Texas Water Development Board
San Antonio District Office
Open-File Report

SUBSURFACE SALINE WATER RESOURCES IN THE SAN ANTONIO AREA, TEXAS

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Texas Water Development Board

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SUBSURFACE SALINE WATER RESOURCES
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ABSTRACT

The study of Subsurface Saline Water Resources in the San Antonio Area was conducted from November 1973 to June 1974. The San Antonio area lies within the Nueces, San Antonio, and Guadalupe River basins. It consists of all or parts of Atascosa, Bexar, Comal, Frio, Guadalupe, Karnes, Medina, and Wilson Counties. The general scope of this investigation includes: (a) the occurrence, quantity, and quality of saline water available in the San Antonio area; (b) to discuss and identify aquifers containing saline water; and (c) studies of saline aquifers using digital computer model techniques and graphical yield rates.

The following are estimated quantities of saline groundwater in artesian storage by aquifer in the San Antonio area: (a) Wilcox Group - 387,000 acre-feet, of which 81,000 acre-feet are classed as moderately saline (containing 3,000 to 10,000 mg/l of total dissolved solids); (b) Austin Group - 1,927,000 acre-feet; (c) Edwards and associated limestones - 2,131,000 acre-feet with 85,000 acre-feet being classed as moderately saline; (d) Glen Rose Formation - 2,447,000 acre-feet; and (e) Travis Peak Formation - 2,070,000 acre-feet.

Saline water in the Wilcox Group contains 3,000 to 50,000 mg/l of total dissolved solids, in the Austin Group 3,000 to 29,000 mg/l of total dissolved solids, and in the Edwards and associated limestones 3,000 to 220,000 mg/l of total dissolved solids. Because of insufficient data, the exact water quality of the Glen Rose and Travis Peak Formations could not be determined.

SUBSURFACE SALINE WATER RESOURCES IN THE SAN ANTONIO AREA, TEXAS

INTRODUCTION

Purpose and Scope

The study of Subsurface Saline Water Resources in the San Antonio Area was initiated as part of the Texas Water Development Board's San Antonio Area Regional Environmental Project. The purpose of this open-file report is to present the results obtained from this investigation. It was conducted from November 1973 to June 1974.

The general scope of this investigation includes: (a) a discussion of the occurrence, quantity, and quality of saline water available in the San Antonio area; (b) discussion and identification of aquifers containing saline water; and (c) studies of saline aquifers using digital computer model techniques and graphical yield rates.

Location and Population

The area covered by this report will be referred to as the San Antonio area. This area occurs within the Nueces, San Antonio, and Guadalupe River basins. It includes all or parts of the following counties: Atascosa, Bexar, Comal, Frio, Guadalupe, Karnes, Medina, and Wilson. It differs somewhat from the San Antonio area as described in some other reports.

According to the figures obtained from the Texas Water Development Board's Economics, Water Requirements and Uses Division, the study area has an estimated 1970 population of 964,786. The largest population and trade center within the study area is San Antonio (1970 population estimate - 654,153). Population projections indicate Bexar County, in which San Antonio is located, will have a population of 1,260,900 by the year 2000. This compares with 830,500 in 1970.

Economy

The region derives its economy from military installations, governmental agencies, light industry, tourism, and the production of various agricultural products. Natural resources in the study area include oil, natural gas, clays, sands, and gravel. Clays used for ceramic purposes are produced in Bexar and Wilson Counties. Sand and gravel are produced throughout the area and are used as an aggregate in concrete and asphalt. Sand suitable for the manufacture of glass has been produced in Atascosa County.

Previous Investigations

Core Laboratories, Inc., as part of their "Survey of the Subsurface Saline Water of Texas" (1972), and Winslow and Kister's 1956 investigation of the "Saline-Water Resources of Texas" provided basic references and data on the occurrence, availability, and quality of saline ground-water resources.

Personnel

The study was carried out by the author under the direct supervision and guidance of Glenward R. Elder, District Chief, San Antonio District Office, and William B. Klemt, Chief of Groundwater Availability Branch, Water Availability Division. General direction of the study was provided by Robert L. Bluntzer, Division Director, Water Availability Division, and Lewis B. Seward, Principal Engineer-Project Development. Typing of the manuscript and various tables along with processing computer data was done by Mrs. Sue Reagan and Mrs. Peggy Behnken, secretaries.

Acknowledgments

The Texas Water Development Board is grateful to Dowell Chemical, Halliburton Division Laboratory, San Antonio City Public Service Board, and Schlumberger Well Surveying Corporation for chemical analyses of groundwater within the study area. Mr. Jim Ellis, Schlumberger Well Surveying Corporation, San Antonio Office, contributed advice and guidance in the field of electric log interpretation.

Acknowledgment is extended to the Texas Railroad Commission for the use of their reservoir characteristics records in the San Antonio area.

Special acknowledgment is extended to Mr. Dick Reeves, United States Geological Survey, and Mr. Porter Montgomery, Montgomery Stratigraphic Service. Mr. Montgomery generously permitted the use of his library and electric logs which greatly contributed to the successful completion of this investigation.

Definition of Terms

Acre-foot - The volume of water required to cover 1 acre to a depth of 1 foot (43,560 cubic feet) or 325,851 gallons.

Aquifer - A formation, group of formations, or a part of a formation that is water bearing; an underground stratum that will yield water in sufficient quantity to be of value as a source of supply. An artesian aquifer is overlain (confined) by an impermeable layer so that the water is under hydrostatic pressure. The water level in an artesian well will rise above the top of the aquifer. A water-table aquifer is an aquifer in which the water is unconfined - the upper surface of the zone of saturation is under atmospheric pressure only and the water is free to rise or fall in response to the changes in the volume of water in storage.

Aquifer yield rate - The maximum yield in gallons per minute produced from a single well pumping 100 years and with a drawdown of no greater than 500 feet.

Artesian storage - The volume of water which can be obtained when the hydrostatic pressure of an artesian aquifer is lowered by pumping; water is derived from storage by the compaction of the aquifer and its associated beds and by expansion of the water itself. Units are in acre-feet.

Coefficient of permeability - The rate of flow of water in gallons per day through a cross-sectional area of 1 square foot under a unit hydraulic gradient.

Coefficient of storage - The volume of water an aquifer releases from or takes into storage per unit of surface area of the aquifer per unit change in the component of head normal to that surface. The storage coefficient is a dimensionless term. In an unconfined water body it is virtually equal to the specific yield.

Coefficient of transmissibility - The number of gallons of water that will move in 1 day through a vertical strip of the aquifer 1 foot wide and having the height of the saturated aquifer when the hydraulic gradient is unity. It is the product of the field coefficient of permeability and the saturated thickness of the aquifer.

Cone of depression - The depression of the water table or piezometric surface surrounding a discharging well or group of wells which is more or less the shape of an inverted cone.

Drawdown - The lowering of the water table or piezometric surface caused by pumping (or artesian flow). It is the difference, in feet, between the static level and the pumping level.

Lithology - The description of rocks, usually from observation of hand specimen or outcrop with the aid of a low-power magnifier.

Water-table storage - The volume of water obtained when the water level is lowered by pumping. Groundwater is derived from storage by gravity drainage from the saturated pore space in the portion of the aquifer unwatered by the pumping. Units are in acre-feet.

METHOD OF ANALYSIS

A saline aquifer, as defined in this report, contains water having more than 3,000 milligrams per liter (mg/l) of total dissolved solids. The saline waters discussed are classified according to Winslow and Kister (1956) as follows:

Fresh Water	-	0 to 1,000 mg/l
Slightly Saline Water	-	1,000 to 3,000 mg/l
Moderately Saline Water	-	3,000 to 10,000 mg/l
Very Saline Water	-	10,000 to 35,000 mg/l
Brine	-	More than 35,000 mg/l

All available literature pertaining to saline aquifers in the San Antonio area was researched to obtain the following: (a) water quality; (b) aquifer coefficients (permeability, transmissibility, and storage); (c) structure; (d) thickness; and (e) lithology.

Saline sand aquifer coefficients and water quality were estimated using methods devised by Archie (1942) and Gondouin and Scala (1958) where the literature did not contain sufficient information. Computer programs were written for these empirical relationships and the data was input into the Board's computer via the San Antonio remote terminal.

The nonleaky artesian solution (Walton 1962) was used to determine the aquifer yield rate, which for the purposes of this report is defined as the maximum yield produced from a single well pumping 100 years and with a drawdown of no greater than 500 feet. The following procedure was used to determine this rate: (a) a computer program utilizing the nonleaky artesian solution computed yields associated with drawdowns of 500 feet for a *pumping* period of 100 years and varying transmissibilities; (b) the relationship between yield and transmissibility was graphed as illustrated in Figure 1; and (c) estimates of an aquifer's transmissibility at various locations were converted into aquifer yield rates which were then contoured or put into tabular form. The aquifer yield rate as determined from the above analysis is subject to the following assumptions: (a) a 100 percent efficient well completion; (b) aquifer recharge was negligible; and (c) the aquifer was assumed to have unlimited areal extent.

Other similar graphics were developed for a single production well within a well field (10 wells at ½ mile spacing) which relates yield and the maximum 500 foot drawdown to transmissibility. These graphics are also illustrated on Figure 1.

The total amount of water available from water-table and artesian storage was determined by calculating the volume in the area affected when static water levels are lowered to the base of the saline aquifer. These calculations assume an artesian storage coefficient of 1×10^{-4} (0.0001) and a water-table storage coefficient ranging from 1 percent (0.01) to 5 percent (0.05) depending on the aquifer.

STRATIGRAPHY

The stratigraphic units in the San Antonio area which could possibly yield saline water to wells are of Paleozoic (oldest), Cretaceous, and Tertiary (youngest) age. Only saline aquifers Cretaceous and Tertiary in age were considered as this aquifer data was readily available. Table 1 gives the Cretaceous and Tertiary stratigraphic units in the study area.

The saline aquifers discussed in this report include the following: (a) Wilcox Group; (b) Austin Group; (c) Edwards and associated limestones; (d)

FIGURE 1

Graphs Showing the Relationship of Transmissibility to Drawdown and Yield as a Result of Pumping 100 Years in the San Antonio Area, Texas

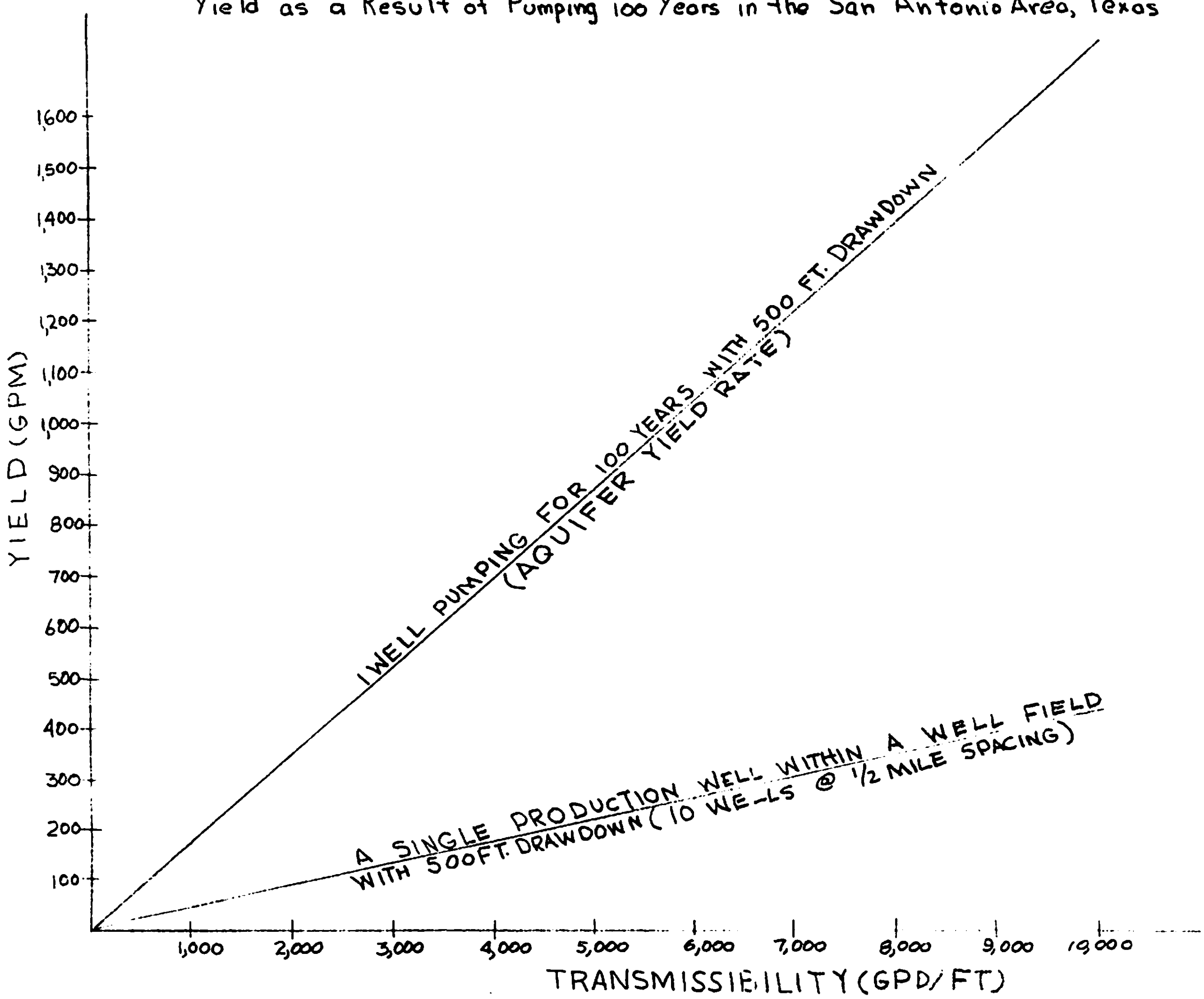


Table 1 -- Cenozoic and Mesozoic Stratigraphic Units in the San Antonio Area, Texas

Era	System	Series	Group	Geologic Unit	Approximate Thickness (ft.)	Character of Rocks
Ceneozoic	Tertiary	Eocene	Wilcox	Wilcox Formation	320 - 1,780	Interbedded sand, clay, and silt with discontinuous beds of lignite
		Paleocene	Midway	Midway Formation	280 - 550	Shale
Mesozoic	Cretaceous	Gulf	Navarro	Navarro Formation	300 - 1,300	Sand, shale, clay, marl, and sandstone
			Taylor	Taylor Marl	240 - 800	Shale and lime
			Austin	Austin Chalk	30 - 460	Chalk and marl
			Eagle Ford	Eagle Ford Shale	0 - 90	Bituminous shale and limestone
		Comanche	Washita	Buda Limestone	13 - 170	Limestone
				Del Rio Clay	12 - 140	Shale
				Georgetown Formation	5 - 275	Limestone
			Fredericksburg	Edwards Limestone	427 - 910	Limestone
				Commanche Peak Limestone	40±	Limestone
				Walnut Clay	1 - 20	Clay, marl, and limestone
			Trinity	Glen Rose Formation	850 - 2,170	Limestone
				Travis Peak Formation	1,010 - 4,000	Dolomite, clastics, sand, and limestone

Glen Rose Formation; and (e) Travis Peak Formation. All of the above saline aquifers are Cretaceous in age except the Wilcox Group which is Tertiary.

SALINE AQUIFERS

Wilcox Group

The Wilcox Group in the San Antonio area containing water greater than 3,000 mg/l of total dissolved solids consists of clays, cross-bedded river sands, thin lignite beds, and stratified silts. The approximate depth to the top of the aquifer ranges from 3,200 feet (Frio County) to 5,900 feet (Karnes County). The average net thickness is 890 feet. The altitude and depth to the top of the Wilcox Group is illustrated in Figure 2, the thickness is illustrated in Figure 3, and water quality is illustrated in Figure 5. The approximate total transmissibility of the Wilcox Group is illustrated in Figure 6 and the aquifer yield rate is illustrated in Figure 7. The following table summarizes the approximate range by county of total dissolved solids, transmissibility, and aquifer yield rates for the Wilcox Group:

County	Total Dissolved Solids (mg/l)	Coefficient of Transmissibility (gpd/ft)	Aquifer Yield Rates Single Well Pumping 100 Yrs. With 500 Feet of Drawdown (gpm)
Atascosa	3,000 - 20,000	200 - 8,700	40 - 1,500
Frio	3,000 - 9,000	200 - 1,000	40 - 200
Karnes	5,000 - 50,000	100 - 2,000	20 - 350
Wilson	3,000 - 6,000	700 - 1,000	100 - 120

The following table summarizes the approximate amount of saline water in storage by county for the Wilcox Group based on an artesian storage coefficient of 1×10^{-4} (0.0001) and water-table storage of 5 percent (0.05):

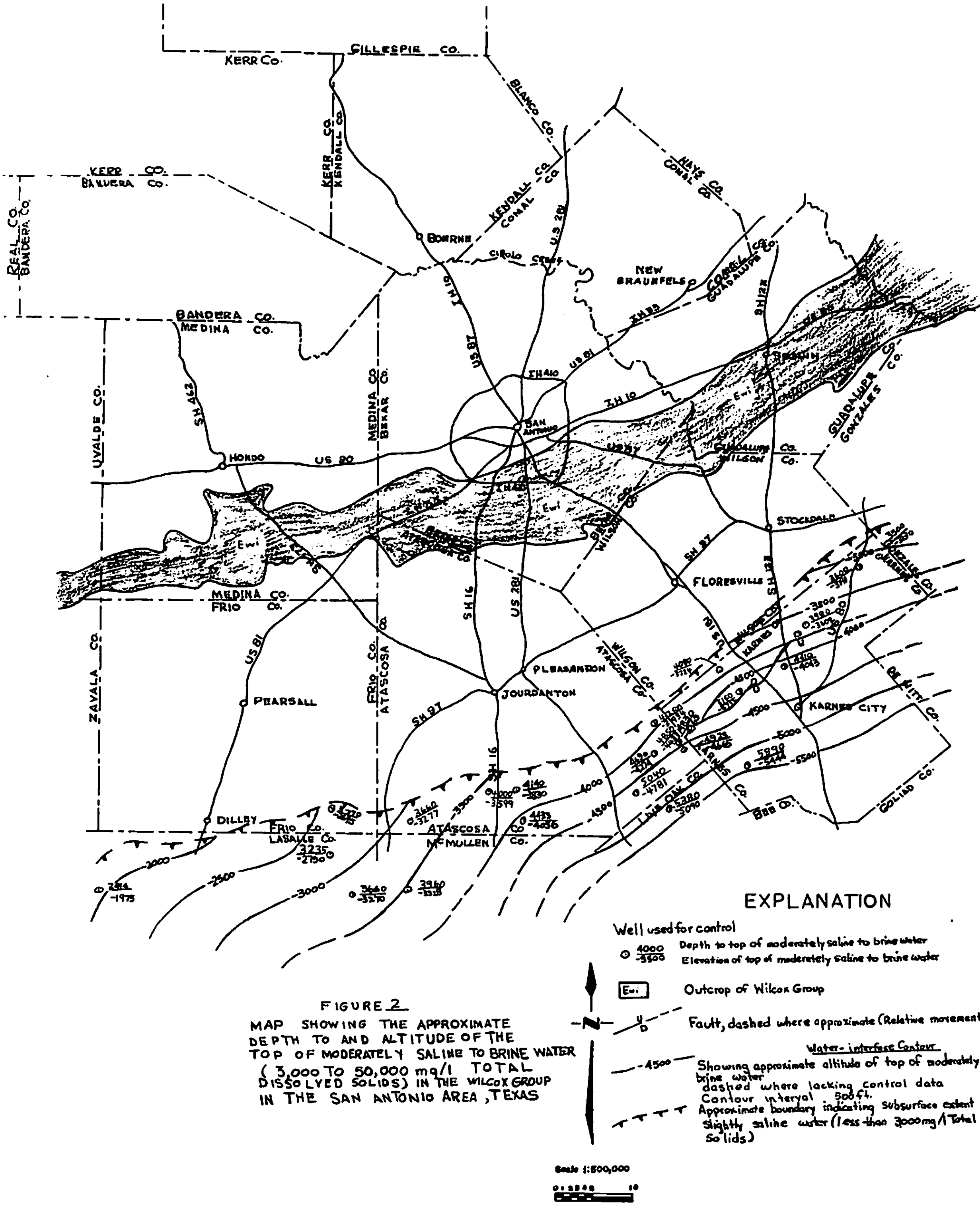
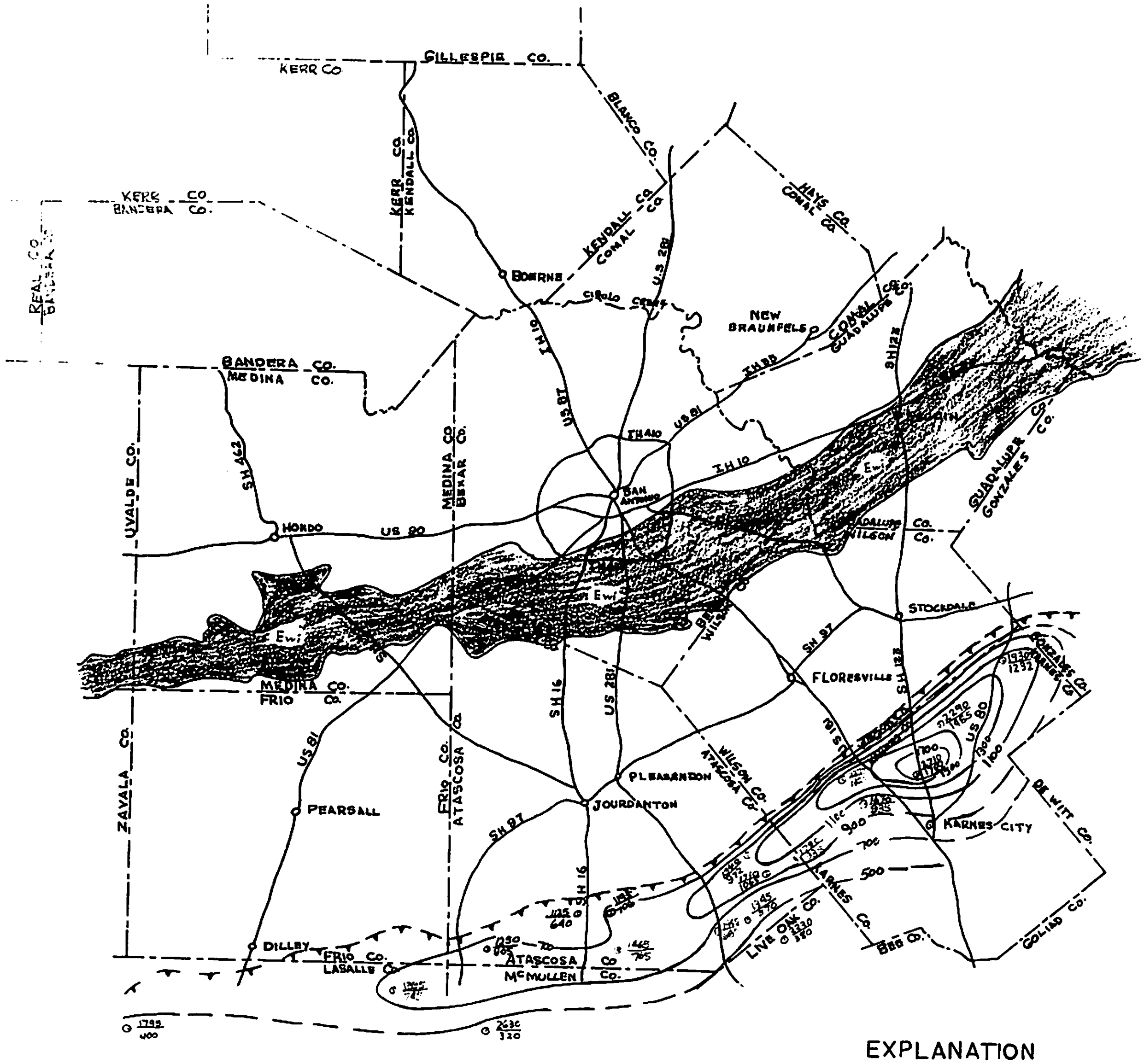


FIGURE 2
MAP SHOWING THE APPROXIMATE DEPTH TO AND ALTITUDE OF THE TOP OF MODERATELY SALINE TO BRINE WATER (3,000 TO 50,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE WILCOX GROUP IN THE SAN ANTONIO AREA, TEXAS



EXPLANATION

Well used for control
○ 500/300 Number indicates total thickness / Number indicates net sand thickness

Ewi Outcrop of Wilcox Group

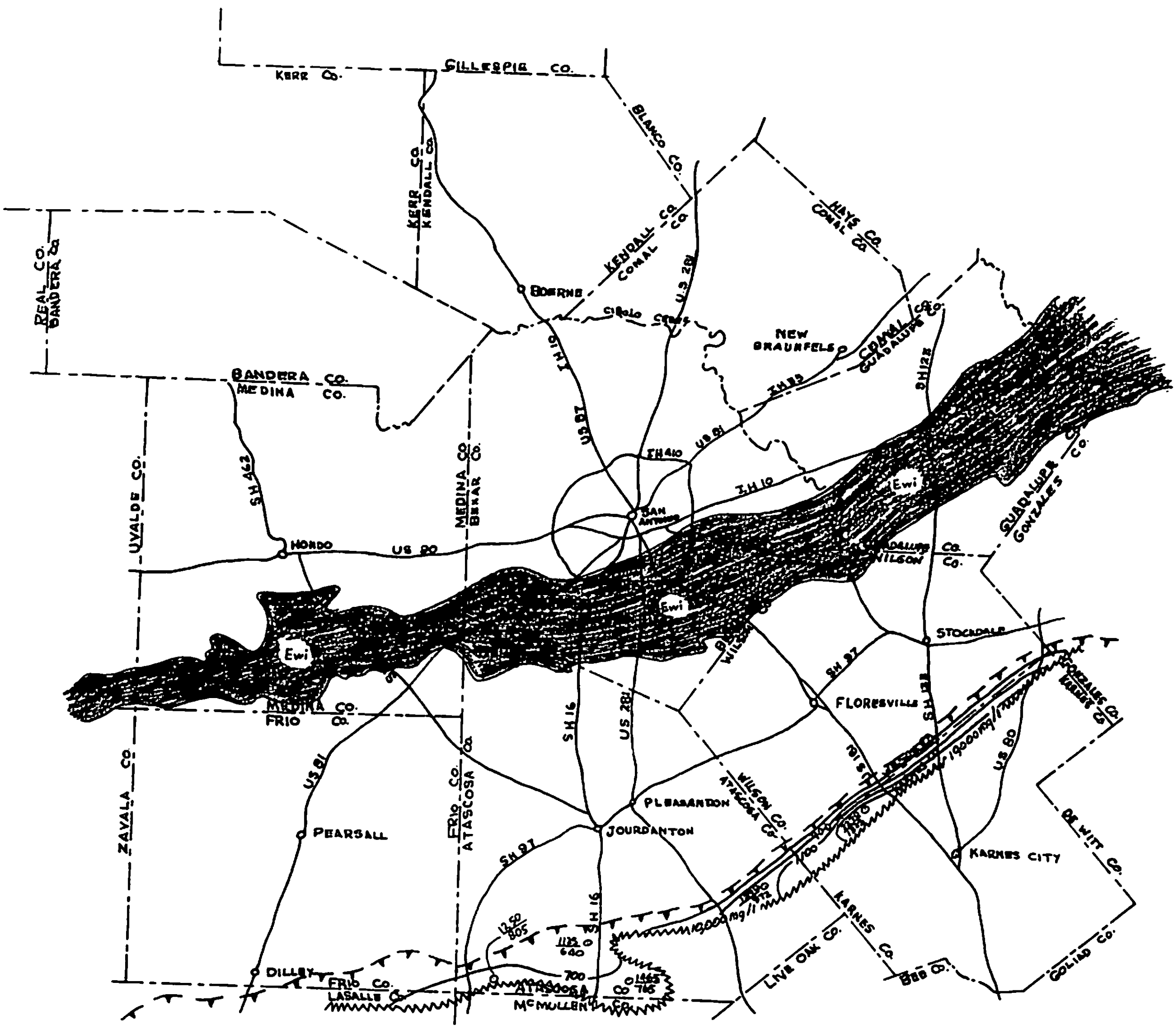
300 Isopach
Shows approximate net thickness of sand containing moderately saline to brine water in the Wilcox Group, dashed where lacking control data
Contour interval 200 feet

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

Scale 1:500,000

FIGURE 3

MAP SHOWING THE APPROXIMATE TOTAL AND NET SAND THICKNESS CONTAINING MODERATELY SALINE TO BRINE WATER (3,000 TO 50,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE WILCOX GROUP IN THE SAN ANTONIO AREA, TEXAS



EXPLANATION

Well used for control

$\frac{600}{400}$ Number indicates total thickness / Number indicates net sand thickness

Ewi — Outcrop of Wilcox Group

Isopach

—700— Shows approximate net thickness of sand containing moderately saline water in the Wilcox Group

Contour interval 200 feet

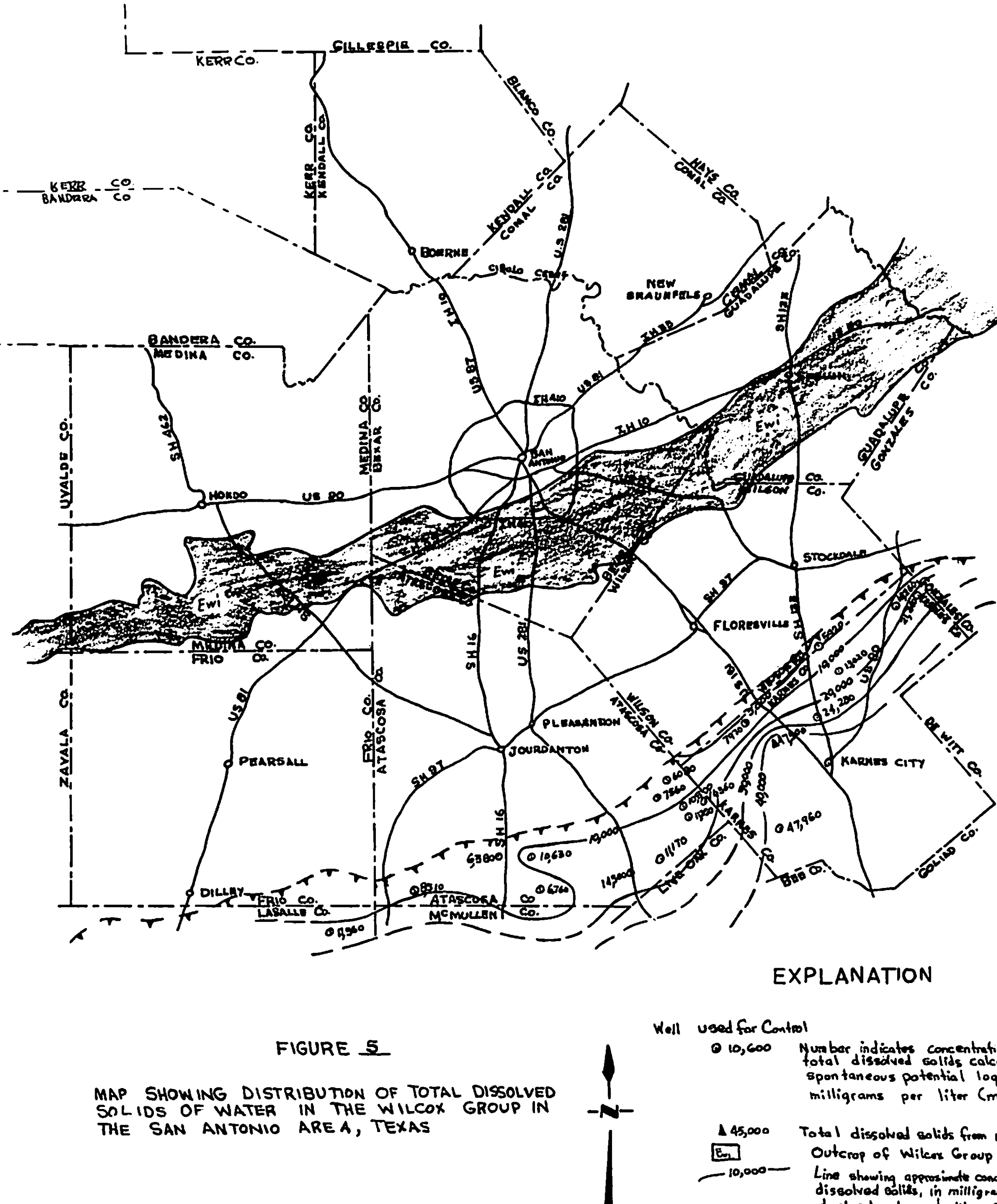
Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3,000 mg/l Total Dissolved Solids)

10,000 mg/l — Approximate boundary indicating subsurface extent of moderately saline water

Scale 1:500,000

FIGURE 4

MAP SHOWING THE APPROXIMATE TOTAL AND NET SAND THICKNESS CONTAINING MODERATELY SALINE WATER (3,000 to 10,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE WILCOX GROUP IN THE SAN ANTONIO AREA, TEXAS



EXPLANATION

Well used for Control

⊙ 10,600 — Number indicates concentration of approximate total dissolved solids calculated from spontaneous potential logs in milligrams per liter (mg/l)

▲ 45,000 — Total dissolved solids from reported data

Ewi — Outcrop of Wilcox Group

—— 10,000 —— Line showing approximate concentration of total dissolved solids, in milligrams per liter (mg/l), dashed where lacking control data. Contour interval varies

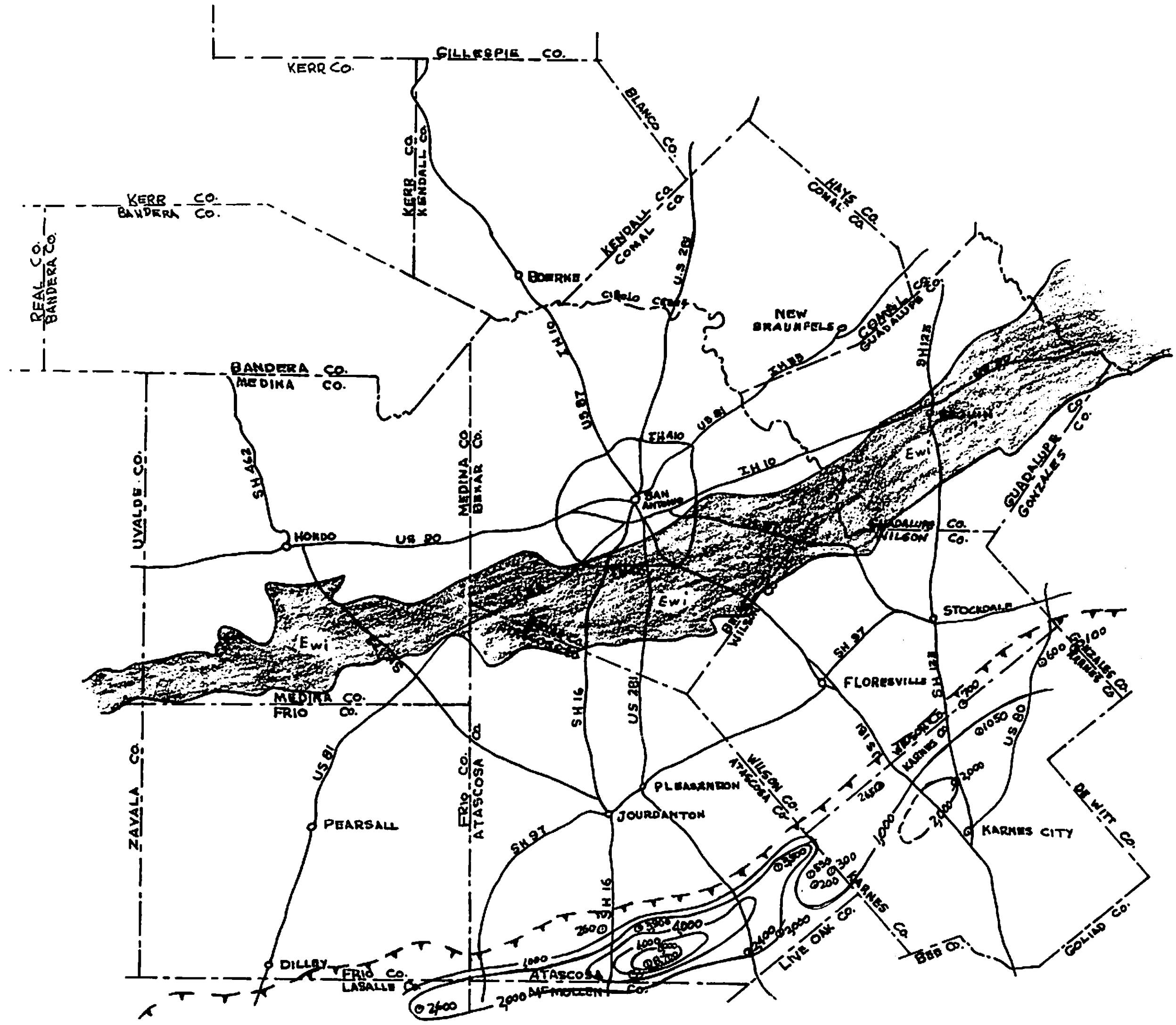
⊤⊤⊤⊤ Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

N

Scale 1:500,000

FIGURE 5

MAP SHOWING DISTRIBUTION OF TOTAL DISSOLVED SOLIDS OF WATER IN THE WILCOX GROUP IN THE SAN ANTONIO AREA, TEXAS



EXPLANATION

Well used for Control

⊙3,500 Number indicates approximate total transmissibility in GPD/FT.

[Ewi] Outcrop of Wilcox Group

—2000— Line shows approximate total transmissibility in GPD/FT., dashed where lacking control data. Contour interval varies

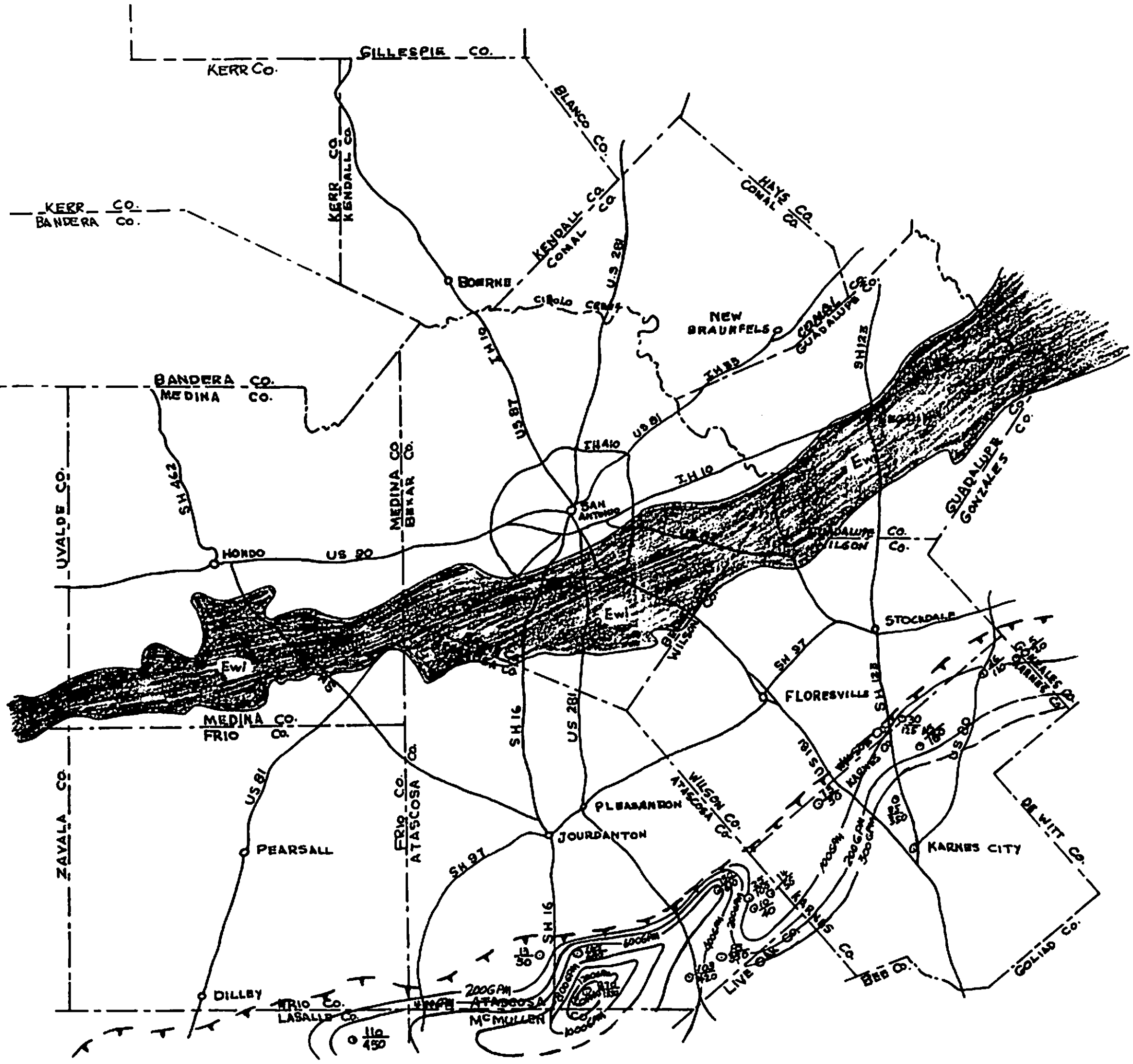
┬┬┬┬ Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

N

Scale 1:500,000

FIGURE 6

MAP SHOWING THE APPROXIMATE TOTAL TRANSMISSIBILITY OF THE WILCOX GROUP IN THE SAN ANTONIO AREA, TEXAS



EXPLANATION

Well used for control

$\circ\,\frac{20}{200}$ 10 Wells pumping for 100 years with 500ft. drawdown / 1 well pumping for 100 years with 500ft. drawdown

Ewl — Outcrop of Wilcox Group

—1000GPM— Line showing aquifer yield rate (GPM) for 1 well pumping 100 years with 500ft drawdown, dashed where lacking control data. Contour interval varies

ㅜㅜㅜㅜ Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

FIGURE 7

MAP SHOWING THE IDEAL CALCULATED AQUIFER YIELD RATE FOR THE WILCOX GROUP AS A RESULT OF PUMPING 100 YEARS WITH 500 FEET OF DRAWDOWN IN THE SAN ANTONIO AREA, TEXAS

N

Scale 1:500,000

0 1 2 3 4 5 10

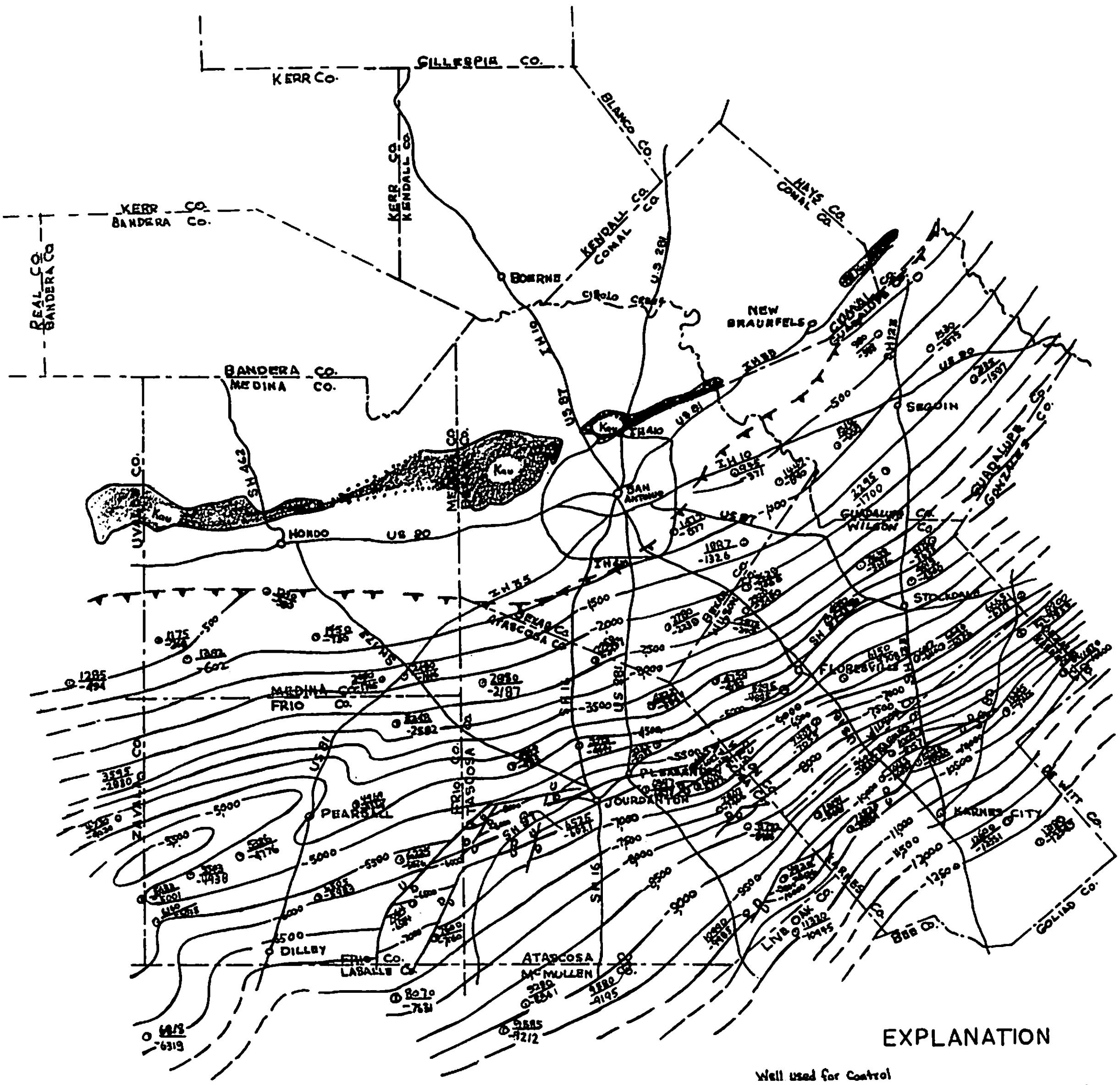
County	Water In Artesian Storage (acre-feet)	Water In Water-table Storage (acre-feet)	Total Water In Storage (acre-feet)
Atascosa	102,000	9,152,000	9,254,000
Frio	10,000	960,000	970,000
Karnes	270,000	20,848,000	21,118,000
Wilson	5,000	448,000	453,000

Austin Group

The Austin Group in the San Antonio area containing water greater than 3,000 mg/l of total dissolved solids consists chiefly of white to buff chalk, marl, and limestone. The approximate depth from the land surface to the top of the aquifer ranges from 700 feet (Guadalupe County) to 13,000 feet (Karnes County). The average thickness is 250 feet. The altitude and depth to the top of the Austin Group is illustrated in Figure 8 and the thickness is illustrated in Figure 9. The transmissibility of the Austin Group is low, averaging about 6 gallons per day per foot (gpd/ft); aquifer yield rates should range from 2 to 5 gallons per minute (gpm). Artesian storage approximates 1×10^{-4} (0.0001) and water-table storage is in the neighborhood of 1 percent (0.01).

The following are estimated ranges of total dissolved solids for the Austin Group by county in the San Antonio area: (a) Bexar - 3,000 to 8,000 mg/l; (b) Guadalupe - 3,000 to 29,000 mg/l; and (c) Medina - 3,000 to 13,000 mg/l. Total dissolved solids in Frio County probably exceed 25,000 mg/l.

The following table summarizes the approximate amount of saline water in storage for the Austin Group:



EXPLANATION

Well used for Control

$\circ\ \frac{2000}{-1500}$ Depth to top of moderately saline to brine water / Elevation of top of moderately saline to brine water

Kau — Outcrop of Austin Group, dotted where approximate

U/D — Fault, dashed where approximate (Relative movement; U, Up; D, Down)

—3500— Water-interface Contour: Showing approximate altitude of top of moderately saline to brine water, dashed where lacking control data. Contour interval 500 feet

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

Scale 1:500,000

0 1 2 3 4 5 10

FIGURE 8

MAP SHOWING THE APPROXIMATE DEPTH TO AND ALTITUDE OF THE TOP OF MODERATELY SALINE TO VERY SALINE WATER (3,000 to 29,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE AUSTIN GROUP IN THE SAN ANTONIO AREA, TEXAS

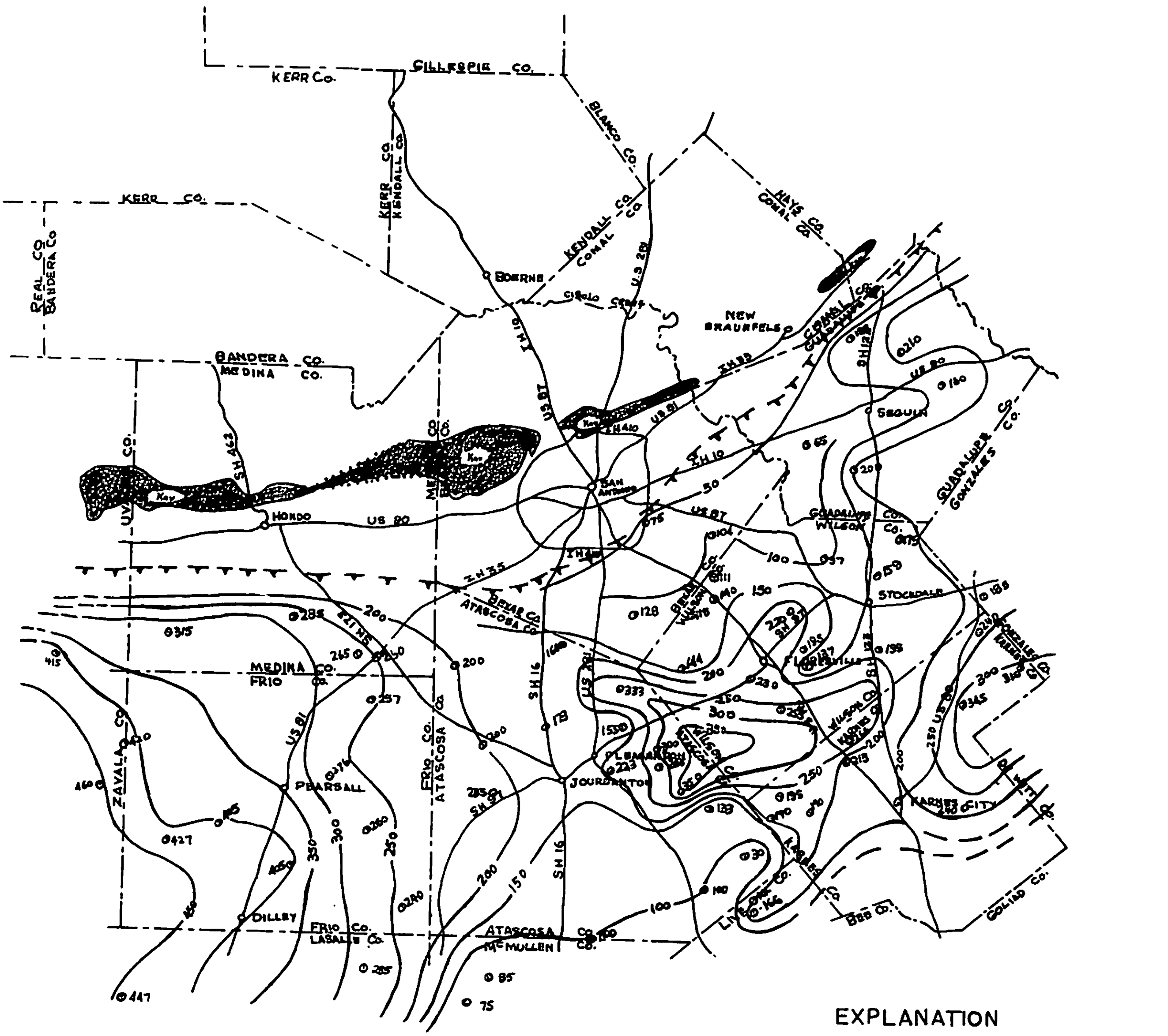


FIGURE 9

MAP SHOWING THE APPROXIMATE TOTAL THICKNESS OF STRATA CONTAINING MODERATELY SALINE TO VERY SALINE WATER (3,000 TO 29,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE AUSTIN GROUP IN THE SAN AREA, TEXAS

N

Scale 1:500,000

EXPLANATION

Well used for control

⊙ 200 Number indicates total thickness

Kau Outcrop of the Austin Group, dotted where approximate

Isopach

—150— Shows approximate total thickness of strata containing moderately saline to brine water in the Austin Group, dashed where lacking control data. Contour interval 50 feet

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

County	Water In Artesian Storage (acre-feet)	Water In Water-table Storage (acre-feet)	Total Water In Storage (acre-feet
Atascosa	571,000	1,632,000	2,203,000
Bexar	52,000	246,000	298,000
Frio	366,000	2,270,000	2,636,000
Guadalupe	73,000	680,000	753,000
Karnes	536,000	803,000	1,339,000
Medina	58,000	784,000	842,000
Wilson	272,000	994,000	1,266,000

Edwards and Associated Limestones

The Edwards and associated limestones in the San Antonio area containing water greater than 3,000 mg/l of total dissolved solids is composed of hard, porous, and fossiliferous limestones and dolomites. The approximate depth to the top of the aquifer ranges from 1,200 feet (Guadalupe County) to 13,800 feet (Karnes County). The average thickness is 750 feet. The altitude and depth to the top of the Edwards and associated limestones is illustrated in Figure 10, the thickness is illustrated in Figure 11, and water quality is illustrated in Figure 13. The approximate total transmissibility of the Edwards and associated limestones is illustrated in Figure 14 and the aquifer yield rate is illustrated in Figure 15. The following table summarizes the approximate range by county of total dissolved solids, transmissibility, and aquifer yield rates for the Edwards and associated limestones:

County	Total Dissolved Solids (mg/1)	Coefficient of Transmissibility (gpd/ft)	Aquifer Yield Rates Single Well Pumping 100 Yrs. With 500 Feet of Drawdown (gpm)
Atascosa	3,000 - 168,000	100 - 10,000	20 - 1,740
Bexar	3,000 - 50,000	5,000 - 10,000	870 - 1,740

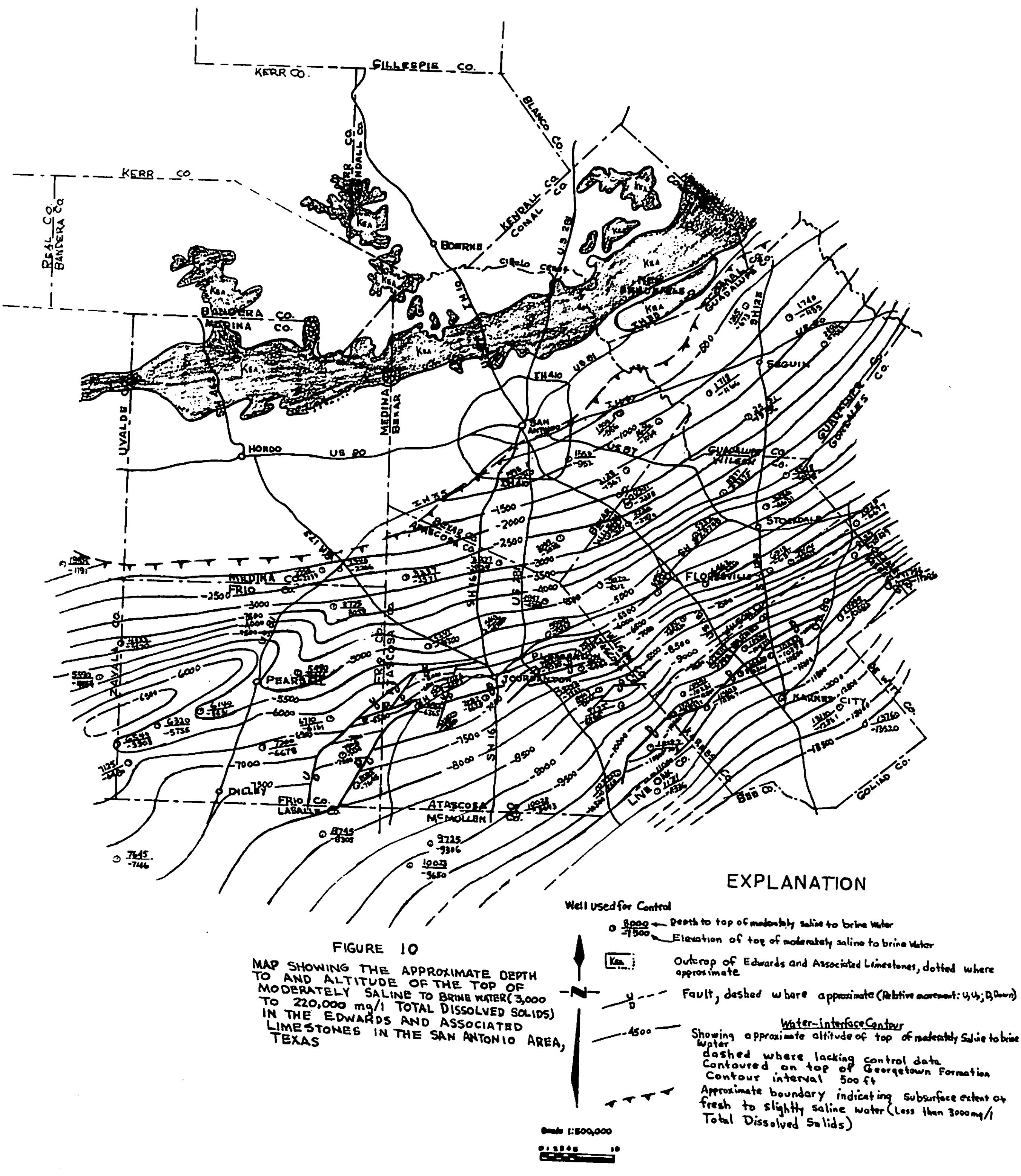
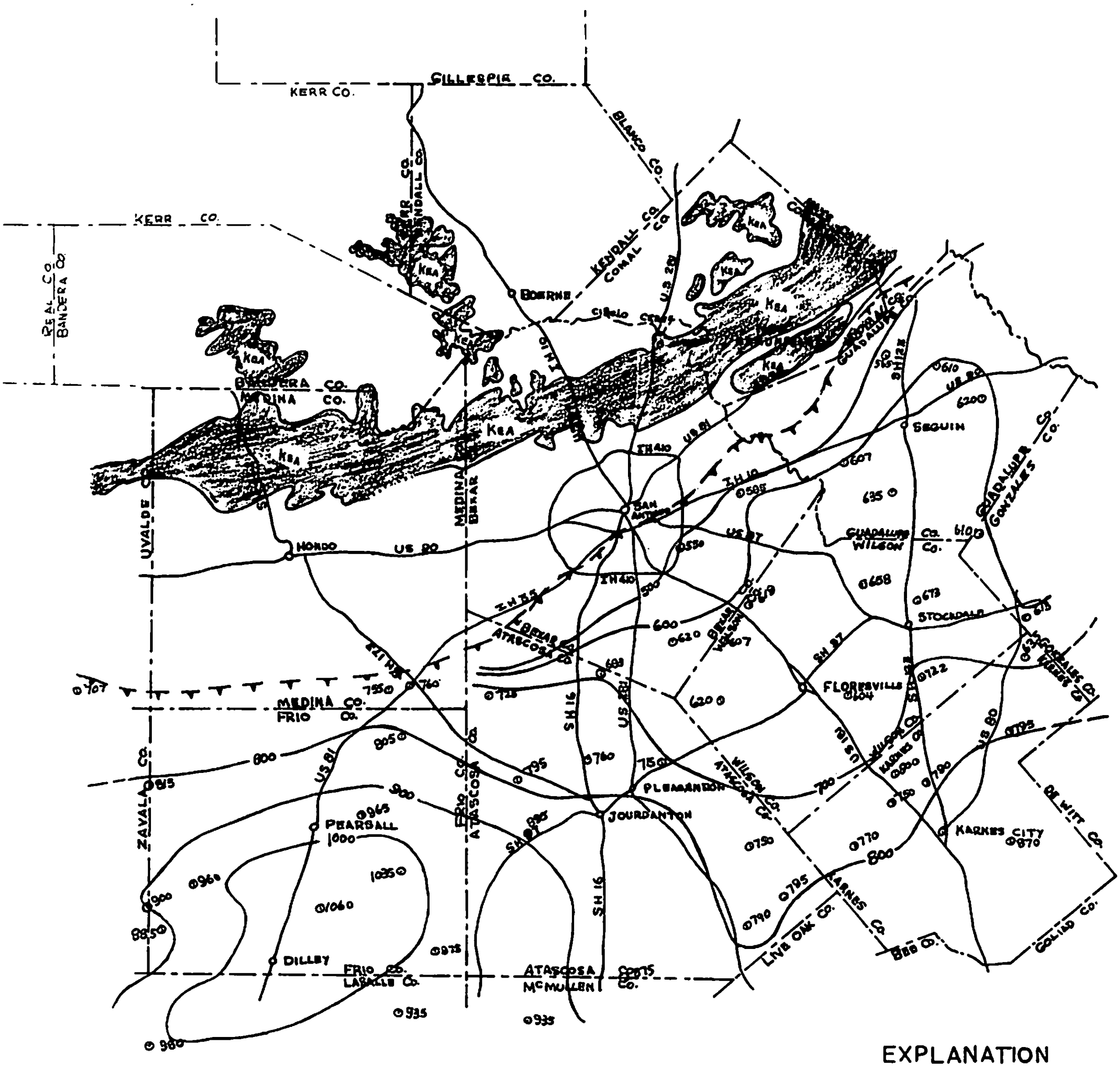


FIGURE 10

MAP SHOWING THE APPROXIMATE DEPTH TO AND ALTITUDE OF THE TOP OF MODERATELY SALINE TO BRINE WATER (3,000 TO 220,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE EDWARDS AND ASSOCIATED LIMESTONES IN THE SAN ANTONIO AREA, TEXAS



EXPLANATION

Well used for control

⊙ 600 Number indicates total thickness

KEA Outcrop of Edwards and associated limestone, dotted where approximate

—200— **Isopach**

Shows approximate total thickness of limestones containing moderately saline to brine water in the Edwards and associated limestones, dashed where lacking control data

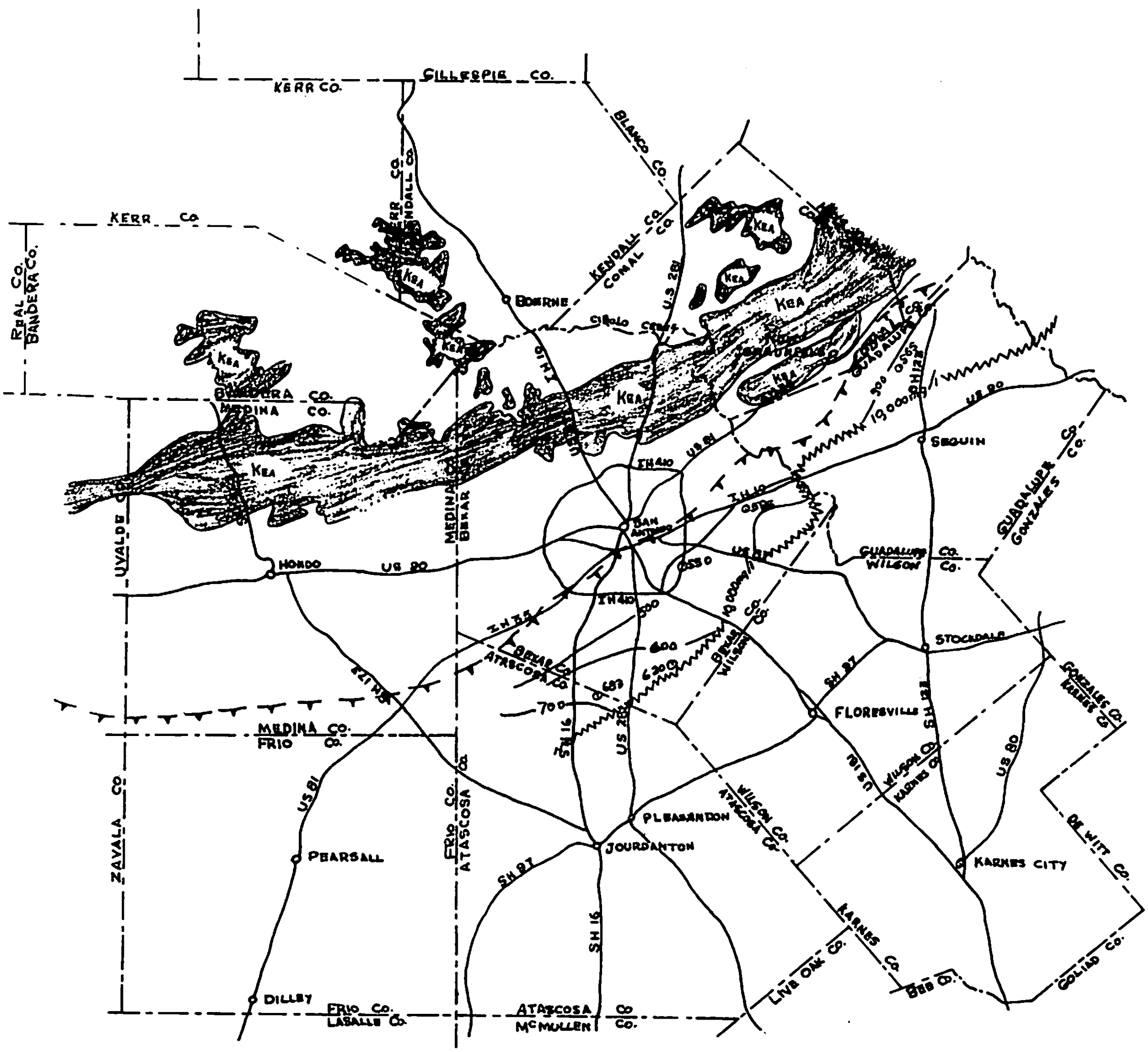
Contour interval 100 feet

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

Scale 1:500,000

FIGURE 11

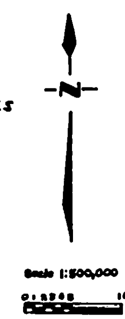
MAP SHOWING THE APPROXIMATE TOTAL THICKNESS OF LIMESTONES CONTAINING MODERATELY SALINE TO BRINE WATER (3,000 TO 220,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE EDWARDS AND ASSOCIATED LIMESTONES IN THE SAN ANTONIO AREA, TEXAS



EXPLANATION

FIGURE 12

MAP SHOWING THE APPROXIMATE TOTAL THICKNESS OF LIMESTONES CONTAINING MODERATELY SALINE WATER (3,000 TO 10,000 mg/l TOTAL DISSOLVED SOLIDS) IN THE EDWARDS AND ASSOCIATED LIMESTONES IN THE SAN ANTONIO AREA, TEXAS



Well used for Control

○ 500 Number indicates total thickness

KEA Outcrop of Edwards and associated limestones, dotted where approximate

600 Isopach
Shows approximate total thickness of limestones containing moderately saline water in the Edwards and associated limestones

Contour interval 100 feet

Approximate boundary indicating subsurface extent of fresh to slighty saline water (less than 3,000 mg/l Total Dissolved Solids)

10,000 mg/l Approximate boundary indicating subsurface extent of moderately saline water

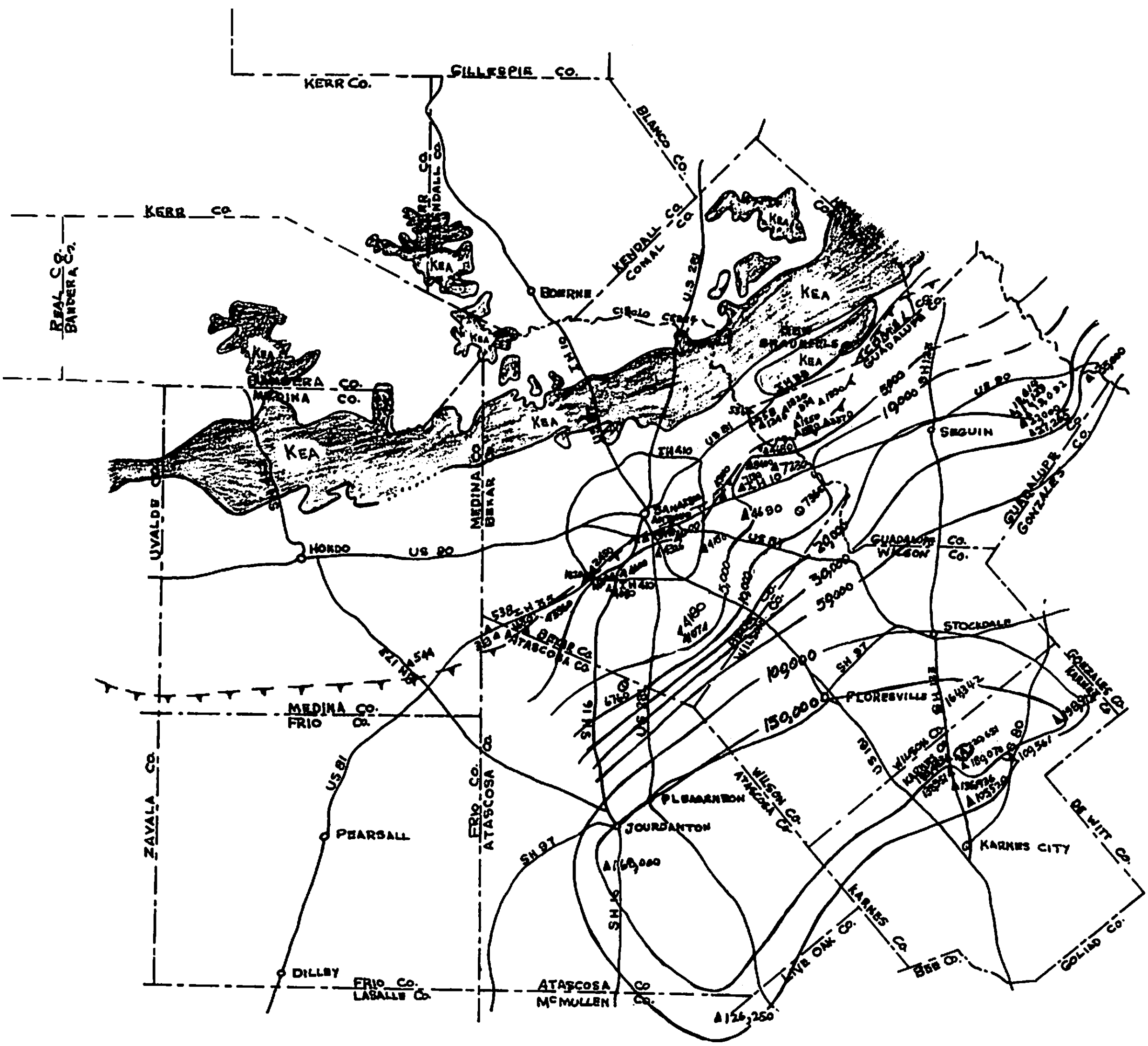


FIGURE 13

MAP SHOWING DISTRIBUTION OF TOTAL DISSOLVED SOLIDS OF WATER IN THE EDWARDS AND ASSOCIATED LIMESTONES IN THE SAN ANTONIO AREA, TEXAS

EXPLANATION

Well used for Control

⊙ 50,000 Number indicates concentration of approximate total dissolved solids calculated from spontaneous potential logs, in milligrams per liter (mg/l)

▲ 100,000 Total dissolved solids from reported data

KEA Outcrop of Edwards and associated limestones, dotted where approximate

—10,000— Line showing approximate concentration of total dissolved solids, in milligrams per liter (mg/l), dashed where lacking control data. Contour interval varies

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l total dissolved solids)

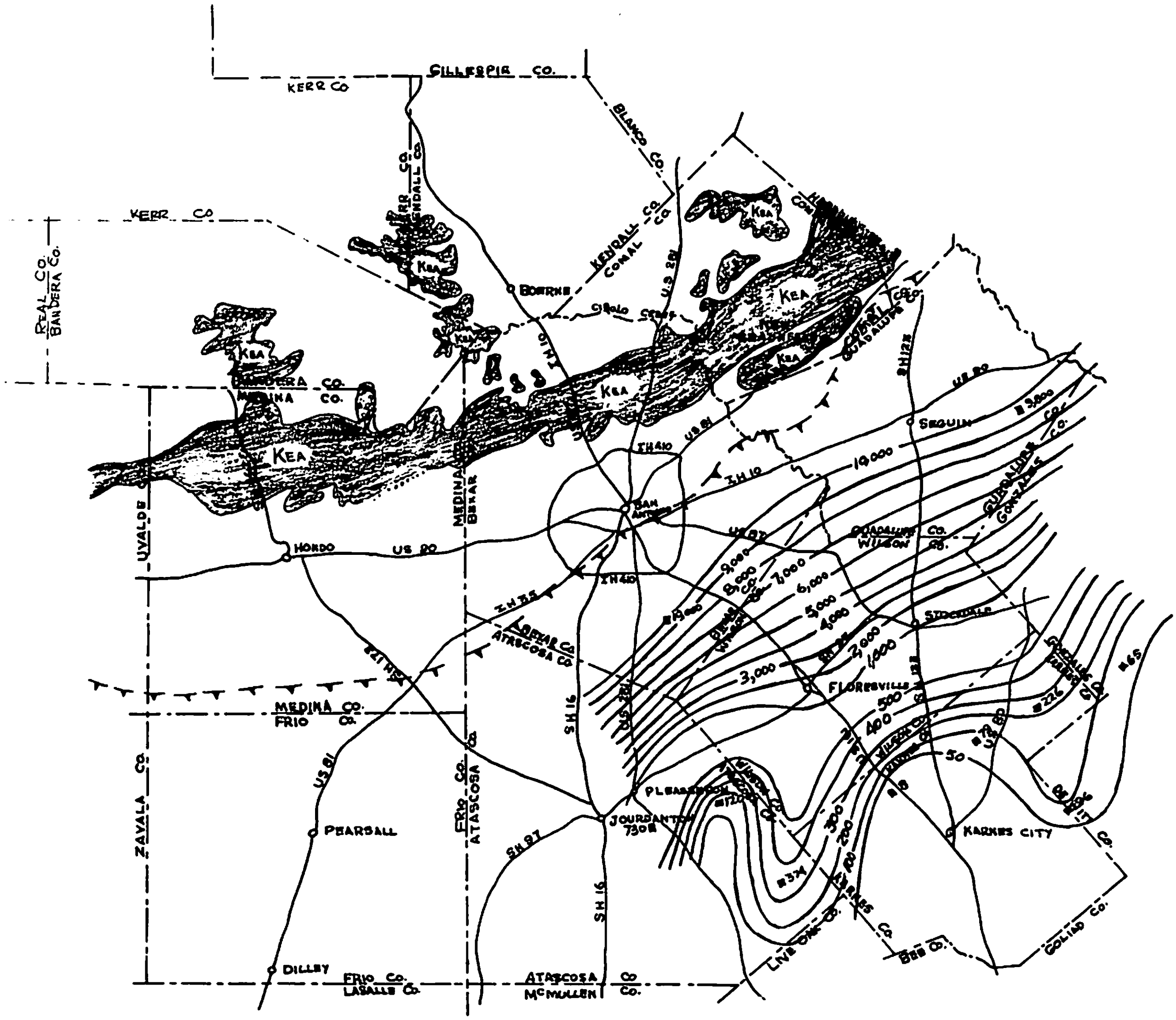


FIGURE 14

MAP SHOWING THE APPROXIMATE TOTAL TRANSMISSIBILTY OF THE EDWARDS AND ASSOCIATED LIME STONES IN THE SAN ANTONIO AREA, TEXAS

N

EXPLANATION

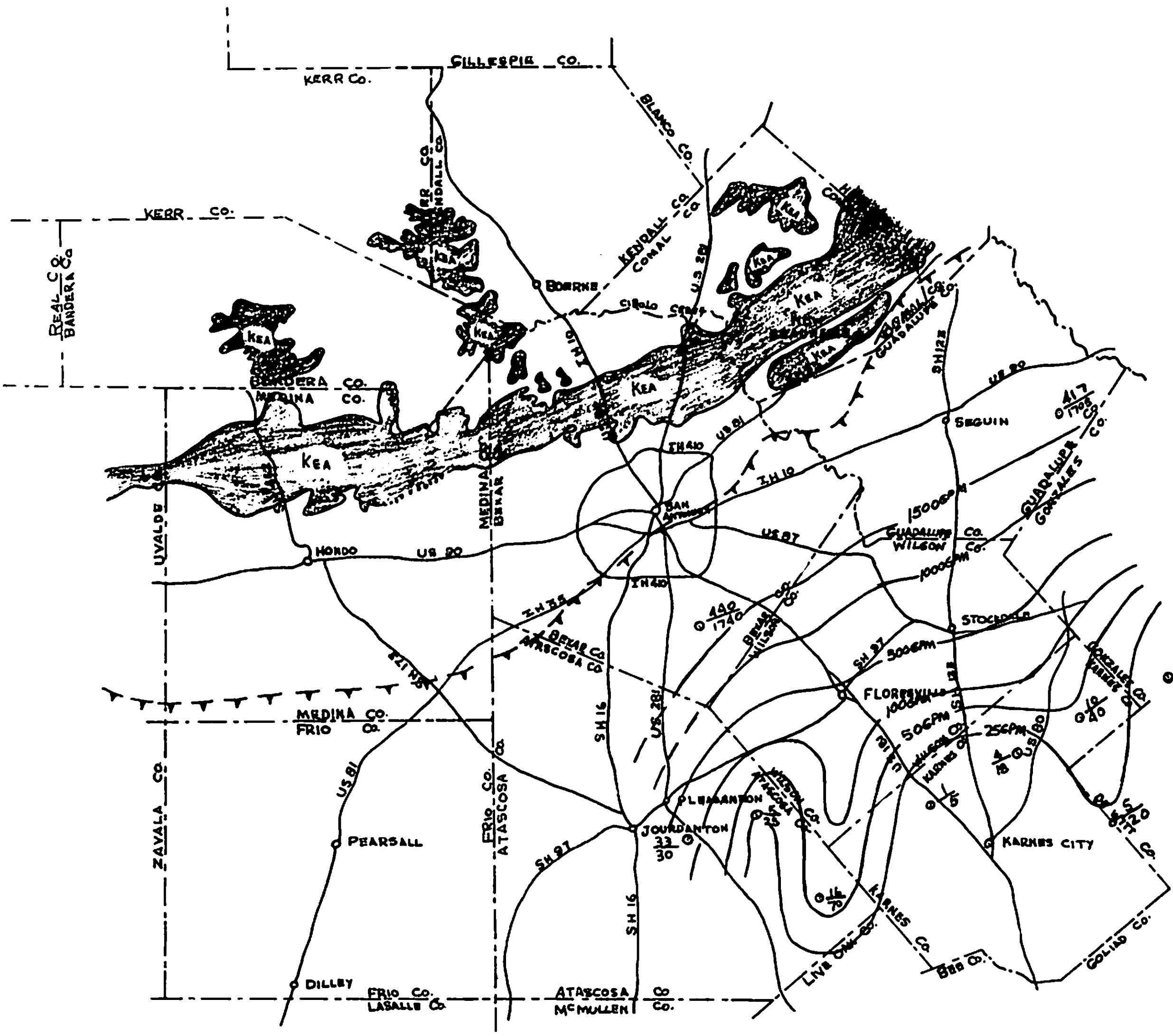
Well used for Control

■ 5,800 Number indicates approximate total transmissibility in GPD/FT

KEA : Outcrop of Edwards and associated limestones dotted where approximate

—5,000— Line shows approximate total transmissibility in GPD/FT Contour interval varies

T T T T Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3,000 mg/l Total Dissolved Solids)



EXPLANATION

Well used for Control

⊙ $\frac{5}{20}$ — 10 wells pumping for 100 years with 500ft drawdown; 1 well pumping for 100 years with 500ft drawdown

Kea: Outcrop of Edwards and associated limestones

500GPM — Line showing aquifer yield rate (GPM) for 1 well pumping 100 years with 500 ft. drawdown, dashed where lacking Control data. Contour interval varies

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3,000 mg/l Total Dissolved Solids)

FIGURE 15

MAP SHOWING THE IDEAL CALCULATED AQUIFER YIELD RATE FOR THE EDWARDS AND ASSOCIATED LIMESTONES AS A RESULT OF PUMPING 100 YEARS WITH 500 FEET OF DRAWDOWN IN THE SAN ANTONIO AREA, TEXAS

N

Scale 1:500,000

County	Total Dissolved Solids (mg/l)	Coefficient of Transmissibility (gpd/ft)	Aquifer Yield Rates Single Well Pumping 100 Yrs. With 500 Feet of Drawdown (gpm)
Comal	3,000 - 4,000	10,000 - 20,000	1,740 - 3,200
Frio	Greater than 10,000	- -	- -
Guadalupe	3,000 - 50,000	5,000 - 10,000	870 - 1,740
Karnes	100,000 - 220,000	8 - 500	5 - 90
Medina	3,000 - 10,000	10,000 - 20,000	1,740 - 3,200
Wilson	20,000 - 164,000	200 - 9,000	40 - 1,560

The following table summarizes the approximate amount of saline water in storage for the Edwards and associated limestones based on an artesian storage coefficient of 1×10^{-4} (0.0001) and water-table storage of 3 percent (0.03):

County	Water In Artesian Storage (acre-feet)	Water In Water-table Storage (acre-feet)	Total Water In Storage (acre-feet)
Atascosa	608,000	19,368,000	19,976,000
Bexar	65,000	5,000,000	5,065,000
Comal	1,000	92,000	93,000
Frio	427,000	18,643,000	19,070,000
Guadalupe	95,000	7,029,000	7,124,000
Karnes	597,000	11,791,000	12,388,000
Medina	45,000	3,269,000	3,314,000
Wilson	294,000	9,055,000	9,349,000

Glen Rose Formation

The Glen Rose Formation in the San Antonio area containing water greater than 3,000 mg/l of total dissolved solids consists of beds of moderately resistant, massive, and chalky limestones alternating with beds of less resistant marly limestone. The approximate depth to the top of the aquifer ranges from 500 feet (Bexar County) to 13,900 feet (Karnes County). The average thickness is 1,550 feet. The altitude and depth to the top of the Glen Rose Formation is illustrated in Figure 16 and the thickness is illustrated in Figure 17. Because of insufficient data, the water quality, transmissibility, and aquifer yield rates could not be determined for the Glen Rose Formation. The following table summarizes the approximate amount of saline water in storage for the Glen Rose Formation based on an artesian storage coefficient of 1 x 10^{-4} (0.0001) and water-table storage of 2 percent (0.02):

County	Water In Artesian Storage (acre-feet)	Water In Water-table Storage (acre-feet)	Total Water In Storage (acre-feet)
Atascosa	665,000	23,573,000	24,238,000
Bexar	119,000	12,090,000	12,209,000
Comal	3,000	545,000	548,000
Frio	480,000	23,244,000	23,724,000
Guadalupe	112,000	9,506,000	9,618,000
Karnes	611,000	12,176,000	12,787,000
Medina	138,000	13,192,000	13,330,000
Wilson	320,000	12,226,000	12,546,000

Travis Peak Formation

The Travis Peak Formation in the San Antonio area containing water greater than 3,000 mg/l of total dissolved solids is composed of limestone, sand, and shale. The approximate depth ranges from 1,700 feet (Guadalupe County) to 15,000 feet (Karnes County). The average thickness is 2,400 feet. The altitude and depth to the top of the Travis Peak Formation is illustrated in Figure 18 and the thickness is illustrated in Figure 19. Because of

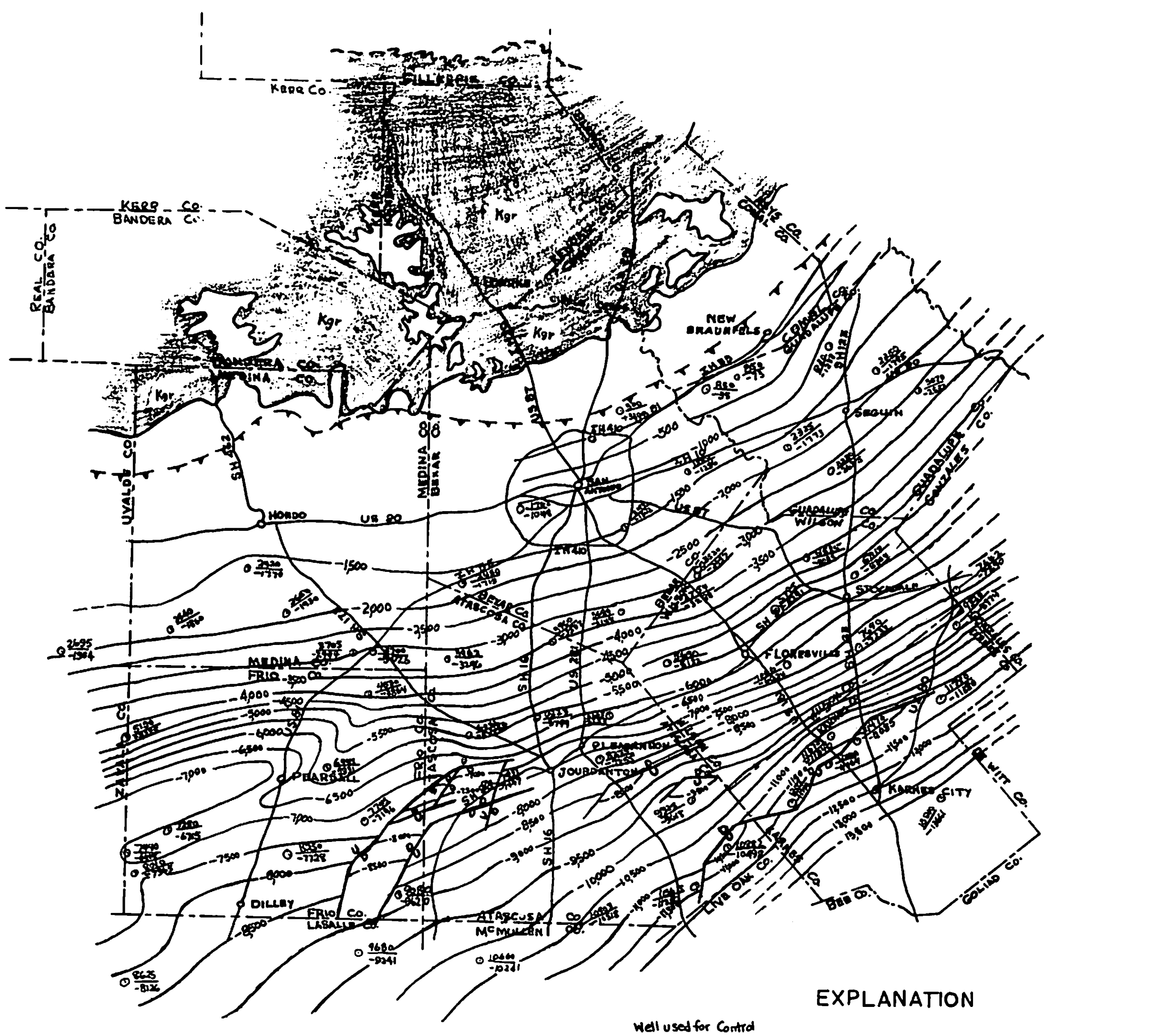


FIGURE 16

MAP SHOWING THE APPROXIMATE DEPTH TO AND ALTITUDE OF THE TOP OF MODERATELY SALINE TO BRINE WATER IN THE GLEN ROSE FORMATION IN THE SAN ANTONIO AREA, TEXAS

EXPLANATION

Well used for Control

1800 / -1200 — Depth to top of moderately saline to brine water; Elevation of top of moderately Saline to brine water

Kgr — Outcrop of Glen Rose Formation

U/D — Fault, dashed where approximate (Relative movement. U, Up; D, Down)

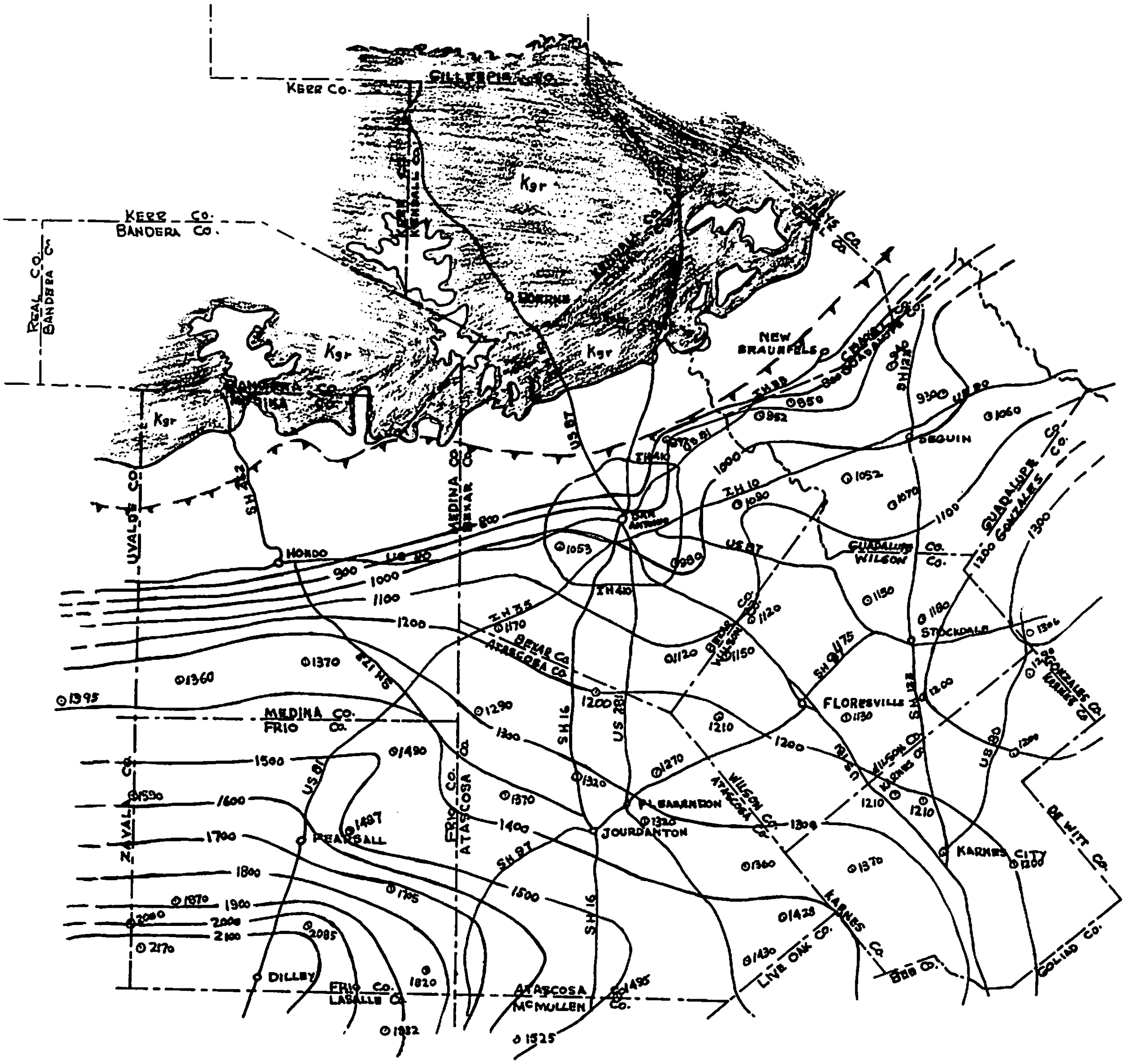
Water-interface Contour

-2500 — Showing approximate altitude of top of moderately Saline to brine water, dashed where lacking control data

Contour interval 500 ft.

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

Scale 1:500,000



EXPLANATION

FIGURE 17

MAP SHOWING THE APPROXIMATE TOTAL THICKNESS OF LIMESTONES CONTAINING MODERATELY SALINE TO BRINE WATER IN THE GLEN ROSE FORMATION IN THE SAN ANTONIO AREA, TEXAS

N

Well used for control

⊙ Number indicates total thickness

Kgr Outcrop of the Glen Rose Formation

—300— Isopach

Shows approximate total thickness of limestone containing moderately saline to brine water in the Glen Rose Formation, dashed where lacking control data

Contour interval 100 feet

Scale 1:500,000

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

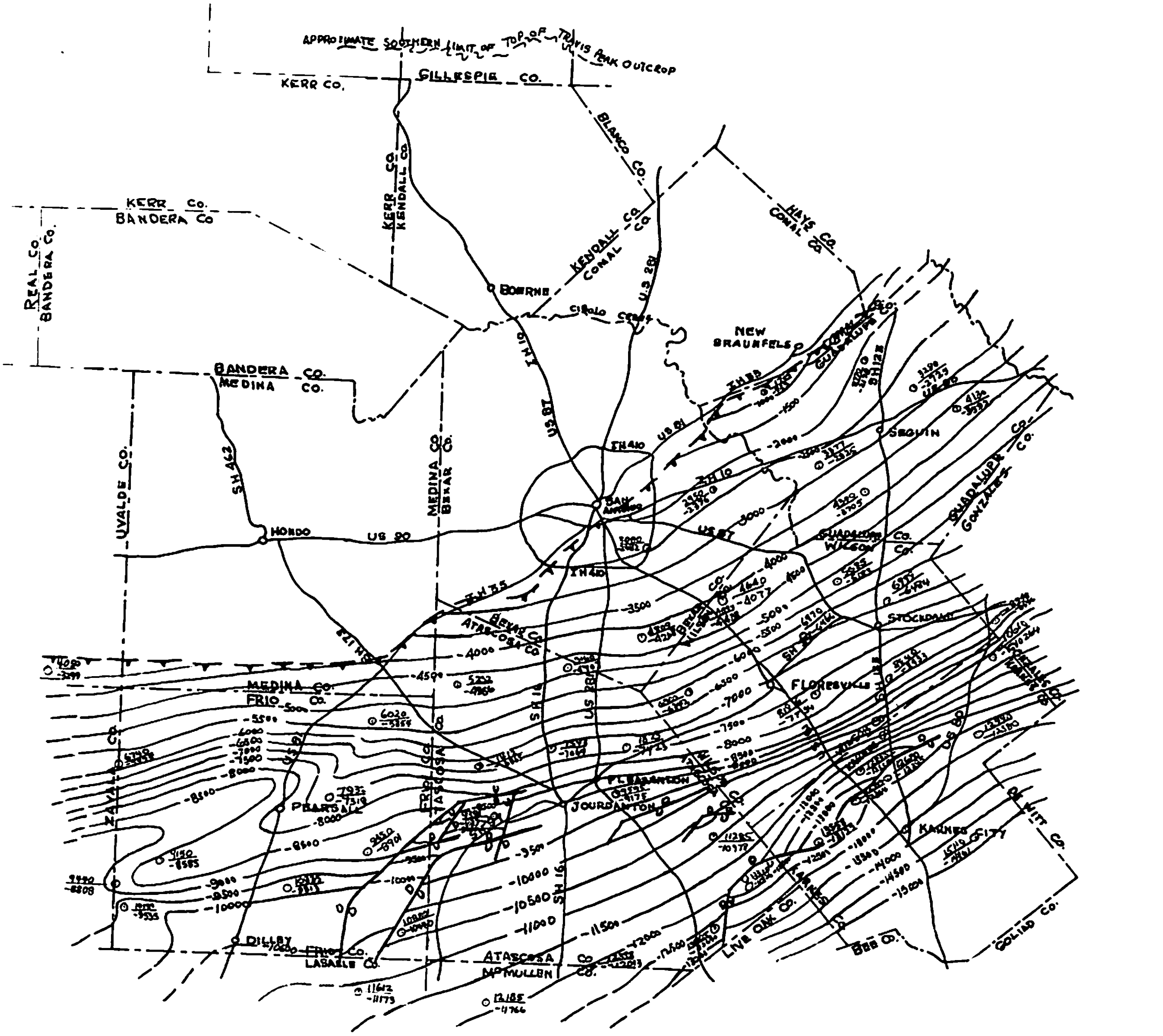


FIGURE 18

MAP SHOWING THE APPROXIMATE DEPTH TO AND ALTITUDE OF THE TOP OF MODERATELY SALINE TO BRINE WATER IN THE TRAVIS PEAK FORMATION IN THE SAN ANTONIO AREA, TEXAS

EXPLANATION

Well used for Control

o 4500 / -4200 Depth to top of moderately saline to brine water; Elevation of top of moderately saline to brine water

U / D Fault, dashed where approximate (Relative movement: U, Up; D, Down)

-4200 **Water-interface Contour** Showing approximate altitude of top of moderately saline to brine water, dashed where lacking control data

Contour interval 500ft.

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

N

Scale 1:500,000

0 1 2 3 4 5 10

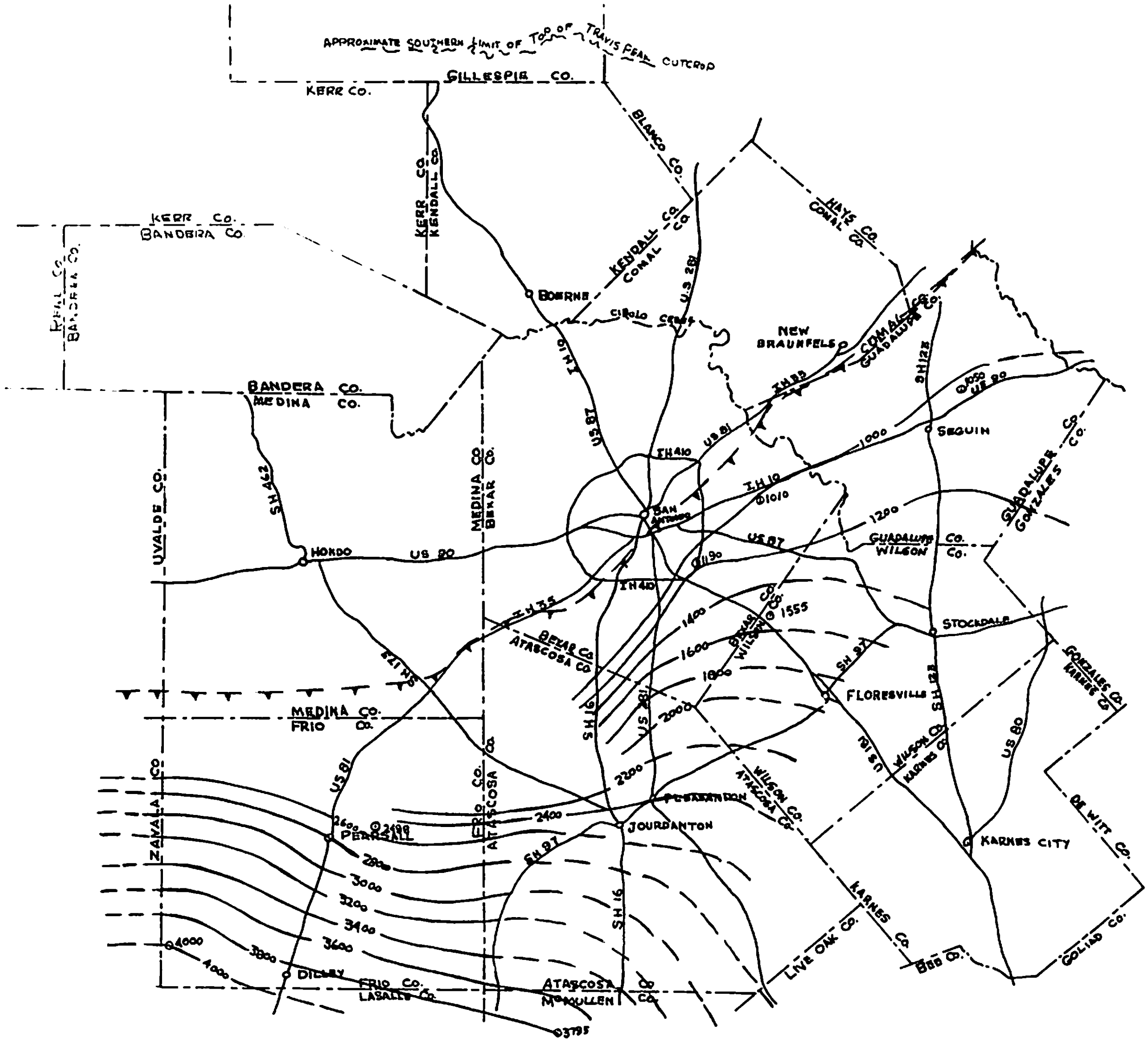


FIGURE 19

MAP SHOWING THE APPROXIMATE TOTAL THICKNESS OF STRATA CONTAINING MODERATELY SALINE TO BRINE WATER IN THE TRAVIS PEAK FORMATION IN THE SAN ANTONIO AREA, TEXAS

EXPLANATION

Well used for control

⊙ 200 Number indicates total thickness

Isopach

—2000— Shows approximate total thickness of strata containing moderately saline to brine water in the Travis Peak Formation, dashed where lacking control data

Contour interval 200 feet

Approximate boundary indicating subsurface extent of fresh to slightly saline water (less than 3000 mg/l Total Dissolved Solids)

Scale 1:500,000

insufficient data, the water quality, transmissibility, and aquifer yield rates could not be determined for the Travis Peak Formation. The following table summarizes the approximate amount of saline water in storage for the Travis Peak Formation based on an artesian storage coefficient of 1×10^{-4} (0.0001) and water-table storage of 2 percent (0.02):

County	Water In Artesian Storage (acre-feet)	Water In Water-table Storage (acre-feet)	Total Water In Storage (acre-feet)
Atascosa	768,000	39,322,000	40,090,000
Bexar	120,000	7,133,000	7,253,000
Comal	1,000	26,000	27,000
Frio	593,000	39,520,000	40,113,000
Guadalupe	161,000	7,416,000	7,577,000
Medina	46,000	589,000	635,000
Wilson	381,000	16,112,000	16,493,000

AVAILABILITY OF MODERATELY SALINE WATER

Moderately saline water (containing 3,000 to 10,000 mg/l of total dissolved solids) can be converted into fresh water by means of desalting. Desalting means demineralization to the extent that dissolved minerals are reduced well below 1,000 mg/l. The total cost of reducing dissolved solids from 2,500 mg/l to 500 mg/l in a plant that produces 100,000 gallons per day of fresh water is approximately $1.00 per 1,000 gallons (Johnson 1966).

The total amount of moderately saline water available from storage was determined for the Wilcox Group and Edwards and associated limestones; determinations were not made for the Austin Group, Glen Rose, and Travis Peak Formations due to insufficient data. The net sand thickness and downdip limits of moderately saline water in the Wilcox Group are illustrated in

Figures 4 and 5. The total thickness of limestones and downdip limits of moderately saline water in the Edwards and associated limestones are illustrated in Figures 12 and 13. The amount of water in storage was based on an artesian storage coefficient of 1×10^{-4} (0.0001) and a water-table storage coefficient of 5 percent (0.05) in the Wilcox Group and 3 percent (0.03) in the Edwards and associated limestones. The following table summarizes the approximate amount of moderately saline water in storage for each aquifer:

Wilcox Group

County	Water In Artesian Storage (acre-feet)	Water In Water-table Storage (acre-feet)	Total Water In Storage (acre-feet)
Atascosa	39,000	3,258,000	3,297,000
Frio	9,000	864,000	873,000
Karnes	21,000	2,851,000	2,872,000
Wilson	12,000	1,142,000	1,154,000

Edwards and Associated Limestones

County	Water In Artesian Storage (acre-feet)	Water In Water-table Storage (acre-feet)	Total Water In Storage (acre-feet)
Atascosa	16,000	171,000	187,000
Bexar	31,000	2,743,000	2,774,000
Comal	1,000	31,000	32,000
Guadalupe	16,000	1,567,000	1,583,000
Medina	21,000	1,219,000	1,240,000

WELL DESIGN

Proper well design involves selecting the right materials to be used in its construction. Good design assures an optimum combination of performance, long service life, and reasonable cost. Sound engineering practice requires that these objectives be considered together. Recommendations for proper construction and completion of limestone and sandstone saline wells in the San Antonio area are discussed in the following paragraphs.

A limestone saline aquifer requires the well to be drilled to the base of the aquifer thereby utilizing its maximum thickness. The well should be cased and cemented from ground level to the top of the aquifer. The casing selected should resist corrosion, deterioration, and collapse.

Wells completed in a saline sand aquifer should be cased from land surface to the top of the aquifer. To insure a long service life, the screen length should be based on optimum screen entrance velocities of less than two fpm (feet per minute). Other factors to be considered when determining screen length are the aquifer thickness, available drawdown, and stratification of the aquifer. Slot openings of the screen should be large enough to retain only about 40 percent of the aquifer material in order that the well may be developed naturally. The casing and screen should also be selected on their ability to resist corrosion, deterioration, and collapse.

Well completions are seldom 100 percent efficient even when the best construction methods are used. However, Figure 20 illustrates generalized computer-simulated cones of depression associated with an idealized artesian well field (10 wells at ½ mile spacing) pumping 100 years at a rate which produces drawdowns of approximately 500 feet. The computer analysis assumes all well completions are 100 percent efficient. Such an analysis can assist in obtaining maximum efficiency of ground-water withdrawal from an aquifer.

SUMMARY

Large quantities of saline water are available in the San Antonio area from aquifers which range in age from Cretaceous to Tertiary. These saline

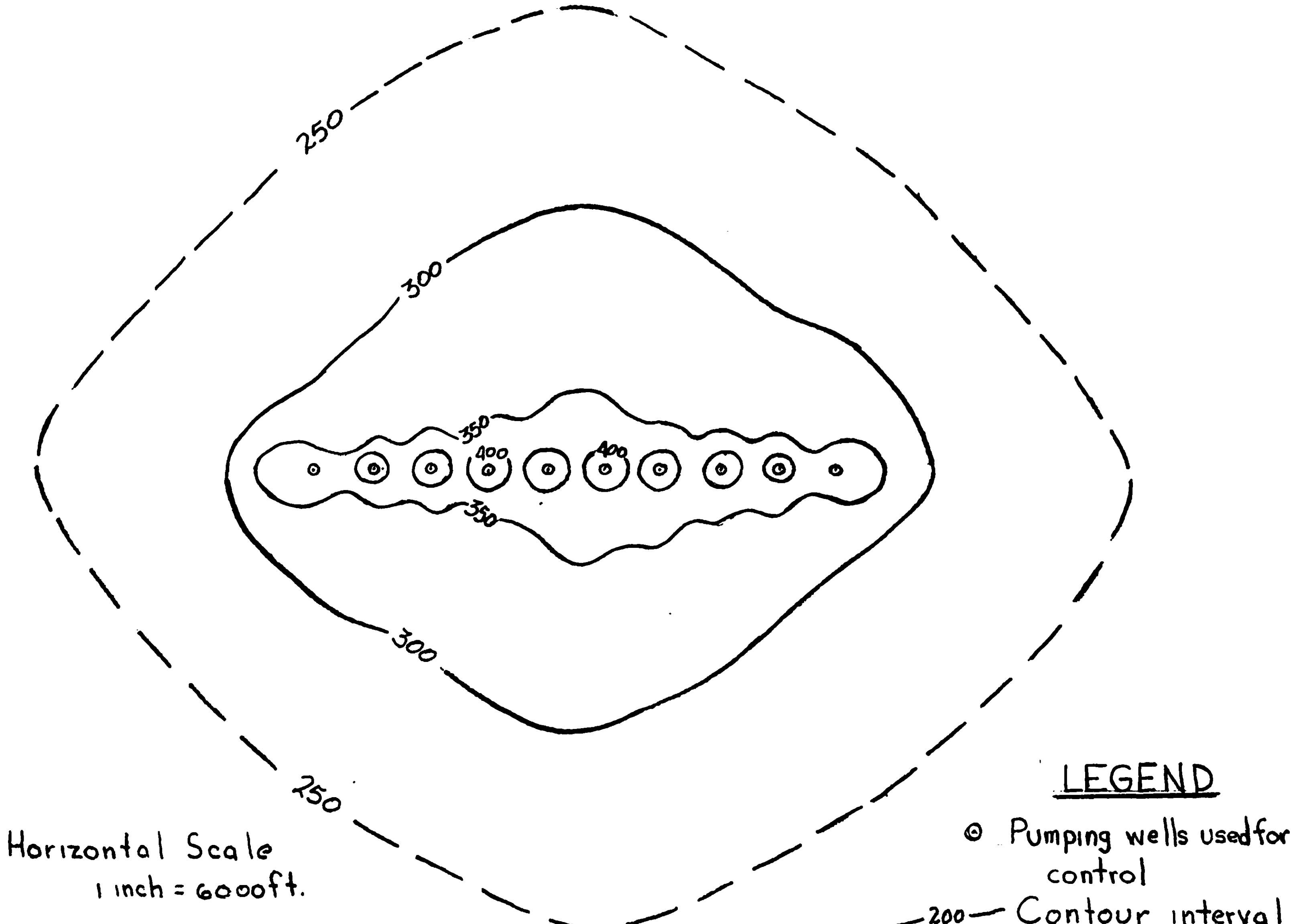


FIGURE 20

Idealized Map Illustrating Computer-Simulated Cones of Depression Associated with an Artesian Well Field Pumping 100 Years at a Rate which Produces Drawdowns of Approximately 500 Feet in the San Antonio Area, Texas aquifers contain the following amounts of water in artesian storage: (a) Wilcox Group - 387,000 acre-feet; (b) Austin Group - 1,927,000 acre-feet; (c) Edwards and associated limestones - 2,131,000 acre-feet; (d) Glen Rose Formation - 2,447,000 acre-feet; and (e) Travis Peak Formation - 2,066,000 acre-feet. At this time, saline water in water-table storage does not appear feasible to recover because of the great depths involved.

Moderately saline water (containing 3,000 to 10,000 mg/l of total dissolved solids) is available for demineralization from the above aquifers in order that it may be used for municipal, industrial, or agricultural applications. However, only the following aquifers were analyzed as to the amount of moderately saline water available from artesian storage: Wilcox Group - 81,000 acre-feet, and Edwards and associated limestones - 85,000 acre-feet.

Because the amount of water available for recovery from artesian storage would be small (10 to 50 percent), the extreme depths from which it must be recovered, the minimal yield rates, and the very high cost of development, it is doubtful the expenditure of large sums of money would be justified for the development of these aquifers.

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