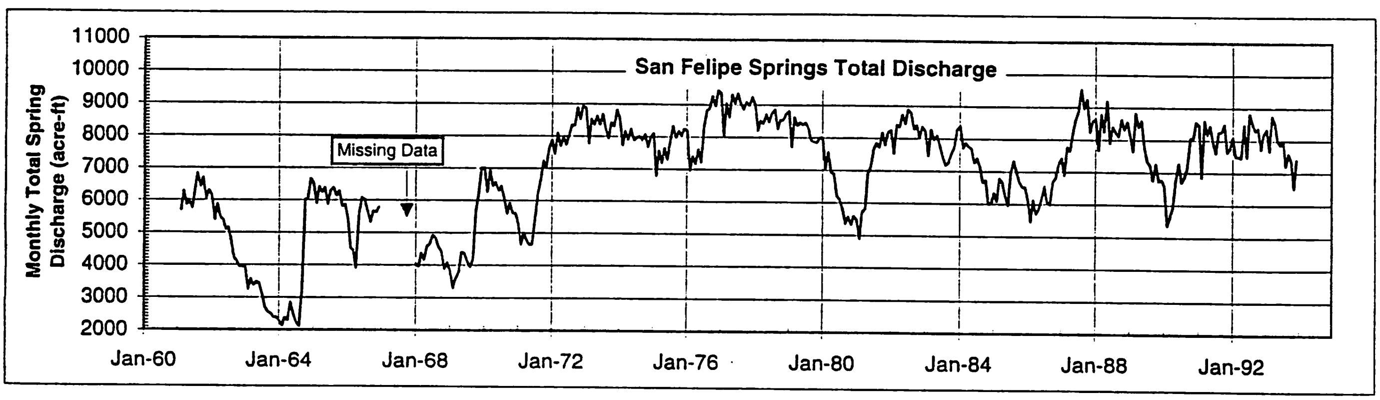
FIGURE 13

LBG-GUYTON ASSOCIATES





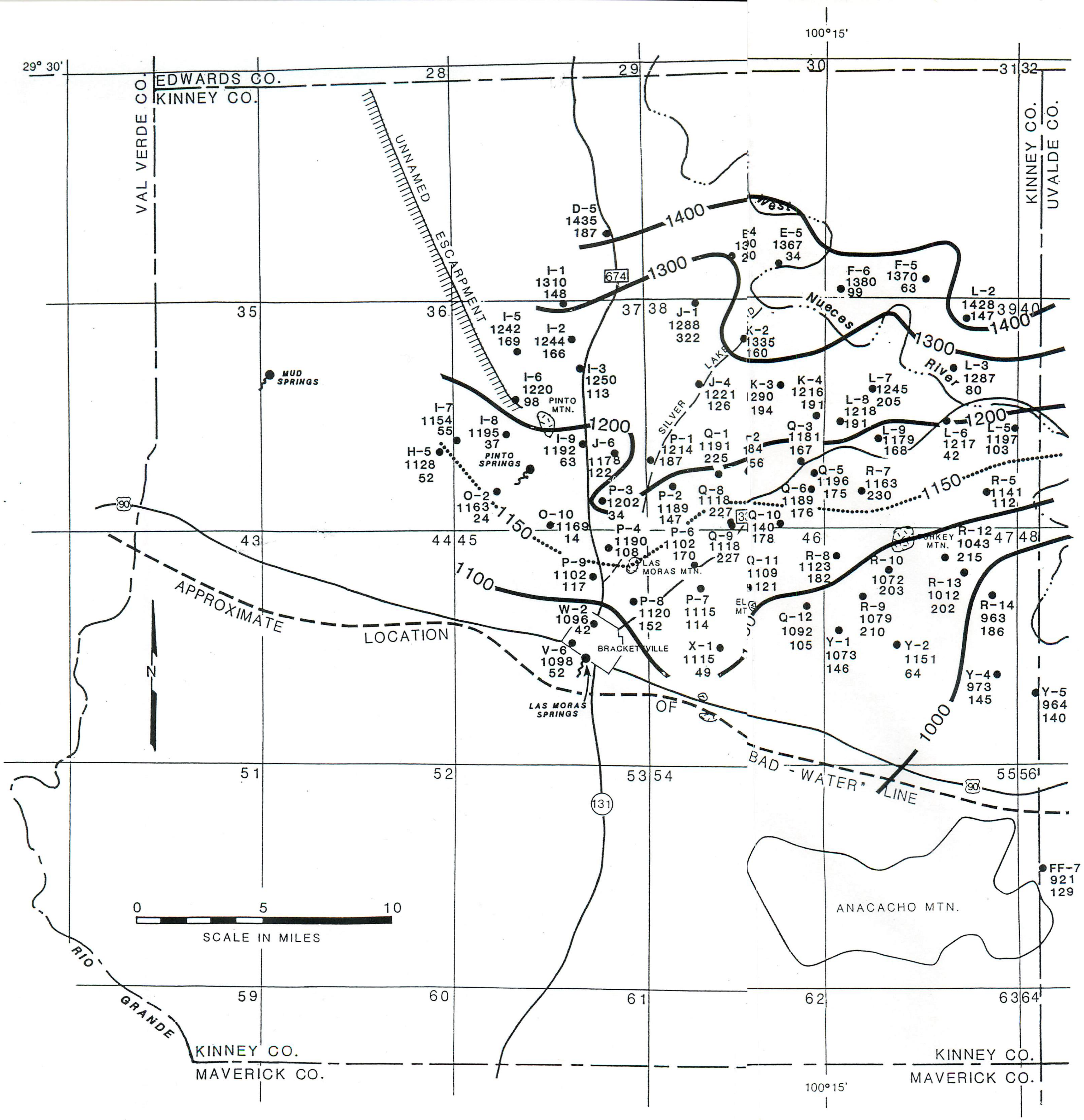




HYDROGRAPHS FOR EDWARDS AQUIFER
SPRINGS NEAR BRACKETTVILLE
(DATA FROM IBWC)

FIGURE 14

LBG-GUYTON ASSOCIATES



EXPLANATION

● WELL USED FOR CONTROL

Q-2 — WELL NUMBER
1184 — WATER LEVEL, FEET ABOVE MEAN SEA LEVEL
225 — DEPTH TO WATER LEVEL, FEET

1200 — CONTOUR SHOWING APPROXIMATE ELEVATION OF WATER LEVEL, FEET ABOVE MEAN SEA LEVEL. DASHED WHERE CONTROL IS ABSENT OR LIMITED.

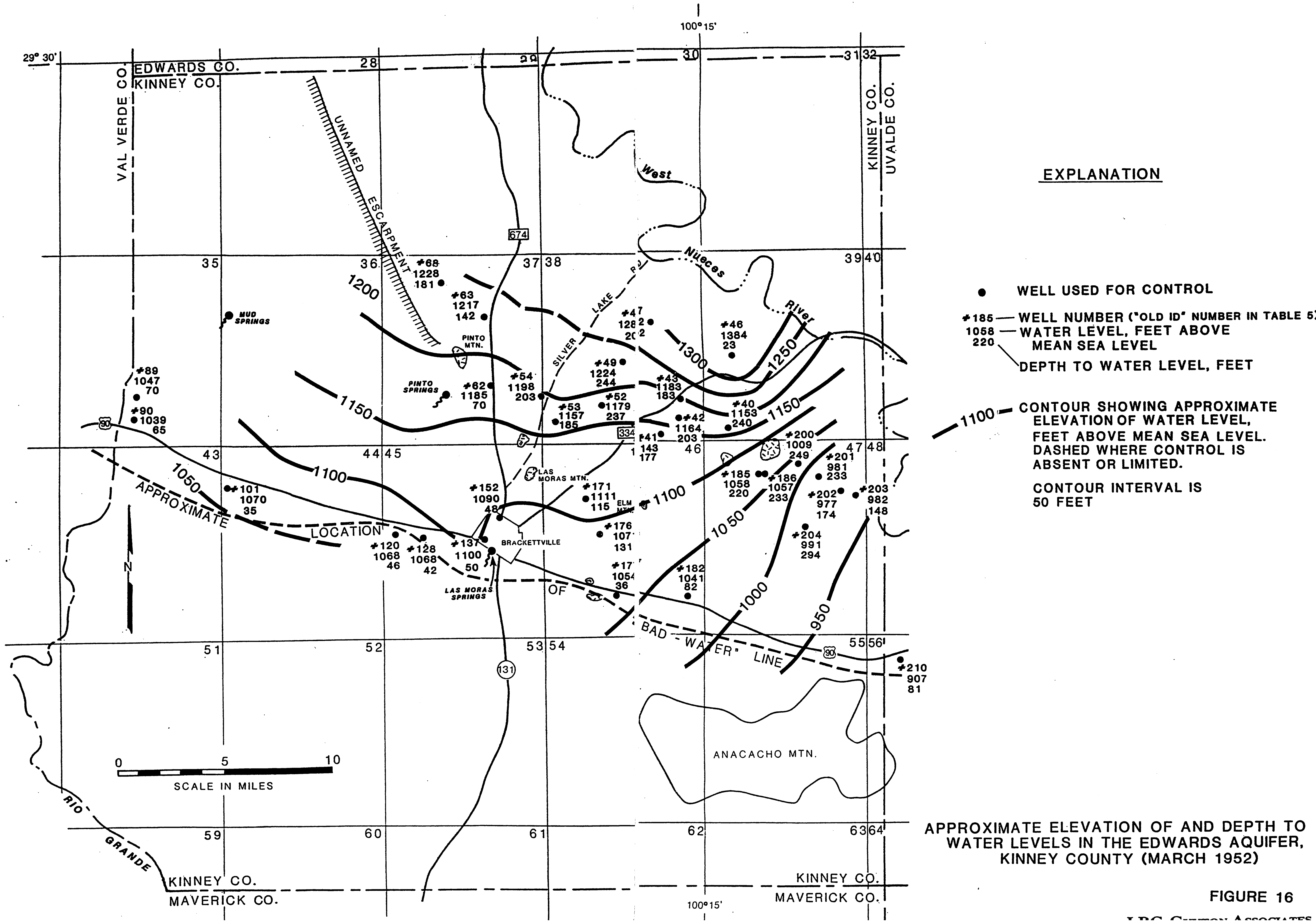
CONTOUR INTERVAL IS 100 FEET

·····1150····· SUPPLEMENTAL CONTOUR INTERVAL IS 50 FEET

APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, KINNEY COUNTY (1937-1940)

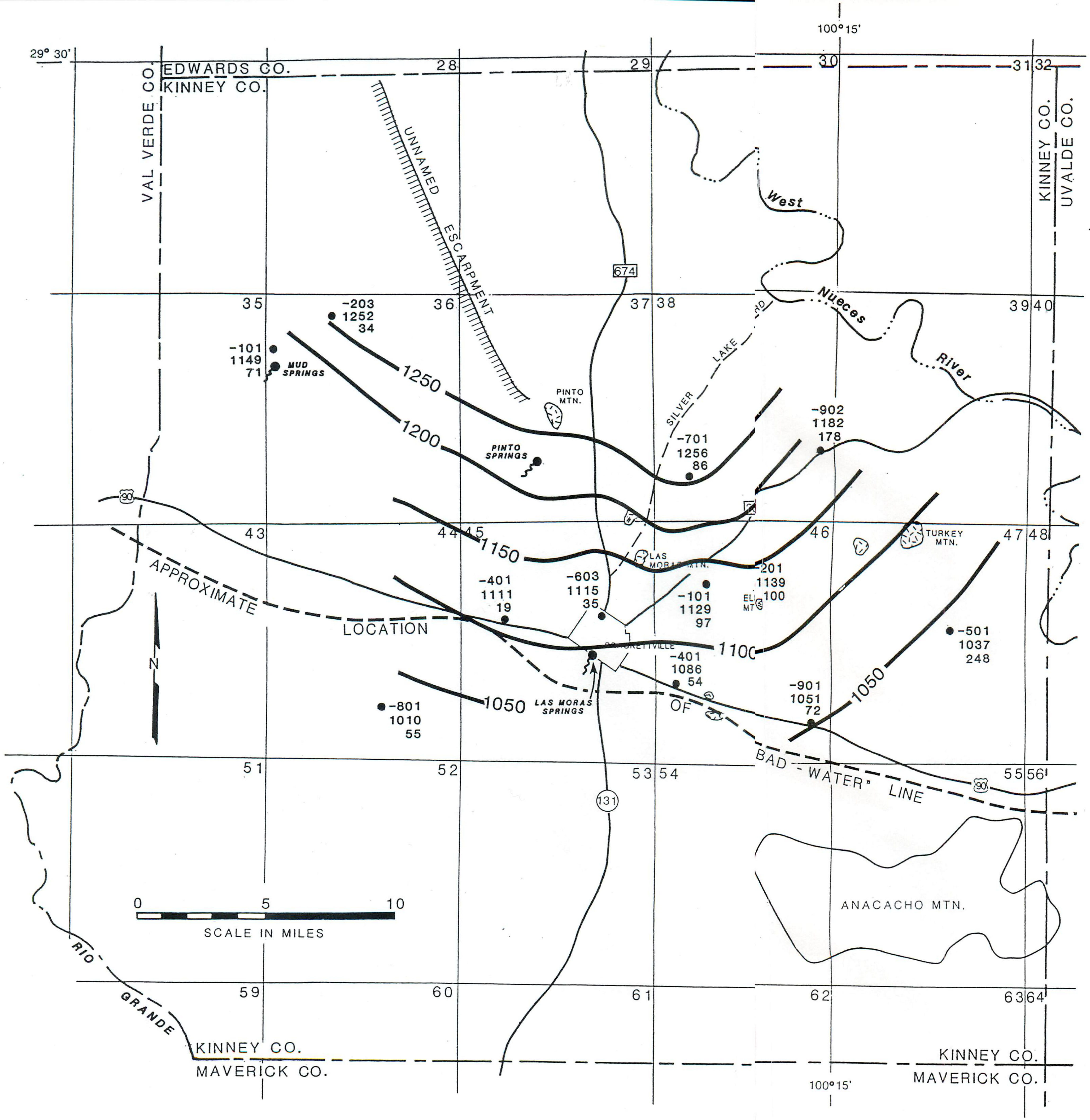
FIGURE 15

LBG-GUYTON ASSOCIATES



APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, KINNEY COUNTY (MARCH 1952)

FIGURE 16



EXPLANATION

● WELL USED FOR CONTROL

-101 — WELL NUMBER
1129 — WATER LEVEL, FEET ABOVE MEAN SEA LEVEL
97 — DEPTH TO WATER LEVEL, FEET

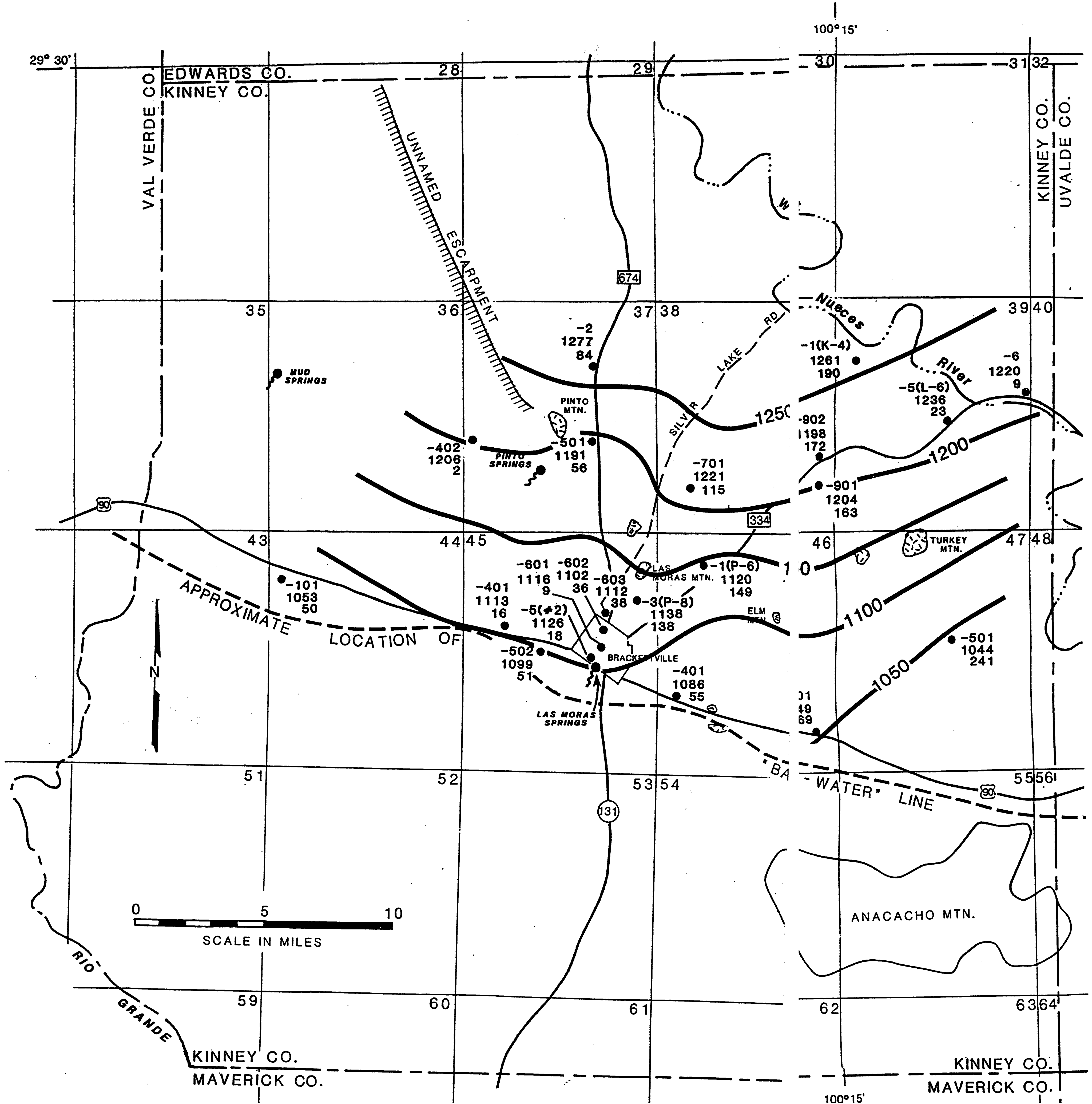
1100 — CONTOUR SHOWING APPROXIMATE ELEVATION OF WATER LEVEL, FEET ABOVE MEAN SEA LEVEL. DASHED WHERE CONTROL IS ABSENT OR LIMITED.

CONTOUR INTERVAL IS 50 FEET

APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, KINNEY COUNTY (JULY 1976)

FIGURE 17

LBG-GUYTON ASSOCIATES



EXPLANATION

● WELL USED FOR CONTROL

-701 — WELL NUMBER

1221 — WATER LEVEL, FEET ABOVE MEAN SEA LEVEL

115 — DEPTH TO WATER LEVEL, FEET

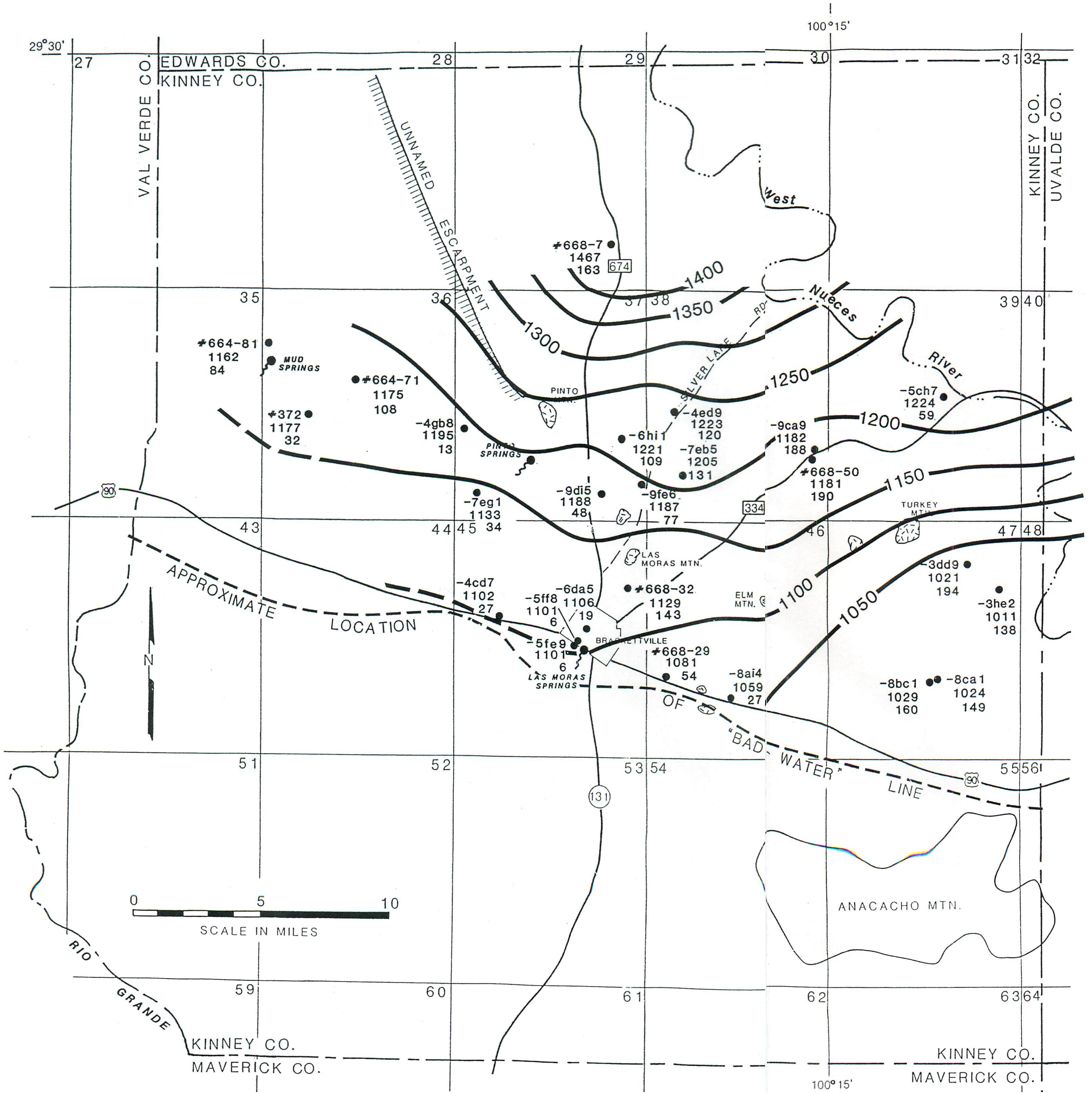
1200 — CONTOUR SHOWING APPROXIMATE ELEVATION OF WATER LEVEL, FEET ABOVE MEAN SEA LEVEL. DASHED WHERE CONTROL IS ABSENT OR LIMITED.

CONTOUR INTERVAL IS 50 FEET

APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, KINNEY COUNTY (JULY 1992)

FIGURE 18

LBG-GUYTON ASSOCIATES



EXPLANATION

● WELL USED FOR CONTROL

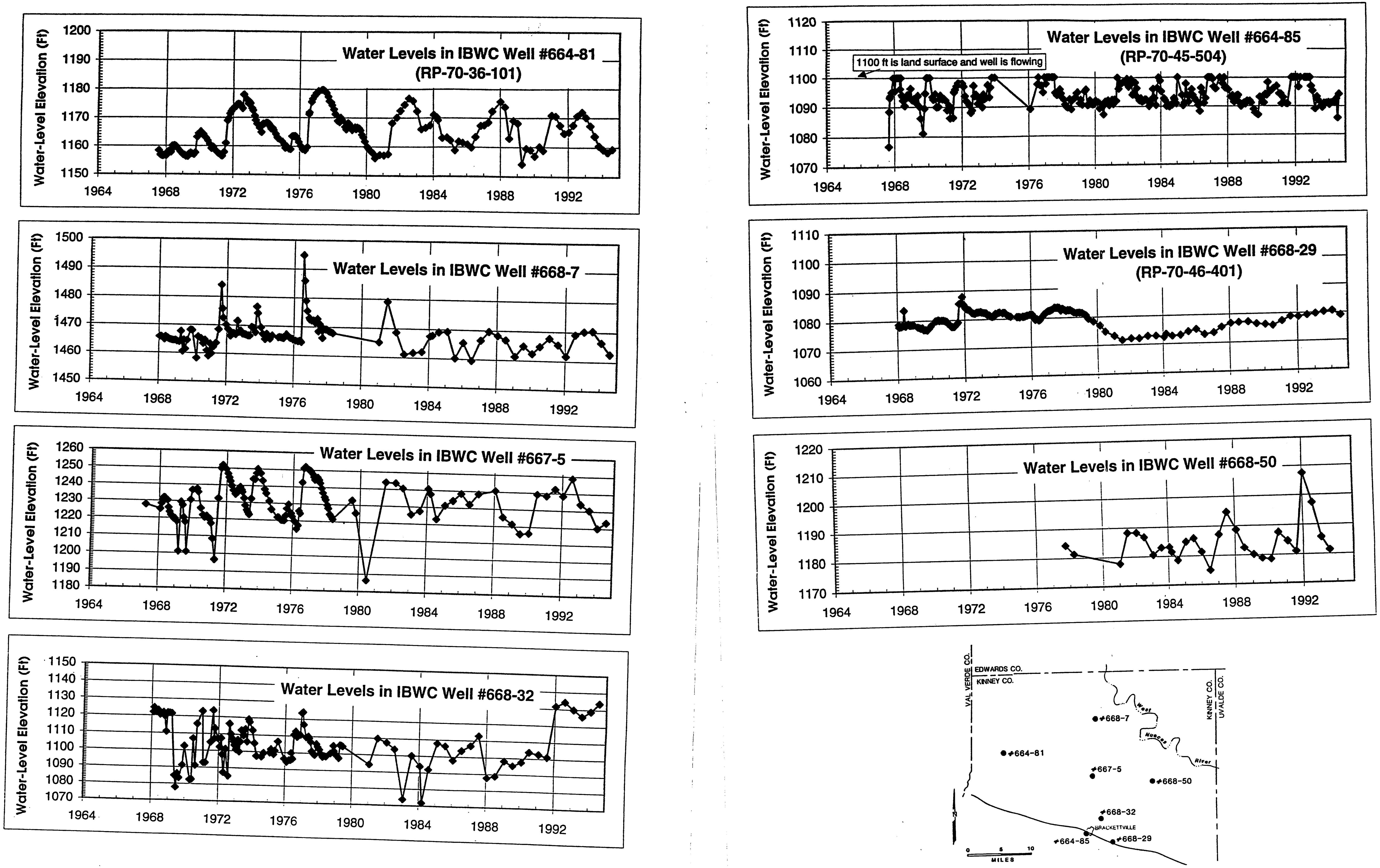
-6hi4 — WELL NUMBER
1221 — WATER LEVEL, FEET ABOVE MEAN SEA LEVEL
109 — DEPTH TO WATER LEVEL, FEET

1200 — CONTOUR SHOWING APPROXIMATE ELEVATION OF WATER LEVEL, FEET ABOVE MEAN SEA LEVEL. DASHED WHERE CONTROL IS ABSENT OR LIMITED.

CONTOUR INTERVAL IS 50 FEET

APPROXIMATE ELEVATION OF AND DEPTH TO WATER LEVELS IN THE EDWARDS AQUIFER, KINNEY COUNTY (JANUARY TO MARCH 1994)

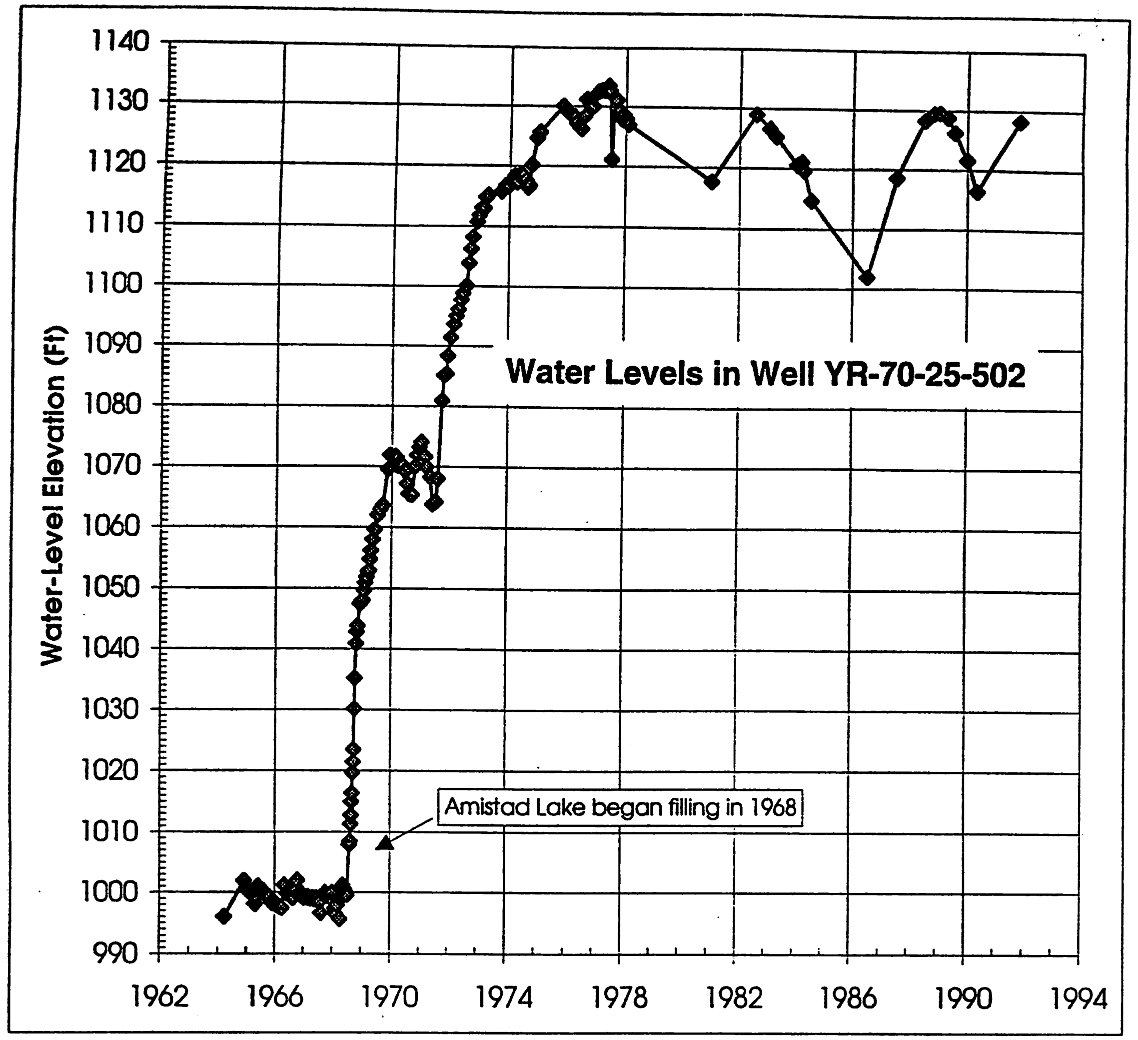
FIGURE 19

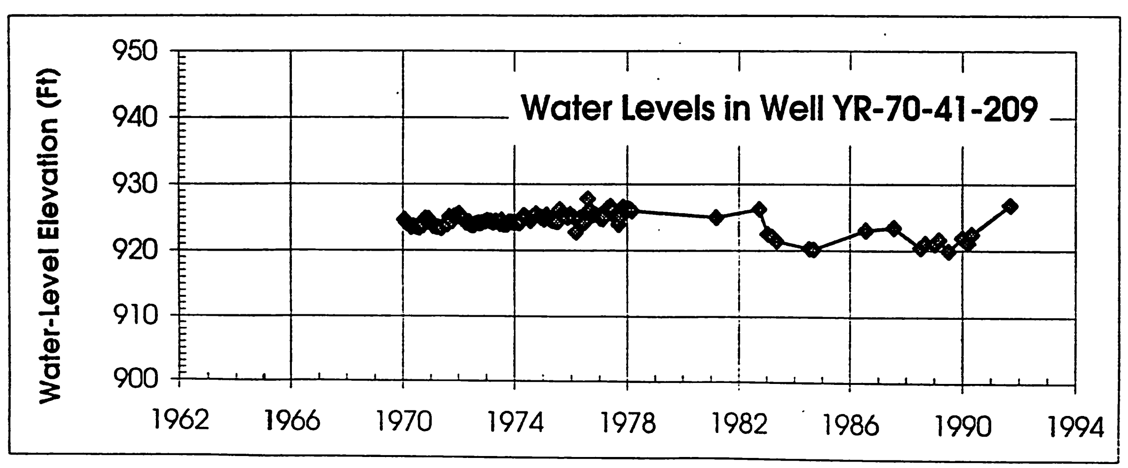


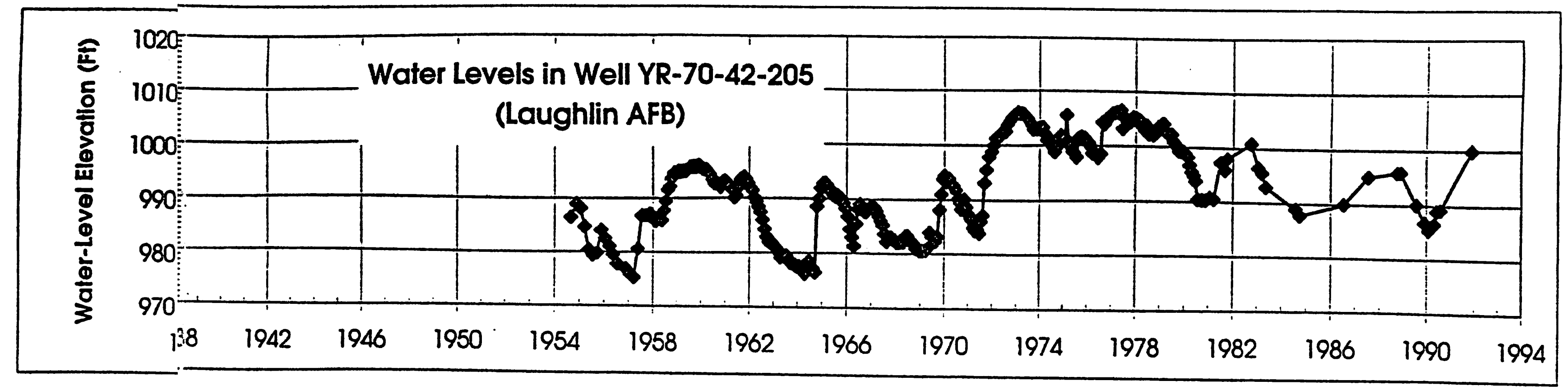
WATER LEVELS IN WELLS IN KINNEY COUNTY PERIODICALLY MEASURED BY THE IBWC

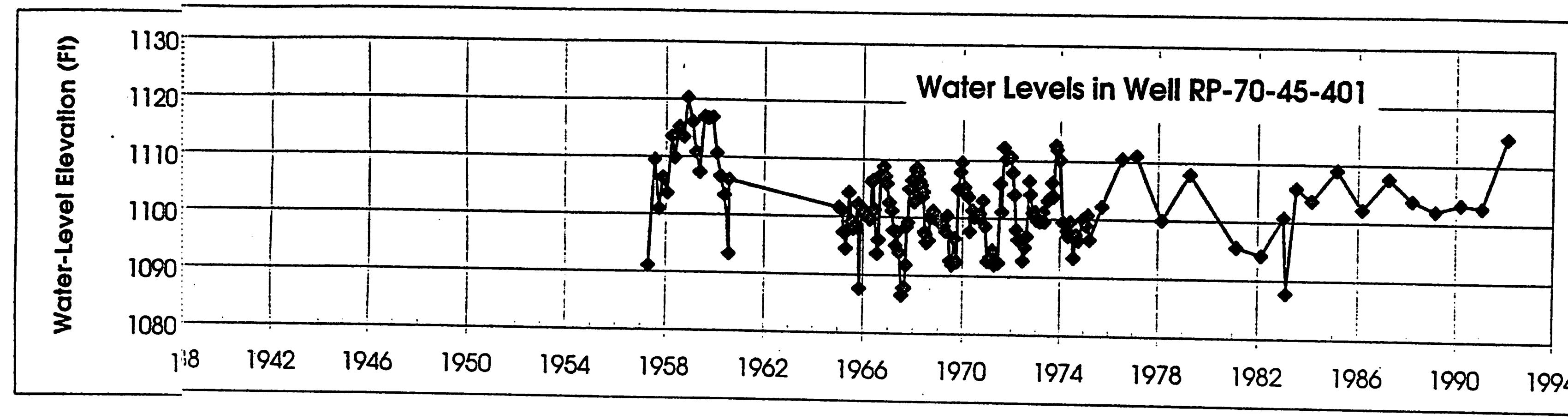
FIGURE 20

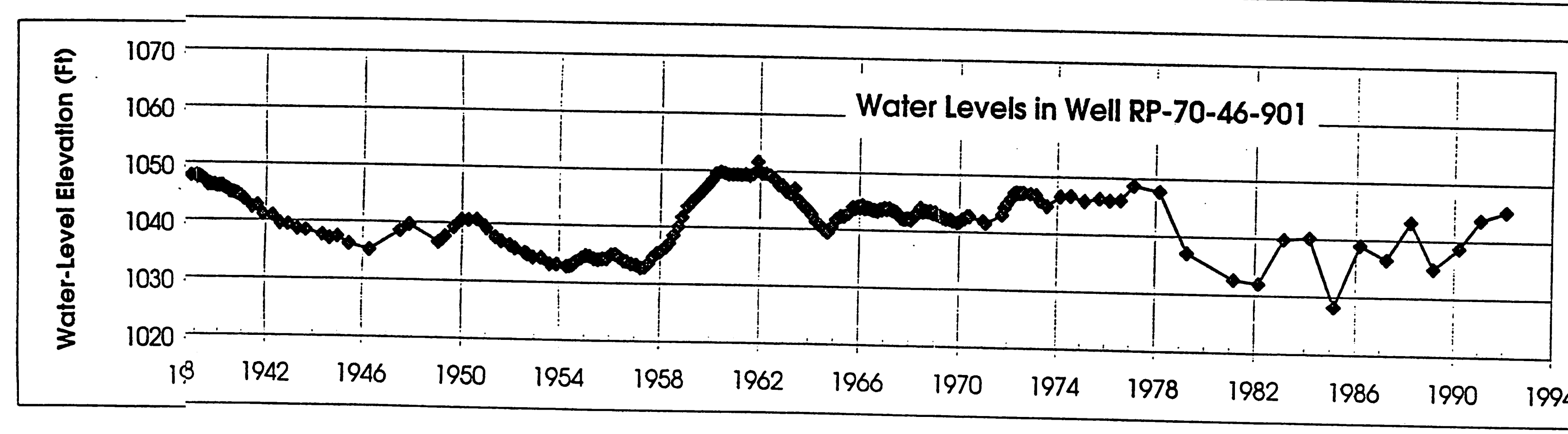
LBG-GUYTON ASSOCIATES

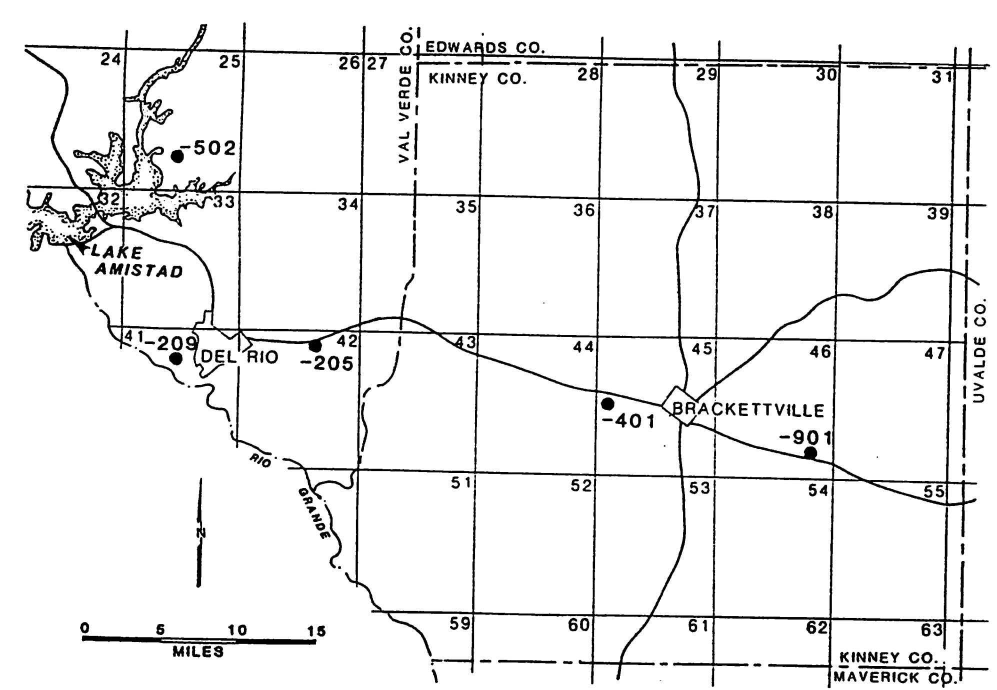






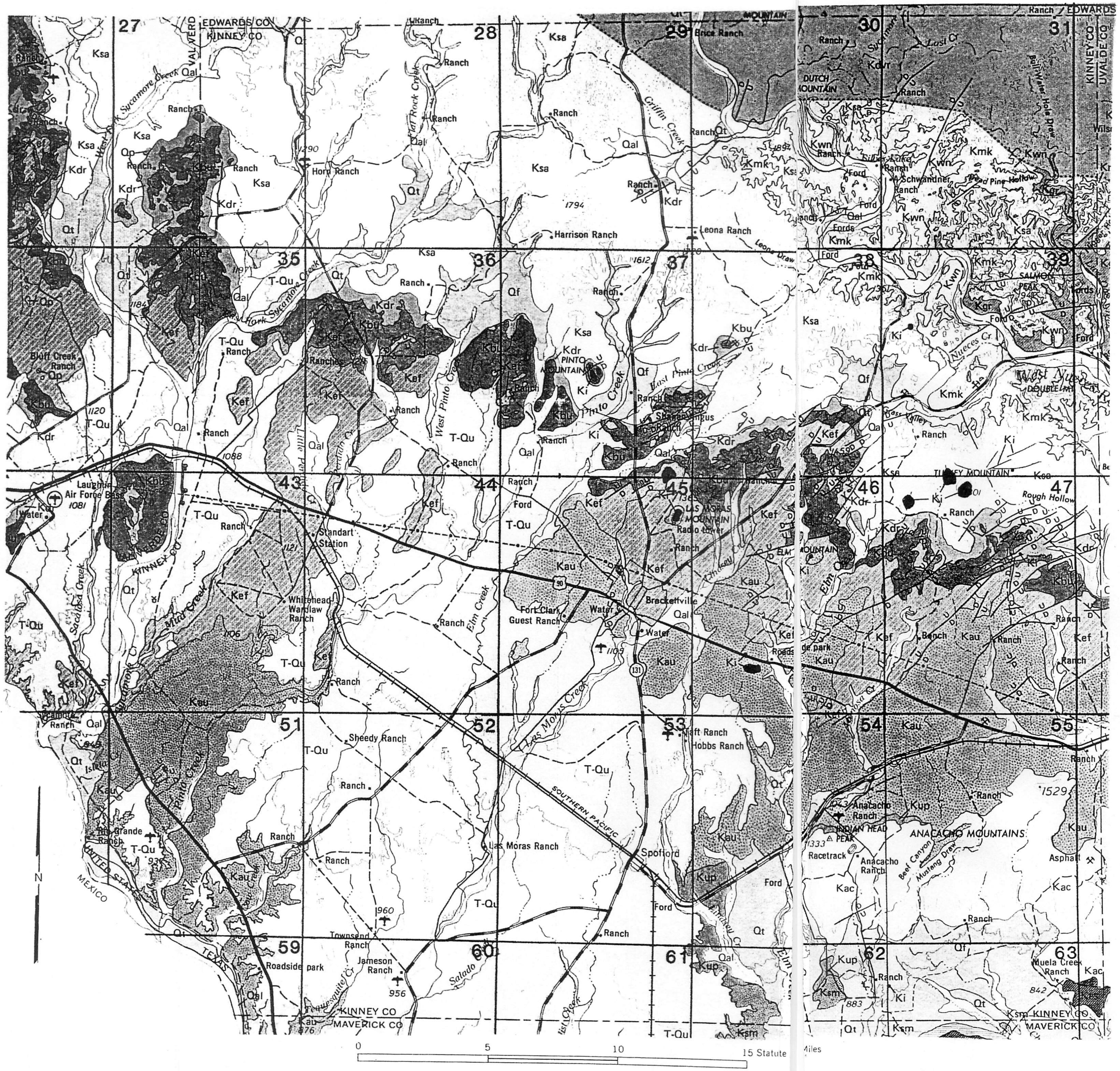






WATER LEVELS IN WELLS OVER AN AREA FROM LAKE AMISTAD THROUGH BRACKETTVILLE (DATA FROM TWDB)

FIGURE 21



EXPLANATION

Ki — Cretaceous igneous rocks

Kac — Austin Chalk

Kau — Anacacho Limestone

Kef — Eagle Ford Group

Kbd, Kbu, Kdr — Buda Limestone and Del Rio Clay

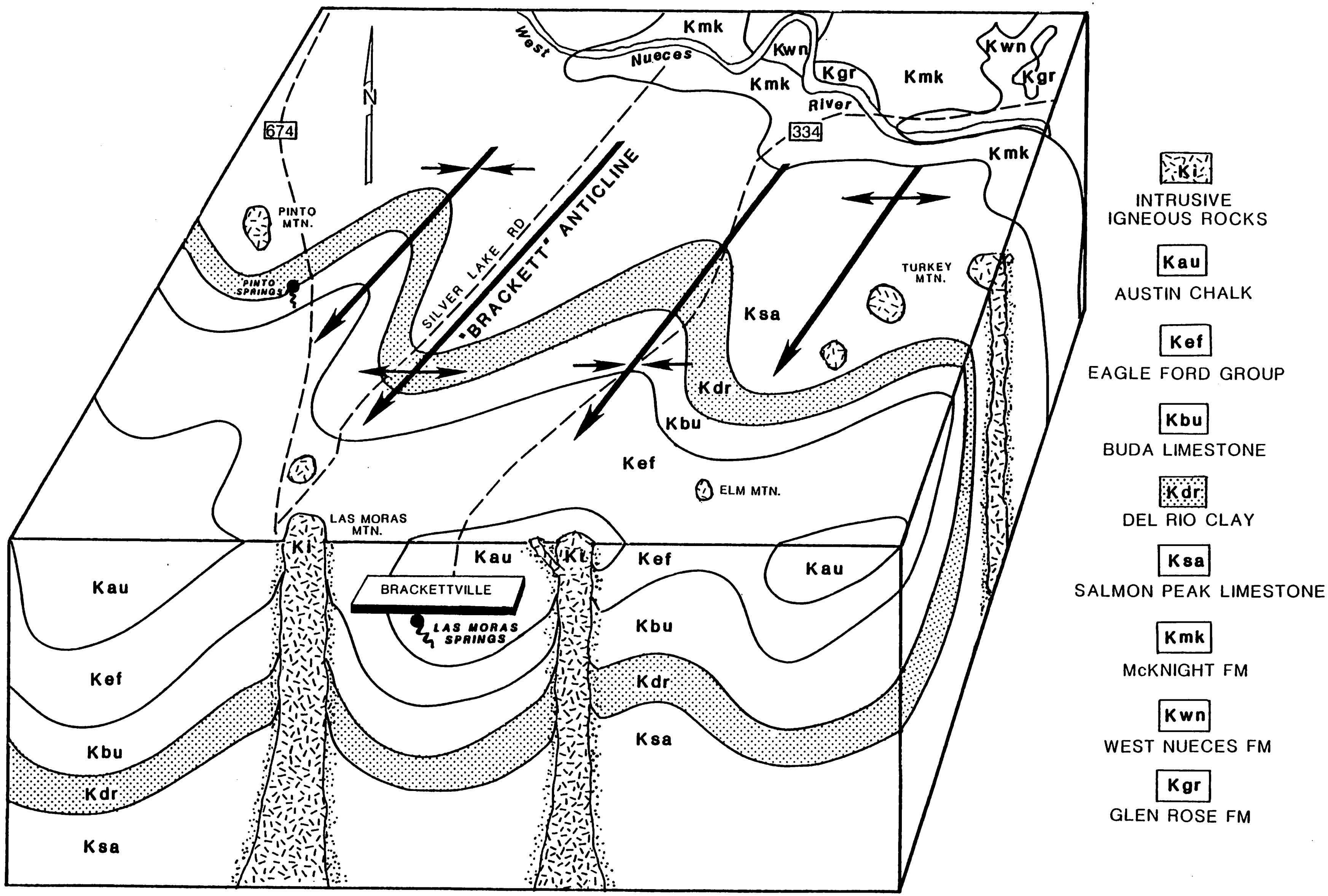
Kse, Ksa, Kdvr, Ks, Ksu, Kmk, Kft, Kdm, Kwn — Segovia and Fort Terrett Members, Devils River Limestone, Salmon Peak Limestone, McKnight Formation, West Nueces Formation, Santa Elena Limestone, Sue Peaks Formation, and Del Carmen Limestone

Kgr — Glen Rose Formation

GEOLOGIC MAP OF KINNEY COUNTY GROUND-WATER DIVIDE AREA (MODIFIED FROM BEG, 1977)

FIGURE 22

LBG-GUYTON ASSOCIATES



THREE DIMENSIONAL GEOLOGIC SCHEMATIC
FOR NORTHERN KINNEY COUNTY

FIGURE 23

LBG-GUYTON ASSOCIATES

APPENDIX 1

METRIC CONVERSIONS

APPENDIX 1
METRIC CONVERSIONS

The inch-pound units of measurement used in this report may be converted to metric units (International System) by the following factors:

Multiply inch-pound unit	by	To obtain metric units
acre-foot (ac-ft)	1,233	cubic meter (m^3)
foot (ft)	0.3048	meter (m)
inch	25.4	millimeters (mm)
mile (mi)	1.609	kilometer (Km)
gallons per minute (gpm)	0.06300	liters per second (l/s)
gallons per minute per foot (gpm/ft)	0.207	liters per second per meter (l/s/m)
degree Fahrenheit (°F)	5/9 x (°F-32)	degree Celsius (°C)