TEXAS WATER DEVELOPMENT BOARD

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GROUND-WATER CONDITIONS OF THE TRINITY GROUP AQUIFER IN WESTERN HAYS COUNTY

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INTRODUCTION

This project was conducted to assist the people in western Hays County to understand the ground-water conditions in their area. Additionally, the Texas Water Development Board had scheduled an investigation of the area for 1987 in an effort to establish water-level and water-quality monitoring programs.

Purpose

The Board recognized that land-use conditions in western Hays County have changed from the basic rural agricultural ranch setting to residential developments which require additional public and domestic ground-water supply wells. The objectives of this limited investigation were to: (1) understand the existing ground-water resources of the Trinity Group aquifer in the study area, (2) compare current ground-water conditions to those of the past, (3) establish water-level and water-quality observation well programs which can be employed to monitor changes in ground-water conditions for resource planning purposes, and (4) evaluate and recommend additional work needed to keep abreast of residential growth and related ground-water conditions.

Scope

The area covered by this study is defined as that portion of Hays County west of the Edwards (Balcones Fault Zone) aquifer (Figures 1 and 2). The geology and the water-bearing characteristics of the aquifers in this region are briefly discussed to explain the nature of the ground-water supply (Table 1).

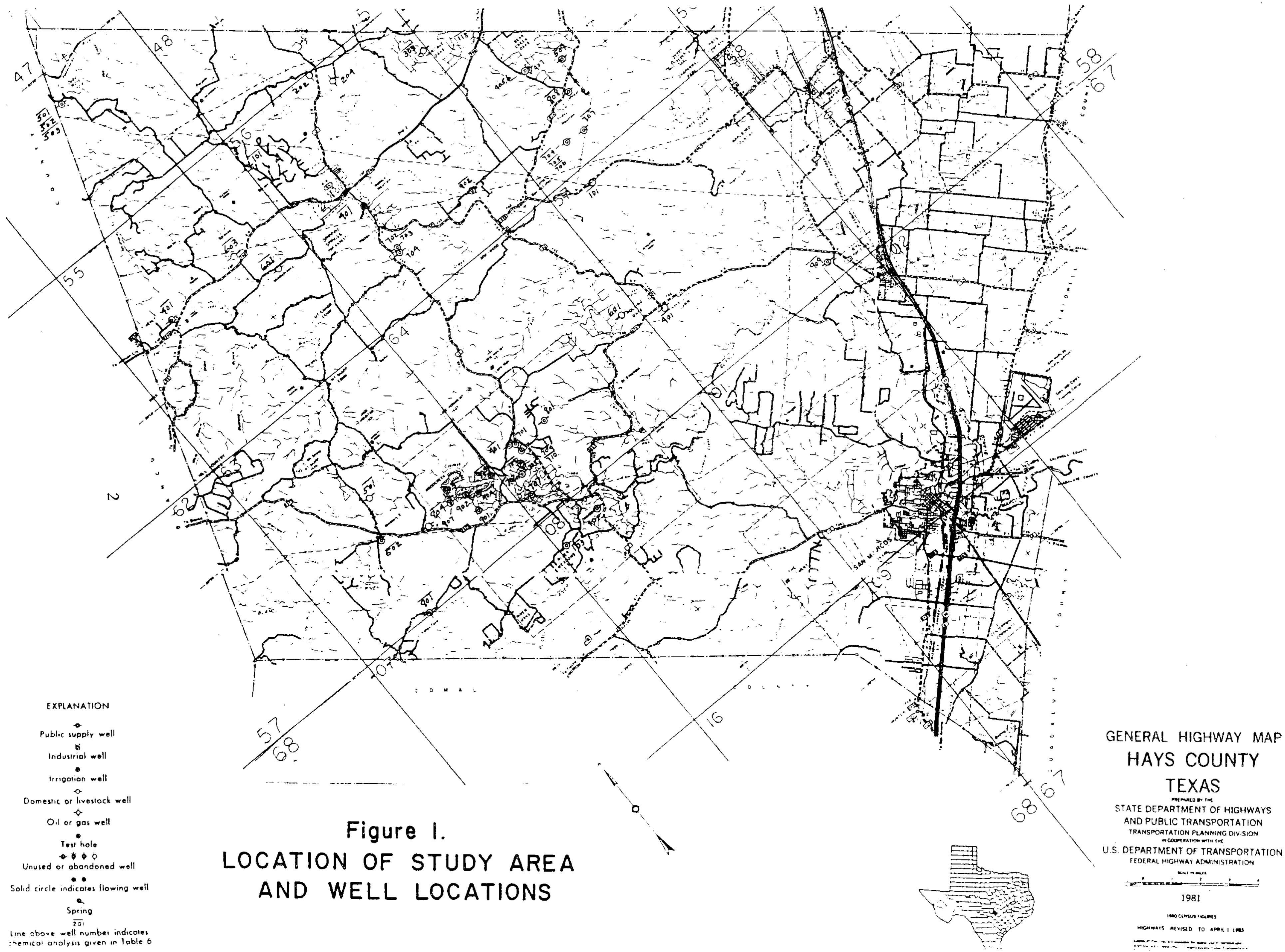


Figure 1.
LOCATION OF STUDY AREA AND WELL LOCATIONS

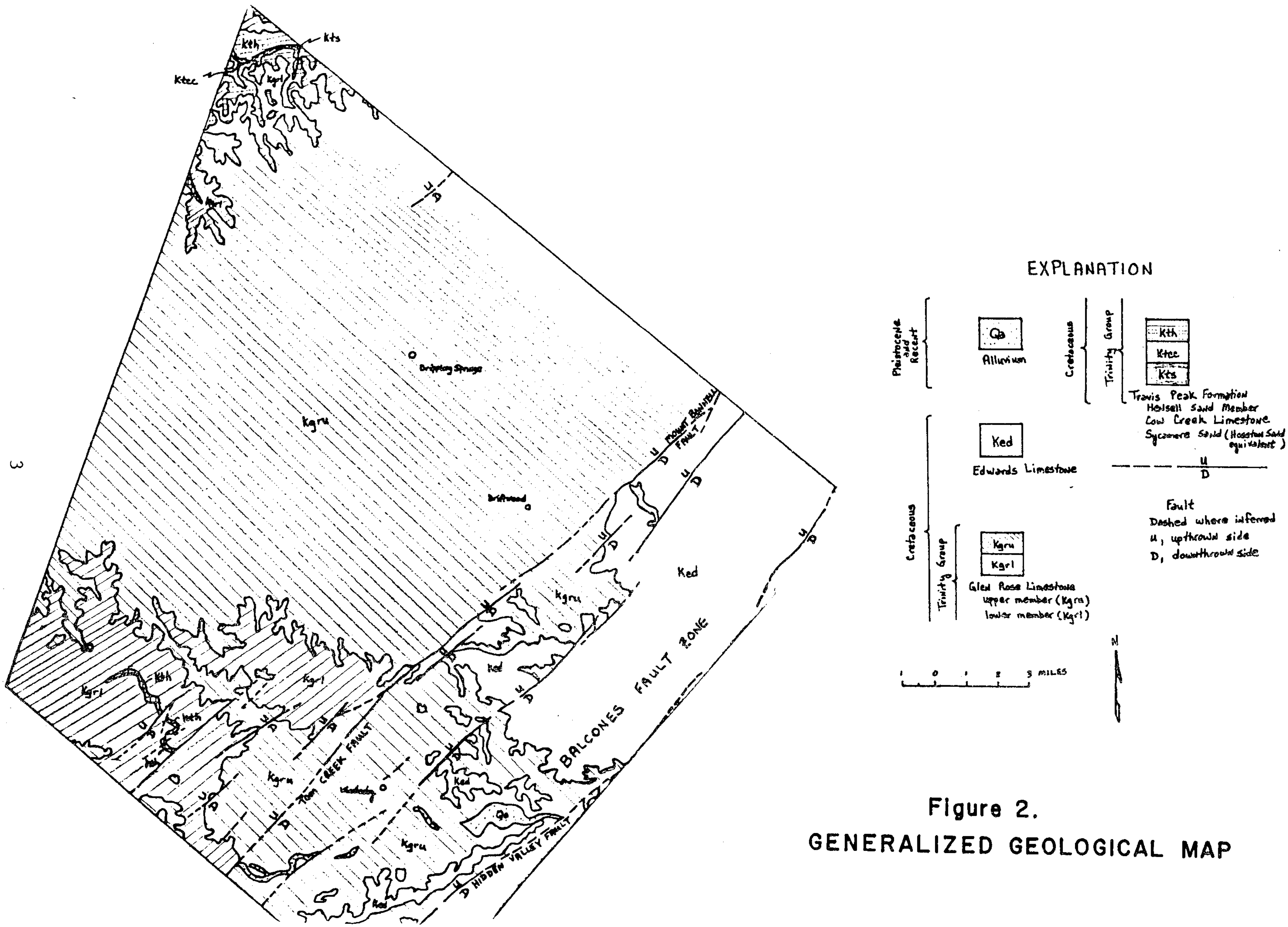


Figure 2.
GENERALIZED GEOLOGICAL MAP

Table 1.—Trinity Group Aquifer Stratigraphic Units and Their Water-Bearing Properties

System	Series	Group	Stratigraphic Unit		Hydrologic Unit	Approximate Maximum Thickness (feet)	Character of Rocks	Water-Bearing Properties
Quaternary	Recent and Pleistocene		Flood plain, terrace, and fan alluvium		(A) Alluvium	50	Gravel, sand, silt, clay caliche.	Yields small quantities of fresh water.
Cretaceous	Comanche	Trinity	Glen Rose Formation	Upper Member	Upper Trinity	500	Alternating resistant and nonresistant beds of blue shale, nodular marl, and impure, fossiliferous limestone. Also contains two distinct evaporite zones.	Yields very small to small quantities of relatively highly mineralized water.
				Lower Member	Middle Trinity	320	Massive, fossiliferous limestone grading upward into thin beds of limestone, dolomite, marl, and shale. Numerous caves and reefs occur in the lower portion of the member.	Yields small to moderate quantities of fresh to slightly saline water.
			Travis Peak Formation	Hensel Sand Member		300	Red to gray clay, silt, sand conglomerate, and thin limestone beds.	
				Bexar Shale Member			Silty dolomite, marl, calcareous shale, and shaley limestone.	
				Cow Creek Limestone Member		90	Massive, fossiliferous, white to gray, argillaceous to dolomitic limestone with local thinly bedded layers of sand, shale, and lignite.	
				Hammett Shale Member		80	Dark blue to gray, fossiliferous, calcareous and dolomitic shale with thinly interbedded layers of limestone and sand.	Not known to yield water.
				Sligo Limestone Member	Lower Trinity	120	Sandy dolomitic limestone.	Yields small to large quantities of fresh to slightly saline water.
				Hosston Sand Member		350	Red and white conglomerate, sandstone, claystone, shale dolomite, and limestone.	

Also, ground-water quality is an important factor when considering water supply for public and domestic use.

Historical ground-water hydrological information is a necessary element in planning future water supplies; therefore, a water-level and water-quality monitoring well network was established. Selected historical water-level and water-quality data are included in this report for comparison with the current work.

Growth Trends

Beginning in the late 1960's and early 1970's, resort and residential development increased in the Wimberley area. Several public supply and irrigation wells were drilled to provide water for the seasonal influx in population and watering of a golf course. Additional developments have continued to the present time in the Wimberley area as well as throughout western Hays County, primarily in the Dripping Springs area and in areas adjacent to FM 1826. In some of these developments, public supply wells were drilled to provide water for the entire development while in other developments each buyer drilled individual domestic wells. This report includes the public supply wells and selected domestic wells which were inventoried to supplement areal coverage.

Previously Published Ground-water Reports on Hays County

Previous reports describing the geology and ground-water hydrology of Hays County are as follows:

1. Hays County, Texas: Records of Wells and Springs, Driller's Logs, Water Analyses and Map Showing Location of Wells, by B.A. Barnes, WPA Project 9864. Published in 1938, this report is an inventory of wells and springs in Hays County, Texas that was conducted during a three-month period in 1937. It is useful in that it provides historical water levels and chemical analyses to compare with those collected during this investigation.

2. Records of Wells in Hays County, Texas, by Kenneth J. DeCook and W.W. Doyel, Texas Board of Water Engineers Bulletin 5501. This report, published in 1955, includes all the data from the previous report and adds additional information collected from 1938 to 1954.

3. Records of Water-Level Measurements in Hays, Travis, and Williamson Counties, Texas, by C.R. Follett, Texas Board of Water Engineers Bulletin 5612. This report was published in 1956 and includes the data in the previous two reports as well as information collected from selected water-level observation wells.

4. Geology and Ground-Water Resources of Hays County, Texas, by Kenneth J. DeCook, Texas Board of Water Engineers Bulletin 6004. Published in 1960, this report is an excellent reference for the geology and ground-water hydrology of Hays County.

5. Ground-Water Availability of the Lower Cretaceous Formations in the Hill Country of South-Central Texas, by John B. Ashworth, Texas Department of Water Resources Report 273. Covering 11 counties,

this 1973 publication is a regional overview of the Trinity Group aquifer in an area that includes western Hays County.

Acknowledgements

The authors wish to thank Mrs. Jean O. Williams, Mrs. Margaret Bains, and Mr. Nugent Chamberlain for their cooperation and assistance in supplying information for this ground-water study. Appreciation is also expressed to the local landowners, water-supply superintendents, and municipal officials who aided by supplying information and assistance in the collecting of field data.

Messrs. Ron Mohr and John Derton, Engineering Technicians with the Texas Water Development Board and under the supervision of the authors, inventoried water wells, measured water levels, and collected water samples in the project area. Additionally, they tabulated and proofread much of the data presented in this report.

This report was prepared under the general direction of Tommy R. Knowles, Chief, Water Availability Data and Studies Section; Henry J. Alvarez, Head of the Ground Water Unit; and, Robert L. Bluntzer, Head, Ground-Water Unit Area 4, who supervised the work.

Well-Numbering System

The well-numbering system in this report, illustrated on Figure 3, was adopted by the Texas Water Development Board for statewide use. It was designed to identify, facilitate the location of, and avoid duplication of well numbers in present and future studies. The system is based upon the division of the State

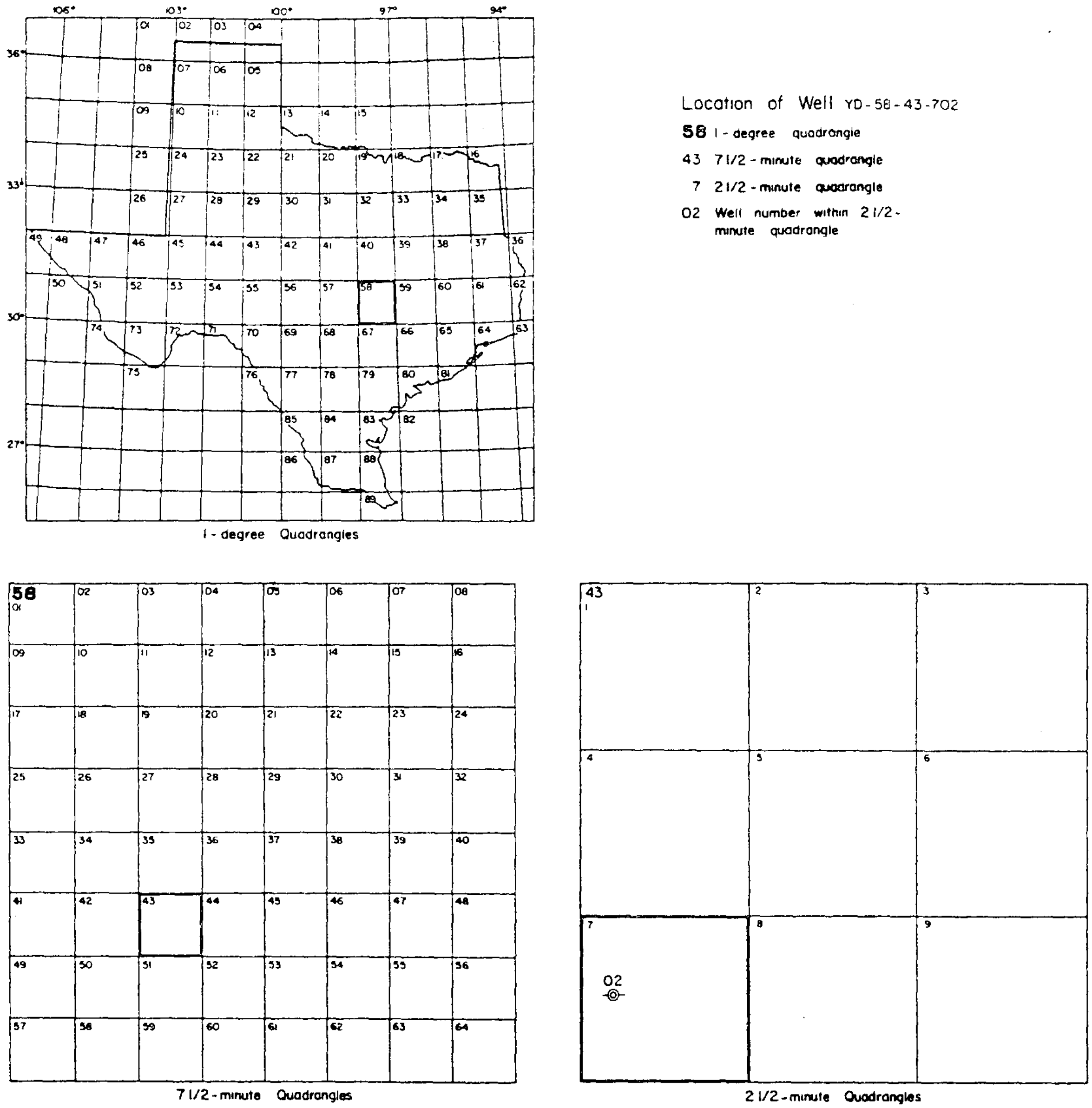


Figure 3.—Well-Numbering System

into quadrangles of latitude and longitude and the repeated division of these quadrangles into smaller ones.

The State is first divided into one-degree quadrangles which are numbered 01 through 89 (Figure 3). Each one-degree quadrangle is then subdivided into sixty-four 7 1/2-minute quadrangles. And lastly, each 7 1/2-minute quadrangle is subdivided into nine 2 1/2-minute quadrangles. Within each 2 1/2-minute quadrangle, each well is assigned a two-digit number usually in the sequence inventoried, beginning with 01 which are the last two digits of the well number.

Each well or spring is assigned a seven-digit number. The first two digits of a well number identify the one-degree quadrangle in which the well or spring is located. The second two digits identify the 7 1/2-minute quadrangle. The fifth digit identifies the 2 1/2-minute quadrangle and the sixth and seventh digits identify the particular well within the 2 1/2 minute quadrangle.

GENERAL HYDROLOGIC PRINCIPLES OF GROUND WATER AND DEFINITION OF TERMS

Hydrologic Cycle

For the benefit of the general reader, this section is included for familiarization of some basic ground-water hydrologic principles and terms.

Water available for use by man -- whether as rain, ground water from wells, or surface water from streams -- is captured in transit, and after its use and reuse, is returned to the hydrologic cycle illustrated in Figure 4. Graphically, this cycle shows the continuing movement of water from the oceans through evaporation to precipitation and its return, either directly or indirectly, to the ocean. Ground water is part of the returning water which has entered the subsurface and filled the void spaces of the porous rocks which are within the zone of saturation. The primary source of ground water is precipitation, and in general, only a small percentage of the precipitation actually becomes ground water by the process of recharge or effective recharge.

Occurrence

Ground water is contained in the interstices or void spaces of rocks. Two rock characteristics of fundamental importance related to the occurrence of ground water are porosity, which is the amount of open space contained in the rock; and permeability, the ability of the porous material to allow fluids to move through it. In sedimentary rocks, such as sandstone, gravel, clay, and silt; the porosity is a function of the size, shape, sorting, and degree of cementation of the grains (Figure 5). In limestones, another type of sedimentary rock, the porosity is a function of openings such as cracks,

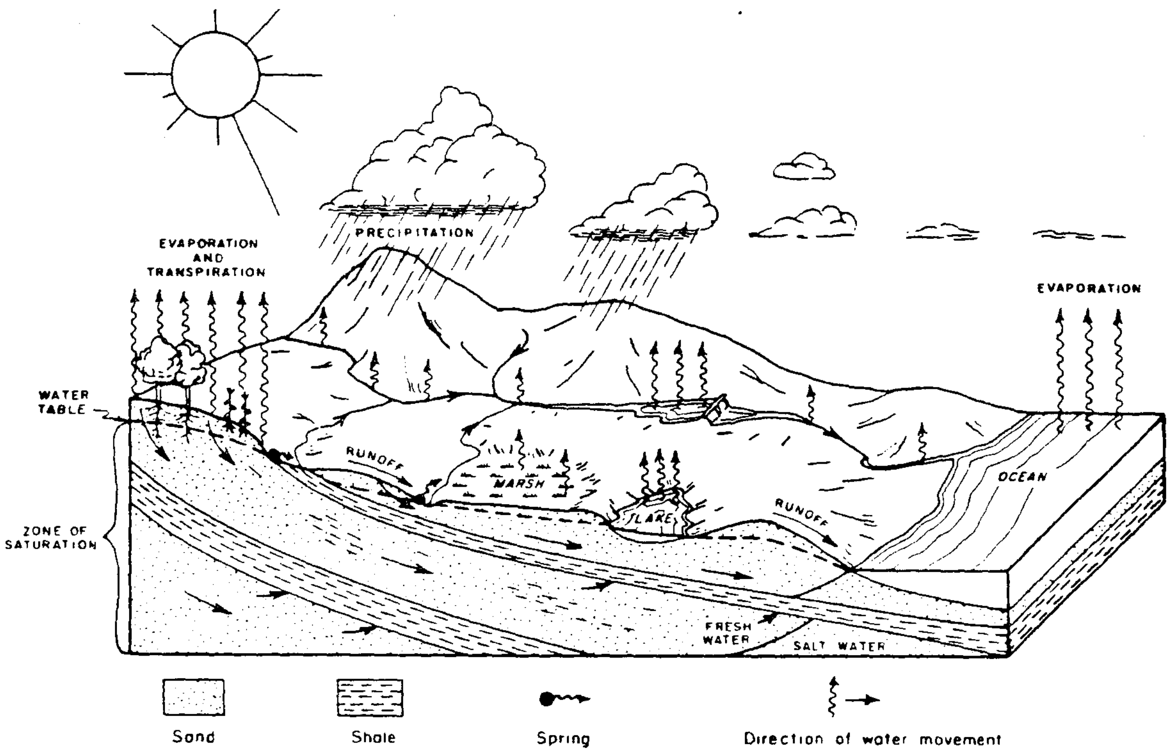
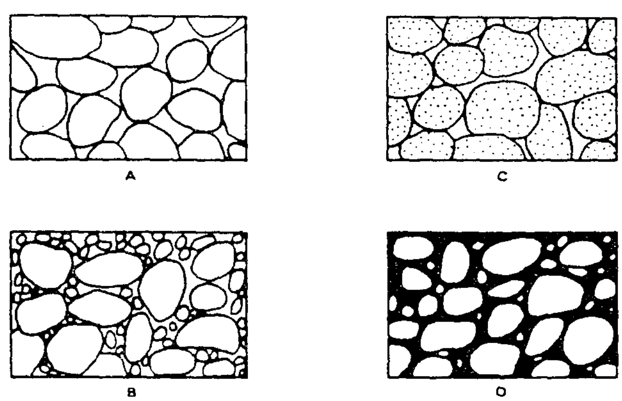


Figure 4. -Hydrologic Cycle



A. Well sorted sedimentary deposit having high porosity.

B. Poorly sorted sedimentary deposit having low porosity.

C. Well sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity.

D. Well sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter (cementation) in the interstices.

Figure 5. -Relationship of Rock Texture to Porosity
(Adapted from Meinzer, 1923, p. 3)

crevices, caverns, and vugs caused in part by dissolution of the limestone by ground water.

Fine-grained sediments, such as clay and silt, usually have high porosity, but due to the small size of the voids, the permeability is low and these formations do not readily yield or transmit water. Therefore, in order for a geologic formation to be a significant water-bearing unit, it must be porous and permeable and have significant water-saturated thickness. An aquifer consists of sufficient saturated porous and permeable rocks of a geologic formation, group of formations, or part of a formation that is water-bearing (Meinzer, 1923, p. 30). In general, to be an aquifer the water-bearing formation should yield water in sufficient quantities to afford usable production by wells; otherwise, the formation may be either an aquitard or aquiclude. An aquitard is a semipermeable, semiconfining geologic formation adjacent to or between aquifers which partially restricts the movement of ground water. A geologic unit of clay lenses interbedded with sands is characteristic of a leaky aquifer. Where clay is sufficiently thick, widespread, and impervious, the impediment to ground-water flow is greater, and therefore, confinement of the aquifer is greater; consequently, the formation is called an aquiclude. Considerable quantities of ground water can be stored in the clay interstices; but due to the clay's very low permeability, very little ground water can be produced by wells.

When precipitation falls on the outcrop of an aquifer, it may take one of many component courses in completing the hydrologic cycle. A large portion of it returns to the atmosphere by evaporation. Vegetation utilizes a part of it and returns moisture to the atmosphere by transpiration. A significant portion of the precipitation will be run off into streams and return to the sea. A small percentage will percolate downward into formations by the force of gravity to the zone of saturation in which the hydrostatic pressure in the water-filled interstices of the permeable rocks of the aquifer is equal to or greater than atmospheric pressure (Meinzer, 1923, p. 21). The upper surface of this zone is called the water table. Water entering the zone of saturation moves to lower elevations where it is discharged naturally, for example, by springs or artificially by wells. Above the zone of saturation, the rock interstices are partially filled by moisture and partially by air. This zone is known as the zone of aeration or vadose zone. Occasionally a local impermeable layer in this zone and above the main water table will intercept the downward percolating water, creating a locally isolated saturated zone above the main water table, thus causing a perched water table of limited areal extent.

An aquifer is under water-table or unconfined conditions when the ground water encountered by a well is in direct contact vertically with the atmosphere (Figure 4). The water table fluctuates with the atmospheric pressure and in response to changes in the volume of water in storage in the aquifer. In an unconfined aquifer, the zone of saturation extends from an underlying confining bed to the water table.

An aquifer is confined when the ground water contained in it is separated from the atmosphere by impermeable material of a confining bed and the water is under sufficient pressure to rise above the level at which it is encountered by a well. In this case, the water is under artesian conditions, whether it flows at the land surface or not, and the levels to which the water rises in well bores define an imaginary surface called the piezometric surface. For a confined or artesian aquifer, the zone of saturation represents complete saturation of the water-bearing formation and is equal to its thickness. The term potentiometric surface applies both to the piezometric surface of a confined aquifer and the water-table surface of an unconfined aquifer, coinciding with the hydrostatic pressure level of the water in the aquifer (Todd, 1959, p. 29; Lohman, 1972, p. 8).

A leaky aquifer system is a heterogeneous assemblage of interrelated permeable, poorly permeable, and relatively impermeable formations that function regionally as an aquifer. The system consists of two or more aquifers separated laterally and vertically by discontinuous aquitards.

The hydraulic gradient or pressure gradient of an aquifer is exemplified by the slope of the potentiometric surface. It is the rate of change of the hydrostatic pressure per unit distance in a given direction. If the rate of change is uniform between these two points, the hydraulic gradient between these points is the ratio of the difference in static level between the points to the horizontal distance between them (Meinzer, 1923, p. 38).

The hydrostatic pressure is that pressure exerted by the water at any given point in a body of water at rest. That of ground water is generally due to the weight of water at higher levels in the zone of saturation (Meinzer, 1923, p. 37).

The water-producing capability of an aquifer depends upon its ability to store and transmit water. Although the porosity of a rock is a measure of its capacity to store water, not all of this water in storage may be recovered by pumping. Some of the water stored in the interstices is retained because of the molecular attraction between the rock particles and the water. The coefficient of storage is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of hydrostatic pressure normal to that surface (Ferris and others, 1962, p. 74).

In confined or artesian aquifers, it is the result of two elastic effects -- compression of the aquifer and expansion of the contained water -- when the hydrostatic pressure is reduced by pumping. The value of the coefficient of storage is small, and it is dimensionless.

In an unconfined aquifer, the storage coefficient is also dimensionless and is assumed equal to the specific yield of the material. The specific yield measures the water drained from an aquifer by the force of gravity. It has been defined as the ratio of the volume of water which an aquifer, after being saturated, will yield by gravity to the volume of the aquifer drained. The ratio is usually expressed as a percentage (Meinzer, 1923, p. 28).

Recharge, Movement, and Discharge

Recharge is the addition of water to the storage of an aquifer and may be absorbed from precipitation, streams, and lakes, either directly into a formation or indirectly by way of another formation. Also, it may mean the quantity of water that is added to the zone of saturation (Meinzer, 1923, p. 46). Effective recharge is the amount of water that enters an aquifer and is available for development. Among the factors that influence the amount of recharge received by an aquifer are: the amount and frequency of precipitation, the areal extent of the outcrop or intake area, topography, type and amount of vegetation, and the condition of soil cover in the outcrop area, and the ability of the aquifer to accept recharge and transmit it to areas of discharge.

The quantity of water an aquifer receives as recharge and the ability of the aquifer to transmit water to the areas of discharge are the principal factors that must be considered in determining the amount of water available for withdrawal on a sustained basis. The coefficient of transmissivity provides an index of an aquifer's ability to transmit water. It is the amount of water that will flow at a hydraulic gradient or slope of 45 degrees through a vertical strip of the aquifer extending through the full saturated thickness and is expressed as gallons per day per foot, (gal/d)/ft. By using the coefficient of transmissivity, the amount of water that will flow through an aquifer under various hydraulic gradients can be determined. The coefficient of permeability is defined as the quantity of water, in gallons per day (gal/d) that will flow through a section of the aquifer 1 foot square under a hydraulic gradient of 45 degrees. The coefficient of permeability may be calculated by dividing the coefficient of transmissivity by the thickness of the aquifer.

Ground water moves from the areas of recharge to areas of discharge or from points of higher water level to points of lower water-level altitudes. Movement is in the direction of the hydraulic gradient just as in the case of surface-water flow. Under normal artesian conditions, movement of ground water usually is in the direction of the aquifer's regional geological dip. Under water-table conditions, the slope of the water table and consequently the direction of ground-water movement usually is closely related to the slope of the land surface. However, in the case of both artesian and water-table conditions, local anomalies are developed in areas of pumping and some water moves toward the center of artificial discharge. The rate of ground-water movement in an aquifer is normally very slow, being in the order of magnitude of a few feet to a few hundred feet per year.

Discharge is the loss of water from an aquifer. The discharge may be either artificial or natural. Artificial discharge takes place from flowing and pumped wells, drainage ditches, gravel pits, and other excavations that intersect the water table. Natural discharge occurs as effluent seepage, springs, evaporation, transpiration, and interformational leakage (Peckham, 1965, p. 18).

Fluctuations of Water Levels

Changes in water levels indicate a change in the ground-water storage of an aquifer. These changes can be due to many causes, some of regional significance whereas others are confined to more local areas. Basically, water-level fluctuations are caused by changes in recharge and discharge.

When recharge is reduced, as in the case of a drought, some of the water discharged from the aquifer must be withdrawn from storage resulting in a decline of water levels. If water levels are lowered excessively, springs and shallow wells may go dry. However, when sufficient precipitation resumes, the volume of water drained from storage during the drought may be replaced and water levels will rise accordingly. When a water well is pumped, the water level in the vicinity is drawn down to form a shape of an inverted cone with its apex located at the well. This cone of depression in the potentiometric surface is illustrated in Figure 6 and 7.

The development or growth of this cone depends on the aquifer's coefficients of transmissivity and storage. As pumping continues, the cone expands until it intercepts a source of replenishment capable of supplying sufficient water to satisfy the pumping demand. This source of replenishment can be either intercepted natural discharge or induced recharge. If the quantity of water received from these sources is adequate to compensate for the water pumped, the growth of the cone will cease and new balances between recharge and discharge are achieved. In areas where recharge or intercepted natural discharge is less than the amount of water pumped by wells, water is removed from storage in the aquifer and water levels will continue to decline.

Where intensive development has taken place in ground-water reservoirs, each well superimposes its cone of depression on the cone of neighboring wells. This results in the development of a regional cone of depression, when the cone of a well overlaps the cone of another, interference occurs and the lowering of water levels is compounded as the wells compete for water by expanding their cones of depression. Figure 7 illustrates the effect of interference between pumping wells. The amount or extent of interference between cones of depression depends on the rate of pumping from each well, the spacing between wells, and the hydraulic characteristics of the aquifer in which the wells are completed.

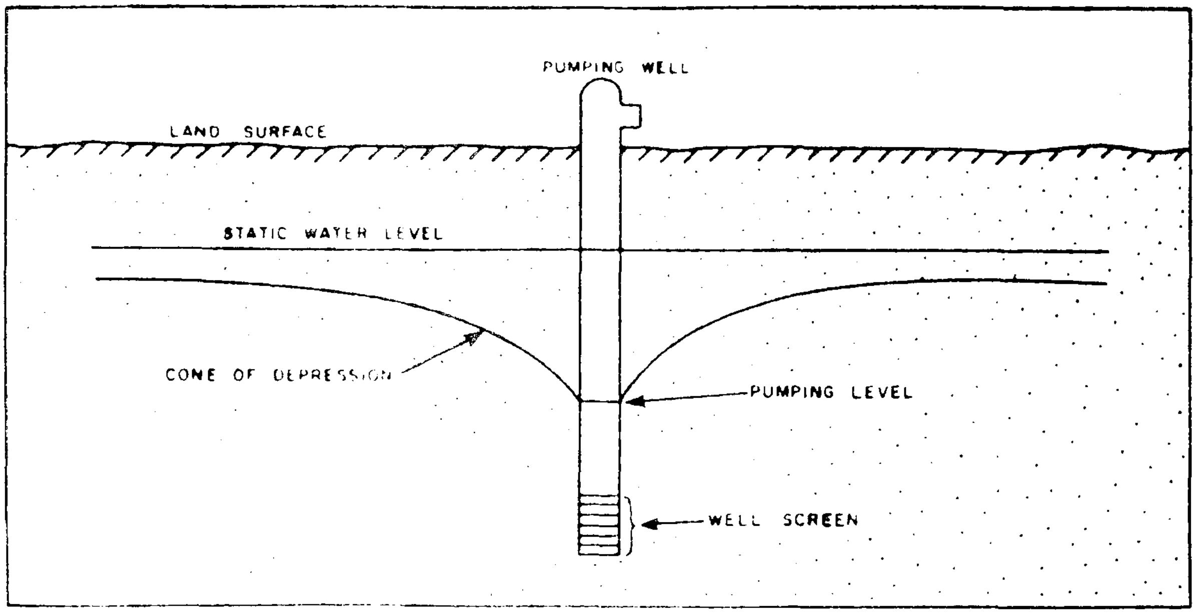


Figure 6.--Cone of Depression Caused by Pumping Well (Taken from Peckham, 1965)

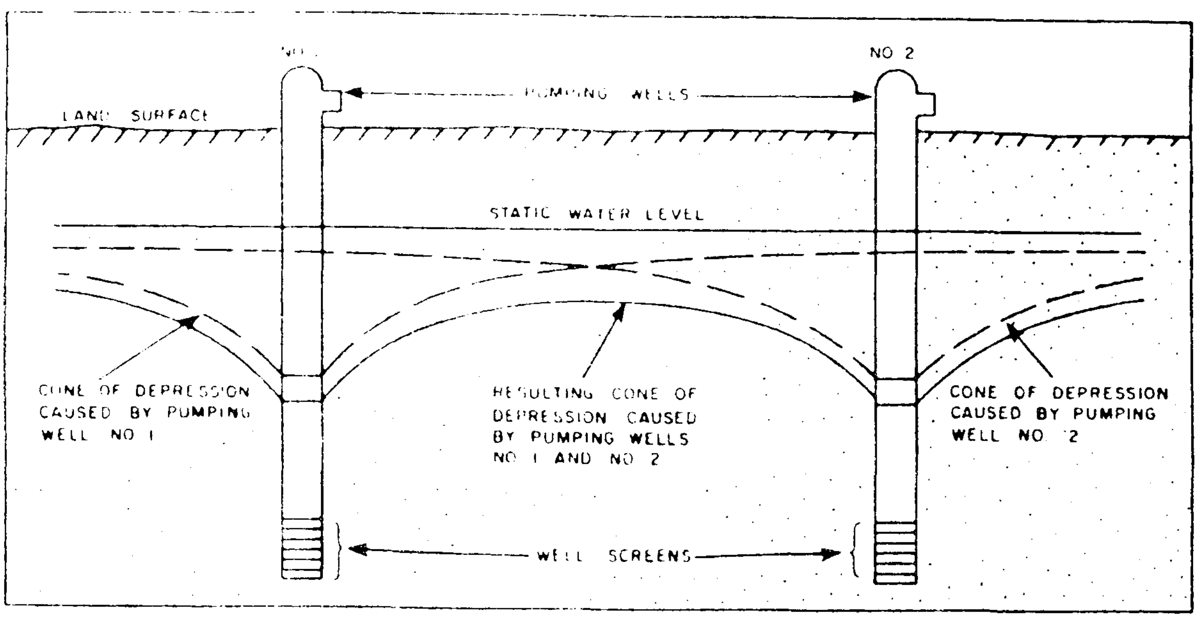


Figure 7.- Effects of Interference Between Two Pumping Wells (Taken from Peckham, 1965)

Chemical Quality of Ground Water as Related to Use

General Chemical Quality of Ground Water. All ground water contains minerals carried in solution, the type and concentration of which depend upon the environment, movement, and source of the ground water. Rainfall is relatively free of minerals until it comes in contact with the various constituents which make up the soils and component rocks of an aquifer; then, as a result of the solvent power of water, minerals are dissolved and carried into solution as the water passes through the aquifer. The concentration depends upon the solubility of the minerals present, the length of time the water is in contact with the rocks, and the amount of dissolved carbon dioxide in the water. In addition, concentrations of dissolved minerals in ground water generally increase with depth and especially increase where circulation has been restricted due to faulting or zones of lower permeability. Restricted circulation retards the flushing action of fresh water moving through the aquifers, causing the water to become more mineralized.

The source and significance of dissolved mineral constituents and properties of natural waters are given in Table 2. Chemical analyses of water from selected wells and springs in the study region are given in Table 5. The sampled wells and springs are indicated on the county well-location maps by a bar over the well number.

The degree and type of mineralization of ground water determines its suitability for municipal, industrial, irrigation, and other uses. Several criteria for water-quality requirements have been developed through the years which serve as guidelines in determining the suitability of water for various uses. Subjects covered by the guidelines are bacterial content; physical

Table 2.—Source and Significance of Dissolved-Mineral Constituents and Properties of Water

(Adapted from Doll and others, 1963, p. 39-43)

Constituent or property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 mg/l. High concentrations, as much as 100 mg/l, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 mg/l stain laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. Texas Department of Health (1977) drinking-water standards state that iron should not exceed 0.3 mg/l. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in oil-field brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon-dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Texas Department of Health (1977) drinking-water standards recommend that the sulfate content should not exceed 300 mg/l.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in oil-field brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. Texas Department of Health (1977) drinking-water standards recommend that the chloride content should not exceed 300 mg/l.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual (Maier, 1950, p. 1120-1132).
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater t an the local average may suggest pollution. Texas Department of Health (1977) drinking-water standards suggest a limit of 45 mg/l (as NO_3) or 10 (as N). Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding (Maxcy, 1950, p. 271). Nitrate has been shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.

Table 2.—Source and Significance of Dissolved-Mineral Constituents and Properties of Water—Continued

Constituent or property	Source or cause	Significance
Boron (B)	A minor constituent of rocks and of natural waters.	An excessive boron content will make water unsuitable for irrigation. Wilcox (1955, p. 11) indicated that a boron concentration of as much as 1.0 mg/l is permissible for irrigating sensitive crops; as much as 2.0 mg/l for semitolerant crops; and as much as 3.0 mg/l for tolerant crops. Crops sensitive to boron include most deciduous fruit and nut trees and navy beans; semitolerant crops include most small grains, potatoes and some other vegetables, and cotton; and tolerant crops include alfalfa, most root vegetables, and the date palm.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils.	Texas Department of Health (1977) drinking-water standards recommend that waters containing more than 1,000 mg/l dissolved solids not be used if other, less mineralized supplies are available. For many purposes the dissolved-solids content is a major limitation on the use of water. A general classification of water based on dissolved-solids content, in mg/l, is as follows (Winslow and Kister, 1956, p. 5): Waters containing less than 1,000 mg/l of dissolved solids are considered fresh; 1,000 to 3,000 mg/l, slightly saline; 3,000 to 10,000 mg/l, moderately saline; 10,000 to 35,000 mg/l, very saline; and more than 35,000 mg/l, brine.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All of the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness up to 60 mg/l are considered soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; more than 180 mg/l, very hard.
Sodium adsorption ratio (SAR)	Sodium in water.	A ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil (U.S. Salinity Laboratory Staff, 1954, p. 72, 156). Defined by the following equation: $SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$, Where Na^{+}, Ca^{++}, and Mg^{++} represent the concentrations in milliequivalents per liter (me/l) of the respective ions.
Residual sodium carbonate (RSC)	Sodium and carbonate or bicarbonate in water.	As calcium and magnesium precipitate as carbonates in the soil, the relative proportion of sodium in the water is increased (Eaton, 1950, p. 123-133). Defined by the following equation: $RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$ where CO_3^{--}, HCO_3^{-}, Ca^{++} and Mg^{++} represent the concentrations in milliequivalents per liter (me/l) of the respective ions.
Specific conductance (micromhos at 25°C)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
Hydrogen ion concentration (pH)	Acids, acid generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals. The Texas Department of Health (1977) recommends a pH greater than 7.

characteristics, including color, taste, odor, turbidity, and temperature; and the chemical constituents. Water-quality problems associated with the first two subjects can usually be alleviated economically. The neutralization or removal of most of the unwanted chemical constituents is usually difficult and often very costly.

Total dissolved-solids content is usually the main factor which limits or determines the use of ground water. Winslow and Kister (1956) used an excellent, and very applicable, general classification of waters based on the dissolved-solids concentration in parts per million (ppm). The classification is as follows:

Description	Dissolved-solids content (ppm)
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000

In recent years, most laboratories have begun reporting analyses in milligrams per liter (mg/l) instead of ppm. These two units, for practical purposes, are identical until the dissolved-solids concentration of water reaches or exceeds 7,000 units (ppm or mg/l). The concentrations of chemical constituents reported in this report are in mg/l. All of the chemical concentrations are below 7,000 mg/l; therefore, the units are interchangeable. For more highly mineralized waters, a density correction should be made using the following formula:

$$\text{parts per million} = \frac{\text{milligrams per liter}}{\text{specific gravity of the water}}$$

Public Supply. As the first step in setting national standards for drinking water quality under the provisions of the Safe Drinking Water Act of 1974, the U.S. Environmental Protection Agency (EPA) issued drinking water regulations on December 10, 1975. These standards apply to all of the public water systems of Texas and became effective June 1977. The responsibility for enforcement of these standards was assumed by the Texas Department of Health on July 1, 1977. Minor revision of the standards became effective on November 30, 1977.

As defined by the Texas Department of Health, municipal systems are classified as follows:

1. A "public water system" is any system for the delivery to the public of piped water for human consumption, if such a system has four or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

2. A "community water system" is any system which serves at least four or more service connections or regularly serves 25 permanent-type residents for at least 180 days per year.

3. A "non-community water system" is any public water system which is not a community water system.

Standards which relate to municipal supplies are of two types: (1) primary and (2) secondary. Primary standards are devoted to constituents and regulations affecting the health of consumers. Secondary standards are those which deal with the esthetic qualities of drinking water. Contaminants for which secondary maximum contaminant levels are set in these standards do not have a direct impact on the health of the consumers, but their presence in excessive quantities may discourage the use of the water.

1. Primary Standards. Primary standards for dissolved minerals apply to community water systems and are as follows:

Contaminant	Maximum Concentration (mg/l)
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.010
Chromium (Cr^6)	0.05
Fluoride (F)	4.0
Lead (Pb)	0.05
Mercury (Hg)	0.002
Selenium (Se)	0.01
Silver (Ag)	0.05
Nitrate (as NO_3)	45.0
Nitrate (as N)	10.0

Except for nitrate content, none of the above contaminant levels for toxic minerals applies to non-community water systems. The maximum of 10 mg/l nitrate as nitrogen (about 45 mg/l nitrate as NO_3) applies to community and non-community systems alike. Water having a concentration of nitrate (as NO_3) in excess of 45 mg/l poses a potential health hazard. A high concentration of nitrate is an indication of organic decomposition, usually within the source well. Steps should be taken to identify and rectify the source of the contamination.

Maximum contaminant limits for organic chemicals, as specified, apply to community water systems and are as follows:

Constituent	Maximum Concentration (mg/l)
1. Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6,7,-epoxy-1,4,4a, 5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimenthano napthalene).	0.0002
Lindane (1,2,3,4,5,6-hexachloro-cyclohexene, gamma isomer).	0.004
Methoxychlor (1,1,1-Trichloro-2,2-bis (p-methoxyphenyl] ethane).	0.1
Toxaphene ($C_{10}H_{10}Cl_8$ - Technical chlorinated camphene, 67-69 percent chlorine).	0.005
2. Chlorophenoxys:	
2,4-D (2,4-Dichlorophenoxyacetic acid).	.1
2,4,5-TP Silvex (2,4,5-Trichloro-phenoxypropionic acid).	.001

Maximum levels for coliform bacteria, as specified by the Texas Department of Health, apply to community and non-community water systems. The limits specified are basically the same as in the 1962 U.S. Public Health Service Standards which have been widely adopted in most states.

In addition to the previously stated requirements, there are also stringent rules regarding general sampling and the frequency of sampling which apply to all public water systems. Additionally, community water systems are subject to rigid radiological sampling and analytical requirements.

2. <u>Secondary Standards</u>. Recommended secondary standards applicable to all public water systems are given in the following table:

Constituent	Maximum level
Chloride (Cl)	300 mg/l
Color	15 color units
Copper (Cu)	1.0 mg/l
Corrosivity	non-corrosive
Fluoride (F)	2.0 mg/l
Foaming agents	0.5 mg/l
Hydrogen sulfide (H_2S)	0.05 mg/l
Iron (Fe)	0.3 mg/l
Manganese (Mn)	0.05 mg/l
Odor	3 Threshold Odor Number
pH	>7.0
Sulfate (SO_4)	300 mg/l
Dissolved Solids	1,000 mg/l
Zinc (Zn)	5.0 mg/l

The above secondary standards are recommended limits, except for water systems which are not in existence as of the effective date of these standards. For water systems which are constructed after the effective date, no source of supply which does not meet the recommended secondary standards may be used without written approval by the Texas Department of Health. The determining factor will be whether there is an alternate source of supply of acceptable chemical quality available to the area to be served.

After July 1, 1977 for all instances in which drinking water does not meet the recommended limits and is accepted for use by the Texas Department of Health, such acceptance is valid only until such time as water of acceptable chemical quality can be made available at reasonable cost to the area in question from an alternate source. At such time, either the water which was previously accepted would have to be treated to lower the constituents to acceptable levels or water would have to be secured from the alternate source.

Domestic. Ideally, waters used for rural domestic purposes should be as free of contaminants as those used for municipal purposes; however, this is not economically possible. At present, there are no controls placed on private domestic or livestock wells. In general, the chemical constituents of water used for domestic purposes should not exceed the concentrations shown in the following table except in those areas where more suitable supplies are not available (Texas Department of Health, 1977):

Substance	Concentration (mg/l)
Chloride (Cl)	300
Fluoride (F)	4.0
Iron (Fe)	0.03
Manganese (Mn)	0.05
Nitrate (as N)	10
Nitrate (as NO_3)	45
Sulfate (SO_4)	300
Dissolved solids	1,000

Many areas of south-central Texas do not have and cannot obtain domestic water supplies which meet the above recommended standards; however, supplies which do not meet these standards have been used for long periods of time without any apparent ill effects to the user. It is not generally recommended that water used for drinking purposes contain more than a maximum of 2,000 mg/l dissolved solids; however, water containing somewhat higher mineral concentrations has been used where water of better quality was not available.

Livestock. Generally, water used for livestock purposes is subject to the same quality limitations as those relating to drinking water for humans; however, the tolerance limits of the various chemical constituents as well as the dissolved-solids concentration may be considerably higher for livestock than that which is considered satisfactory for human consumption. The type of animal, the kind of soluble salts, and the respective amount of soluble salts determine the tolerance limits (Heller, 1933, p. 22). In the western United States, cattle may tolerate drinking water containing nearly 10,000 mg/l of dissolved solids providing these waters contain mostly sodium and chloride (Hem, 1970, p. 324). Water containing high concentrations of sulfate are usually considered undesirable for livestock use. Many investigators recommend an upper limit of dissolved solids near 5,000 mg/l as necessary for maximum growth and reproduction. Hem (1970, p. 324) cited a publication of the Department of Agriculture of the state of western Australia as recommending the following maximum upper limits for dissolved-solids concentration in livestock water:

Animal	Dissolved Solids (mg/l)
Poultry	2,860
Hogs	4,290
Horses	6,435
Cattle (dairy)	7,150
Cattle (beef)	10,000
Adult sheep	12,900

Water having concentrations of chemical constituents in excess of the Texas Department of Health's standards may be objectionable for many reasons. Brief explanations for these objections, as well as the significance of each constituent, are given in Table 2.

Irrigation. The suitability of ground water for irrigation purposes is largely dependent on the chemical composition of the water. The extent to which the chemical quality will affect the growth of crops is in part determined by the climate, soil, management practices, crop grown, drainage, and quantity of water applied.

Primary characteristics that determine the suitability of ground water for irrigation, according to the U.S. Salinity Laboratory Staff (1954), are: (1) total concentration of soluble salts, (2) relative proportion of sodium to other cations (magnesium, calcium, and potassium), (3) concentration of boron or other toxic elements, and (4) under some conditions, the carbonate and bicarbonate concentration as related to the concentration of calcium and magnesium. These have been termed respectively, the salinity hazard, the sodium (alkali) hazard, the boron hazard, and the bicarbonate ion hazard (U.S. Salinity Laboratory Staff, 1954, p. 69-82; Wilcox, 1955, p. 11-12; and Lyerly and Longenecker, 1957, p. 13-15).

A high concentration of soluble salts in irrigation water may cause a buildup of salts in the soil. Saline soils decrease the ability of plants to take up moisture and nutrients from the soil resulting in decreased yields. This salinity hazard is expressed in terms of specific conductance, measured in micromhos per centimeter at 25°C (77°F). In general, water having a conductance below 750 micromhos per centimeter is satisfactory for irrigation; however, salt-sensitive crops, such as strawberries and green beans, may be adversely affected by irrigation water having a conductance in the range of 250 to 750 micromhos per centimeter. Table 5 gives the specific conductance for selective water samples analyzed within the study area.

The physical condition of soil can be adversely affected by a high concentration of sodium relative to the concentration of calcium and magnesium in irrigation water. The sodium hazard is expressed as the sodium-adsorption ratio (SAR, see Table 5) which is the measurement of the relative activity of sodium ions in exchange reactions with soil. A high SAR in irrigation water affects the soil by forming a hard impermeable crust that results in cultivation and drainage problems. Under most conditions, irrigation waters having a percent sodium less than 60 (Table 5) and a low bicarbonate content are probably satisfactory. The sodium hazard becomes progressively greater as the sodium percentage increases above 60.

Boron is necessary for good plant growth, but rapidly becomes highly toxic at concentrations above acceptable levels. Maximum tolerable levels for various crops range from 1.0 to 3.0 mg/l (Scofield, 1936). High concentrations of boron are not known to be a problem within the study region. Consult Table 2 for specific crops and their tolerance ranges.

A concentration of bicarbonate in irrigation water often causes calcium and magnesium carbonate to precipitate from solution upon drying, which results in an increase in the proportion of sodium in solution. The effect of higher proportions of sodium has been previously discussed. Water containing 1.24 to 2.5 me/l (milliequivalents per liter) of residual sodium carbonate are considered marginal and those containing greater than 2.5 me/l probably are not suited for irrigation use (Wilcox, 1955).

Industrial. Chemical quality standards for ground water used for industrial purposes vary greatly with the type of industry utilizing the water. The primary concern with many industries is that the water does not have constituents that are corrosive or scale-forming. Also of concern are those minerals that affect color, odor, and taste; therefore, water with a high content of dissolved solids is usually avoided. Table 2 lists the effect that most of the minerals have on industrial usage.

Treatment of Water. When ground water does not meet specific requirements for usage, various methods of treatment can be implemented to alter the chemical composition. Such treatments include softening, aeration, filtration, cooling, dilution, the addition of chemicals and reverse osmosis. The type of treatment is dependent on the particular problem; however, the primary limiting factor is economics.

Additional Terms Defined

Not discussed in the previous section but nevertheless pertinent to this report are terms that necessitate definition.

In an unconfined aquifer, total storage or underground reservoir capacity is the volume of ground water occupying void spaces in the rock which can be recovered by gravity drainage. In a confined aquifer, total storage includes the artesian (pressure) storage and water stored in the pore spaces of the water-bearing formation. Water may be withdrawn from storage at a rate greater than the effective recharge. Under this condition, water levels will decline, storage will decrease, and if continued, recoverable storage will be depleted, but only if sufficient amounts of adequately located wells are established to withdraw the water.

GENERAL GEOLOGY OF WESTERN HAYS COUNTY AND THE WATER-BEARING UNITS OF THE TRINITY GROUP AQUIFER

Sedimentary rocks of the Cretaceous and Quaternary systems occur on and immediately below the land surface in western Hays County. The Cretaceous age strata are underlain by older basement rocks of Paleozoic age that were deformed and metamorphosed in places and exposed to subaerial erosion (Barnes, 1948). At the beginning of the Cretaceous Period, the Paleozoic strata in the study area formed an eroded, uneven, and faulted surface known as the Comanche shelf that sloped southeastward through what is now Hays County away from the uplifted Llano area (Ashworth, 1983). It was upon this irregular pre-Cretaceous surface that the Trinity Group, the water-bearing formations covered in this study, were deposited (Table 1).

The entire depositional history of the Trinity Group is that of a landward transgression of the sea from the southeast, interrupted by short seaward regressions. The rocks of the Llano Uplift Region were the primary source of the sediments deposited during this period. The Trinity Group sediments were deposited in wedge-like, overlapping sequences that thicken southeastward and pinch out on the Llano uplift due to the pre-Cretaceous topographic high and erosional truncation (Ashworth, 1983).

The eastern portion of the study area includes part of the Balcones Fault Zone. This zone is comprised of numerous faults, more or less parallel to one another, which strike generally north-northeastward. Some of these faults act as ground-water barriers which control ground-water movement in the direction of the strike of the faults. Other faults may transmit water, particularly where the Glen Rose Formation is in contact with the Edwards and associated limestones (Ashworth, 1983).

The Trinity Group of Cretaceous age is the most important water-bearing unit in western Hays County. It crops out west of the Balcones Fault Zone which is delineated southeast of Wimberley by the Hidden Valley Fault and east of Driftwood by the Tom Creek Fault that is continuous with the Mount Bonnell Fault (Figure 2). In the eastern portion of Hays County, the Trinity Group is overlain by the younger rocks of the Edwards and associated limestones, also of Cretaceous age. The Trinity Group is divided into two stratigraphic units: the older Travis Peak Formation and the younger Glen Rose Formation (Table 1).

In western Hays County, the Travis Peak Formation is composed of five members from oldest to the youngest: (1) Hosston Sand, (2) Sligo Limestone, (3) Cow Creek Limestone, and (4) Hensell Sand which changes downdip, and becomes (5) the Bexar Shale. The Hammett Shale is an aquiclude which is above the Sligo/Hosston members. Overlying the Travis Peak Formation is the Glen Rose Formation which is divided into the Lower and Upper Glen Rose members (Table 1, Stratigraphic Units). Together these geologic water-bearing rocks make up a leaky aquifer system called the Trinity Group aquifer.

The Trinity Group aquifer is separated into the Lower, Middle, and Upper Trinity aquifers (Table 1, Hydrologic Unit). Each of these aquifers has a characteristic hydrostatic pressure head or water level. The Lower Trinity aquifer has the lowest hydrostatic head while the Middle and Upper Trinity aquifers have respectively higher heads. From a ground-water hydrologic perspective, this can be interpreted to mean that ground water moves at a very slow rate downward through the low-permeable strata (aquitards) to aquifers beneath. This is a semi-confined and or leaky aquifer system.

In order to identify the hydrostatic head characteristic of each aquifer, water wells must be properly cased, cemented, and completed at the proper depth interval to properly represent the depth interval and head of the aquifer. For example, water wells 57-56-902 and 58-49-509 are reported to be cased to 700 and 685 feet respectively and have open hole completion to total depths at 1,000 and 1,060 feet respectively (Table 3). The water levels of these two wells are lower than other water levels in the area and represent the hydrostatic pressure head of the Lower Trinity aquifer composed of the Hosston Sand. Further inspection of Table 3 indicates that most of the wells listed are open hole completion. This is unfortunate since it is not possible to differentiate the heads of the three Trinity Group aquifers from the water levels measured during this investigation. One can only assume that in the case of an open hole completion the water level measured represents the shallowest aquifer encountered and that the aquifer(s) designation must depend on well depth only.

Under the water-bearing properties in Table 1, well yields are rated according to the following:

Description	Yield (gallons per minute)
Very small	0 - 5
Small	5 - 20
Moderate	20 - 100
Large	More than 100

Table 3.--Relationship of Well Completion, Depth, and Water Level in the Trinity Group Aquifer

Aquifers: Kce, Edwards and Associated Limestones; Kct, Trinity Group; Kcgr, Glen Rose Limestone; Kcgru, upper member of the Glen Rose Limestone; Kcgrl, lower member of the Glen Rose Limestone; Kche, Hensell Sand Member of the Travis Peak Formation; Kccc, Cow Creek Limestone Member of the Travis Peak Formation; Kcs, Sligo Limestone Member of the Travis Peak Formation; Kcho, Hosston Sand Member of the Travis Peak Formation

Well	Elevation Above Sea Level in Feet: Land Surface	Elevation Above Sea Level in Feet: Water Level	Elevation Above Sea Level in Feet: Bottom Well	Well Depth in Feet	Aquifer	Area	Well Completion
57-55-401	1,327	1,038	867	460	Kcgrl,Kche	Henly	Csg set from +2-460'
601	1,130	1,008	790	340	Kcgrl,Kche Kccc	Henly	
603	1,370	1,038	890	480	Kcgrl,Kche	Henly	Open hole from 220-480'
56-101	1,250	930	750	500	Kcgr,Kche	North of Dripping Springs	Open hole from 20-500'
202	1,121	1,034	756	365	Kcgr	North of Dripping Springs	Open hole from 20-365'
204	1,145	941	693	452	Kcgr	North of Dripping Springs	Open hole from 44-452'
303	1,180	805	574	606	Kcgrl	Heritage Oaks	Csg set from 0-606'
702	1,030	985	685	945	Kcgru,Kcgrl	South of Dripping Springs	Open hole from 45-345'
703	1,030	956	210	820	Kcgrl,Kccc Kcho	South of Dripping Springs	Slotted from 315-690'
704	1,065	957	685	380	Kcgrl	South of Dripping Springs	Open hole from 288-380'
902	1,010	726	10	1,000	Kcs,Kcho	Two miles north of Driftwood	Open hole from 700-1,000'
63-501	1,270	957	645	625	Kct	Seven miles north-west of Wimberley	Open hole from 39-625'

Table 3.--Relationship of Well Completion, Depth, and Water Level in the Trinity Group Aquifer - Continued

Well	Elevation Above Sea Level in Feet: Land Surface	Water Level	Bottom Well	Well Depth in Feet	Aquifer	Area	Well Completion
502	1,241	957	910	331	Kcgrl	Seven miles northwest of Wimberley	Perf. from 278-320
801	970	923	745	820	Kcgrl,Kccc	Six miles west of Wimberley	Open hole from 90-225'
804	1,163	948	353	810	Kcgrl,Kccc Kcho	Five miles northwest of Wimberley	Open hole from 0-810'
57-63-901	1,040	963	740	300	Kcgrl,Kccc	Woodcreek 56-300', faulted	Open hole
902	1,025	927	655	370	Kcgrl,Kccc	Woodcreek	Open hle from 13-370', faulted
903	1,045	931	745	300	Kcgrl,Kccc	Woodcreek	Open hole from 21-300', faulted
904	1,005	924	605	400	Kccc	Woodcreek	Open hole from 240-400, faulted
905	930	930	?	-	Kcgrl,Kccc	Woodcreek	Jacob's Well, faulted
907	1,040	926	740	300	Kcgrl	Woodcreek	Faulted
64-401	1,077	926	797	280	Kcgrl	--	Open hole from 20-280'
601	1,016	925	824	192	Kcgru?	--	Open hole from 20-192'
701	1,030	939	743	287	Kcgrl	--	Open hole from 19-287'
702	930	902	530	400	Kcgrl,Kccc	Woodcreek	Open hole from 32-400'

Table 3.--Relationship of Well Completion, Depth, and Water Level in the Trinity Group Aquifer - Continued

Well	Elevation Above Sea Level in Feet: Land Surface	Water Level	Bottom Well	Well Depth in Feet	Aquifer	Area	Well Completion
704	959	909	509	450	Kcgrl,Kccc	Woodcreek	Open hole from 30-450'
707	930	744	530	400	Kcgrl,Kccc	Woodcreek	Open hole from 180-400'
709	1,035	1,012	915	200	Kcgrl	Woodcreek	Open hole from 20-120'
710	1,020	1,008	820		Kcgrl	Woodcreek	Open Hole 20-200'
801	1,198	918	--	--	Kcgrl	Skyline Acres	--
58-49-405	985	814	--	--	Kcgr	Nutty Brown	--
406	1,015	965	485	530	Kcgr	Nutty Brown	--
407	1,014	966	--	--	Kcgr	Nutty Brown	--
58-49-509	980	682	- 80	1,060	Kcs,Kcho	Hills of Texas	Open hole from 685-1,060'
704	1,041	648	511	530	Kcgrl	Goldenwood West	--
705	1,030	795	530	500	Kcgrl	Goldenwood West	Csg set from +2.2-500'
706	1,030	--	330	700	Kcs,Kcho	Goldenwood West	Perf. from 480-700'
707	1,093	758	193	900	Kccc,Kcho?	Radiance	Csg. set from +1.5-900' faulted, east side of Mt. Bonnell fault

Table 3.--Relationship of Well Completion, Depth, and Water Level in the Trinity Group Aquifer - Continued

Well	Elevation Above Sea Level in Feet			Well Depth In Feet	Aquifer	Area	Well Completion
	Land Surface	Water Level	Bottom Well				
808	939	717	519	420	Kcgr	Friendship Church	Open hole from 287-420'
58-57-101	993	940	883	101	Kcgr	--	Open hole?
401	963	757	463	500	Kcgr	Hays City Comm.	--
909	830	614	-20	850	Kce,Kcgr	Kyle	--
68-08-102	890	716	340	550	Kcgrl,Kccc	--	

CHEMICAL QUALITY OF GROUND WATER FROM THE TRINITY GROUP AQUIFER OF WESTERN HAYS COUNTY

Ground water from the Trinity Group aquifer can vary from fresh (as low as 236 milligrams per liter) to slightly saline (as high as 2,273 mg/l) in western Hays County (Table 4). All the 27 wells tested yield water that is classified very hard with calcium carbonate ($CaCO_3$). The maximum hardness noted in this investigation is from well 57-57-401 which tested 1,739 mg/l or 102 grains per gallon hardness. By comparison, well 57-63-801 has the lowest hardness tested of 219 mg/l or 13 gr/gal. Excessive sulfate content occurred in 11 out of the 27 wells sampled for analysis. The above two wells again contained the maximum (1,406 mg/l) and minimum (2 mg/l) sulfate content. Fluoride content exceeded public water supply standards in six wells of the 27 wells that were tested (Table 4). The chemical quality in the Trinity Group aquifer can be further analyzed according to its three aquifers; namely, the Lower, Middle, and Upper Trinity aquifers (Table 1).

The Lower Trinity aquifer was penetrated by six wells from which seven water samples were obtained. However, only three of these wells have completion intervals solely in the Sligo Limestone/Hosston Sand or Lower Trinity aquifer (Tables 2 and 4). These are wells 57-56-902, 58-49-509, and 58-49-706. Total dissolved solids ranged from 375 to 1,166 mg/l; sulfates 20 to 621 mg/l; and hardness 343 to 840 mg/l. Apparently, the variation in water quality occurs naturally. While well 58-49-706 can be used for public supply, water quality precludes the use of wells 57-56-902 and 58-49-509 for public supply unless reverse osmosis treatment is conducted.

The Middle Trinity aquifer chemical quality is well represented by 17 samples collected from the Lower Glen Rose, Hensell Sand, and Cow Creek members. Well 57-63-801, located about six miles west of Wimberley, produced the best water tested during the study. Total dissolved solids content (TDS) was 236 mg/l, sulfate, 2 mg/l and hardness, 219 mg/l. In contrast, well 57-55-401 of the Henley Baptist Church produced water containing TDS of 2,273 mg/l, sulfate of 1,406 mg/l, fluoride of 1.7 mg/l, and a hardness of 1,739 mg/l. Another six wells produced water exceeding 1,000 mg/l of TDS. Seven wells had water with sulfate exceeding 300 mg/l and fluoride exceeding 1.4 mg/l. It can be concluded that water quality in the Middle Trinity aquifer in western Hays County can vary from area to area.

Only one water sample was collected from the Upper Trinity aquifer. This was from well 57-56-401 and the quality was good with 381 mg/l of TDS, 32 mg/l of sulfate, and 0.3 fluoride.

ESTABLISHMENT OF WATER-LEVEL AND WATER-QUALITY MONITORING PROGRAMS FOR THE TRINITY GROUP AQUIFER IN WESTERN HAYS COUNTY

Ideally, the objectives when establishing water-level and water-quality monitoring well networks would be analogous to drilling a monitoring well under predetermined specifications to obtain the desired data. That is to say, pertinent criteria in such a case would be: (1) well depth; (2) well completion interval and cemented (sealed) interval; (3) driller's log, geological descriptive log, and geophysical logs; (4) pumping test data; (5) accessibility of wells for measuring water levels and taking water samples; (6) relationship of streamflow, recharge areas, geological structure, and areas of pumpage; and (7) physical accessibility to the well. Unfortunately, the characteristics of related available data for most of the existing water wells in western Hays County does not adequately meet the desired well criteria for effective monitoring well networks.

Selection of Monitoring Wells

In order to setup a monitoring well network in western Hays County, certain guidelines were used based on the available data from water wells inventoried during this limited study. These guidelines were employed during the selection process to provide the best possible information. Guidelines were: (1) well depth and completion interval to represent specific aquifers if possible, (2) well location in areas of current and projected pumpage, (3) location of well network to obtain areal coverage of aquifers in western Hays County, (4) availability of historical water-level and water-quality data, (5) proximity of well location to recharge areas and geological structures, and (6) physical accessibility to the monitoring well. Ideal conditions for a monitoring well were rarely met during the selection process; consequently, this must be considered when evaluating the data obtained.

Water-level observation wells selected to monitor the ground-water storage in Trinity Group aquifers of western Hays County are noted in the "Remarks" column of Table 3. Water-quality observation wells are noted by an asterisk.

Selection of Monitoring Recorder Well

One site was selected to install a water-level recorder. The well, 57-64-703, is open, in good condition, and has been logged by the Board's geophysical logging unit and an automatic water-level recorder was installed on the well. Work will continue to select additional recorder well sites in the Trinity Group aquifers of western Hays County.

COMPARISON OF CURRENT AND HISTORICAL WATER LEVELS AND GROUND-WATER QUALITY

Even though pumpage has increased due to residential development in western Hays County, water levels in wells have remained essentially stable in many areas over the years. There have been areas showing a net slight decline, yet there are other areas showing slight rises in water levels. With the establishment of a water-level monitoring system, the effects of pumping, rainfall, and seasonal changes in water levels can be evaluated for future investigations.

The amounts of ground water available from the Upper Trinity aquifer or Upper Glen Rose Limestone have fluxuated due to gradual declines of water levels in some areas, and conversely increases in other areas due to rises of the water levels. Continued pumping from the Middle Trinity aquifer will affect water levels in the Upper Trinity aquifer due to leaky aquifer conditions.

Concerning ground-water quality, there were 10 wells sampled that had historical quality data for comparison (Table 5). Five of these wells; namely, 57-56-303, 57-56-401, 57-63-501, 58-57-909, and 68-08-103; had no significant change in water quality. However, wells 57-55-603, 57-56-101, 57-56-902, 58-49-118, and 58-49-509, showed increases in sulfate, total dissolved solids, and hardness.

GROUND-WATER PUMPAGE

An examination of pumpage data from the Dripping Springs Water Supply Corporation, the Wimberley Water Supply Corporation, and Woodcreek Utilities, Inc., reveal the rapid population growth of western Hays County.

The Dripping Springs Water Supply Corporation reported a total pumpage of 21.1 acre-feet from its wells in 1965. By 1975, the amount of pumpage had more than doubled to 55.2 acre-feet. The 1984 amount of pumpage had increased to 273.4 acre-feet which is five times greater than the 1975 amount. The total percentage increase for the Dripping Springs Water Supply Corporation from 1965 to 1984 was approximately 1,400 percent.

The Wimberley Water Supply Corporation reported a total pumpage of 15 acre-feet from its wells in 1966. Their amount of pumpage increased to 215.5 acre-feet in 1975, and to 421 acre-feet in 1984. This represents an increase of 2,800 percent in total pumpage for the Wimberley Water Supply Corporation from 1966 to 1984.

Woodcreek Utilities, Inc., pumpage increases were very similar to the two previously mentioned utilities. A pumpage of 6.1 acre-feet was reported for 1977. Pumpage increased to a high of 448.3 acre-feet in 1983, but decreased to 269.8 acre-feet in 1984. Pumpage increased by 4,500 percent for Woodcreek Utilities, Inc., from 1977 to 1984.

CONCLUSIONS AND RECOMMENDATIONS

Water-level and water-quality monitoring well networks have been established in western Hays County. Data collected from these monitoring well networks will be used to evaluate the availability of ground water to meet expected growth.

During this limited investigation in the Woodcreek area, no significant declines in water levels were observed due to increased pumpage. This suggests that currently there is effective recharge to the areas of ground-water withdrawals. It is important to recognize that ground-water availability is limited by the rate of effective recharge, and an amount that can be withdrawn from storage without adverse water-level declines and saline-water encroachment. Additionally, ground-water quality has not changed significantly, and remains only as a result of natural mineralization by dissolution from the parent rocks.

It is recommended that the water-level monitoring wells be measured as frequently as possible during the next two or three years to establish the seasonal fluxuation of water levels and the areal distribution of water-level changes. Additional water-level recorder sites should be established near areas of pumpage.

Wells should be sampled annually, especially in heavily pumped areas to note any changes in water quality. Sulfate, total dissolved solids, and hardness are the primary constituents to observe.

One area of interest where a comprehensive ground-water study could be carried out is in the region west of Wimberley along the Blanco River and the Woodcreek Resort area. Geologically, the area is faulted and fractured, there appears to be hydrologic continuity due to the faults, and there is a natural discharge point at "Jacob's Well." Monitoring streamflow along the Blanco River faulted segment possibly would yield recharge data. Measurement of discharge from Jacob's Well as well as inventory of pumpage in the Woodcreek area should be done more accurately. The observation well 57-64-703 can be used to monitor the water level in this area of recommended additional investigation.

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Table 4. Selected Water Well Inventory Data

Aquifers: kce, Edwards and Associated Limestones; kct, Trinity Group; kcgr, Glen Rose Limestone; kcgru, upper member of the Glen Rose Limestone; kcgrl, lower member of the Glen Rose Limestone; kche, Hensell Sand Member of the Travis Peak Formation; kccc, Cow Creek Limestone Member of the Travis Peak Formation; kcs, Sligo Limestone Member of the Travis Peak Formation; kcho, Hosston Sand Member of the Travis Peak Formation.

Well	Latitude/ Longitude	Owner	Driller	Date Com- pleted	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measure- ment	Method of Lift	Use of Water	Remarks
*57-47-501	30-19-00N 98-10-42W	Mechanical Reps., Inc.	Ray Whisenant	02-80	81	kcho	960	-	-	S,E	PS	Obs. well, 6 in. pvc, 0 to 81 ft. E-log.
* 502	30-18-57N 98-10-43W	do	do	do	71	kcho	965	-	-	S,E	PS	6 in. pvc, 0 to 71, E-log.
* 503	30-18-53N 98-10-45W	do	do	do	81	kcho	960			S,E	PS	6 in. pvc, 0 to 81 ft. E-log.
* 55-401	30-11-45N 98-12-44W	Henly Baptist Church	Tucker Drilling	11-84	460	kcgrl, kche, kccc	1,327	288.50	05-09-86	S,E	PS	Obs. well, 5 in. pvc,+2-460 DL pump set 440 ft. Reported yield 60 to 80 ft. gpm.
* 55-601	30-11-02N 98-08-45W	Udo Haufler	Glass & Tucker, Inc.	07-28-75	340	kcgrl, kche, kccc	1,130	122.40 120	do 07-28-75	S,E	D	Obs. well, DL, pump set 154 ft. Reported yield 200 gpm.
* 603	30-12-07N 98-09-41W	M. S. Bass	do	06-77	480	kcgrl, kche	1,370	331.65 325	05-09-86 06-16-77	S,E	D	Obs. well, open hole 220 to 480 ft. DL. Reported yield 20 gpm.
* 56-101	30-13-55N 98-06-59W	Jerry Nelson	Tucker Drilling	08-13-73	500	kcgrl, kche	1,250	320	08-13-73	S,E	D,S	Open hole 20 to 500 ft. Reported yield 100 gpm pumping WL 480 ft.
202	30-14-58N 98-03-41W	Wiley Hayden	-	1974	365	kcgr	1,121	87.00	05-08-86	S,E	D	Open hole 20 to 365 ft. Est yield 20 gpm.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Completed	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measurement	Method of Lift	Use of Water	Remarks
204	30-14-21N 98-03-08W	V.F. Taylor	Glass and Tucker, Inc.	09-11-76	452 220	kcgr	1,145	204.00 220	10-14-77 09-11-76	N	N	Obs. well, open hole 44-452 ft. DL. Reported yield 20 gpm.
* 303	30-13-57N 98-21-00W	Bobby Whitefield	Delby Glass	07-30-84	606	kcgrl	1,180	375.20	05-08-86	S,E	D	Obs. well 9.5 pvc 0-606 ft. DL.Reported yield 12-15gpm.
* 401	30-10-52N 98-05-03W	Antone Allen	-	-	Spring	kcgru	1,145	-	-	Flows	D	
*57-56-702	30-09-11N 98-05-06W	Dripping Springs	Glass & Tucker, Inc.	04-75	345	kcgru, kcgrl	1,030	45	04-75	T,E	P,S	Obs. well. Open hole 45-345. DL. Reported yield 300-350 gpm.
* 703	30-09-14N 98-05-05W	do	Texas Water Wells, Inc.	06-64	820	kcgrl, kccc, kcho	1,030	74	07-02-64	T,E	P,S	Obs. well. Slotted 315-690 ft. DL Est. 122 gpm.
704	30-09-03N 98-05-11W	do	Central Texas Drilling	02-06-86	380	kcgrl	1,065	108	02-06-86	T,E	P,S	Obs. well. Open hole 288-380 ft. DL. Reported 500 gpm.
* 902	30-09-09N 98-01-49W	The Creek at Driftwood	Byron E.	04-10-85	1,000	kcs, kcho	1,010	283.7 280	04-23-86 04-10-85	S,E	PS	Obs. well. Open hole 700-1000 DL. Reported yield 130 gpm.
* 63-501	30-03-56N 98-11-22W	A.D. Reichert	James B. Tucker, Jr.	08-20-74	625	kct	1,270	313.4 300	04-18-86 08-20-75	S,E	D	Obs. well. Open hole 39-625 ft. DL Est. 30 gpm.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Completed	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measurement	Method of Lift	Use of Water	Remarks
* 502	30-02-46N 98-12-04W	Texas-New Mexico Pipeline Co.	E.R. Osborne	1937	331	kcgrl	1,241	283.6 289	04-18-86 11-37	S,E	Ind	Perf 278-320 ft. DL.
* 801	30-00-03N 98-12-07W	G.W. Haschke	Kutscher Drilling	1968	225	kcgrl, kccc	970	47.23 32.5 42	04-16-86 09-28-77 11-17-77	S,E	D	Obs. well. Open hole 90-225 ft.
* 804	30-02-04N 98-10-37W	J.N. Byler	Sise, Rothrook, Irving	1929	810	kcgrl, kccc, kcho	1,163	214.85 220.4 221.98	05-08-86 12-03-53 11-01-37	S,E	D	Obs. well. Open hole 0-810 ft. See Table 3 for additional water level data.
901	30-01-06N 98-08-49	H.A. Sanson	Central Texas Drilling	03-05-76	300	kcgrl, kccc	1,040	77.00	04-17-86	S,E	Irr	Obs. well. Open hole 56-300 ft. DL reported 200-300 gpm.
57-63-902	30-02-05 98-08-50W	H.A. Sanson	Central Texas Drilling Co.	03-08-76	370	kcgrl, kccc	1,025	98.4	04-17-86	S,E	PS, Irr	Obs. well. Open hole 13-370 ft. DL. Reported yield 100 gpm.
903	30-02-18N 98-09-17W	do	do	03-14-76	300	kcgrl, kccc	1,045	114.00	do	S,E	N	Obs. well. Open hole 21-300 ft. DL. Reported yield 100-200 ft.
904	30-01-52N 98-08-24W	do	do	03-25-76	400	kccc	1,005	80. 80.70	03-30-76 04-17-86	S,E	PS, Irr.	Obs. well. Open hole 240-400 ft. DL. Reported yield 300 gpm.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Completed	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measurement	Method of Lift	Use of Water	Remarks
* 905	30-02-03N 98-07-34W	do	-	-	Spring	kcgrl, kccc	930	-	-	flows	N	Jacob's well. Reported yield 500 gpm.
907	30-02-18N 98-09-17W	Woodcreek North Resorts	-	-	300	kcgrl	1,040	113.5	04-18-86	S,E	PS, Irr	
* 64-401	30-02-31N 98-06-30W	VFW Post 6441	Raymond Whisenant	03-01-85	280	kcgrl	1,077	151.05	05-08-86	S,E	PS, Irr, S	Obs. well. Open hole 20-280 ft. DL. Est. yield 100 gpm.
601	30-03-16N 98-00-43W	Joe Gonzales	Davis Drilling	06-05-76	192	kcgru	1,016	60.00 90.65	06-05-76 11-30-77	S,E	D	Open hole 20-192 ft. DL. Reported yield 12 gpm.
701	30-02-24N 98-06-17	Joe M. Redinger	Owen Drilling	08-29-79	287	kcgrl	1,030	110 91.40	08-29-74 04-16-86	S,E	N	Open hole 19-287 ft. DL. Reported yield 15 gpm.
702	30-01-29N 98-06-51W	H.A. Sanson	Central Texas	07-05-74	400	kcgrl, kccc	930	20 27.65	06-05-74 04-16-86	S,E	PS, Irr	Obs. well. Open hole 32-400 ft. Reported yield 200 gpm.
57-64-703	30-01-42N 98-06-42W	H.A. Sanson	Whisenant	1973	446	kcgrl, kccc	959	63.10	04-16-86	N	N	Recorder well. Open hole 30-460 ft. Reported yield 150 gpm.
* 704	30-01-43N 98-06-41W	do	do	1973	450	kcgrl, kccc	959	49.75	do	S,E	Irr	Open hole 30-450 ft. Est. yield 200 gpm.
707	30-00-54N 98-07-02W	Wimberley WSC	Glass & Drilling Inc.	1974	400	kcgrl, kccc	930	186.20	04-16-86	S,E	PS	Obs. well. Open hole 180-400 ft.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Com- pleted	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measure- ment	Method of Lift	Use of Water	Remarks
* 709	30-02-18N 98-06-14W	Robert Maltsberger	Owens Drilling	06-71	120	kcgrl	1,035	23.00	do	S,E	D,S	Open hole 20-120 ft.
* 710	30-02-18N 98-06-18W	do	do	12-82	200	kcgrl	1,020	12.40	04-15-86	S,E	Irr	Open hole 20-200 ft.
801	30-02-21N 98-04-58W	Skyline Acres Estates				kcgrl	1,198	279.6	04-16-86	S,E	PS	Obs. well.
*58-49-118	30-12-34N 97-58-18W	Mrs. F.J. Turck	S W Glass	1931	623	kcgrl	1,190			S,E	D	
405	30-10-40N 98-57-45W	Johnny Howeth				kcgr	985	171.4	04-24-86	S,E	PS	
58-49-406	30-10-41N 98-57-50W	Johnny Howeth	E. H. Glass	08-85	530	kcgr	1,015	50.0	04-24-86	S,E	PS	
407	30-10-40N 98-57-38W	Johnny Howeth	do	do	do	kcgr	1,040	75.57	04-30-86	N	N	
* 509	30-10-19N 98-56-38W	Kemp Hills Utility Corp.	do	12-23-84	1,060	kcs, kcho	980	313 297.6	12-24-84 04-25-86	S,E	PS	Obs. well, open hole 685-1,060 ft. DL reported yield 150 gpm.
* 704	30-08-21N 98-58-08W	Golden Wood West Water System	Byron Benot	-	530	kcgrl	1,041	393.4	do	S,E	PS	Est. yield 15 gpm.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Com- pleted	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measure- ment	Method of Lift	Use of Water	Remarks
* 905	30-02-03N 98-07-34W	do	-	-	Spring	kcgrl, kccc	930	-	-	flows	N	Jacob's well. Reported yield 500 gpm.
907	30-02-18N 98-09-17W	Woodcreek North Resorts	-	-	300	kcgrl	1,040	113.5	04-18-86	S,E	PS, Irr	
* 64-401	30-02-31N 98-06-30W	VFW Post 6441	Raymond Whisenant	03-01-85	280	kcgrl	1,077	151.05	05-08-86	S,E	PS, Irr, S	Obs. well. Open hole 20-280 ft. DL. Est. yield 100 gpm.
601	30-03-16N 98-00-43W	Joe Gonzales	Davis Drilling	06-05-76	192	kcgru	1,016	60.00 90.65	06-05-76 11-30-77	S,E	D	Open hole 20-192 ft. DL. Reported yield 12 gpm.
701	30-02-24N 98-06-17	Joe M. Redinger	Owen Drilling	08-29-79	287	kcgrl	1,030	110 91.40	08-29-74 04-16-86	S,E	N	Open hole 19-287 ft. DL. Reported yield 15 gpm.
702	30-01-29N 98-06-51W	H.A. Sanson	Central Texas	07-05-74	400	kcgrl, kccc	930	20 27.65	06-05-74 04-16-86	S,E	PS, Irr	Obs. well. Open hole 32-400 ft. Reported yield 200 gpm.
57-64-703	30-01-42N 98-06-42W	H.A. Sanson	Whisenant	1973	446	kcgrl, kccc	959	63.10	04-16-86	N	N	Recorder well. Open hole 30-460 ft. Reported yield 150 gpm.
* 704	30-01-43N 98-06-41W	do	do	1973	450	kcgrl, kccc	959	49.75	do	S,E	Irr	Open hole 30-450 ft. Est. yield 200 gpm.
707	30-00-54N 98-07-02W	Wimberley WSC	Glass & Drilling Inc.	1974	400	kcgrl, kccc	930	186.20	04-16-86	S,E	PS	Obs. well. Open hole 180-400 ft.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Com- pleted	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measure- ment	Method of Lift	Use of Water	Remarks
* 709	30-02-18N 98-06-14W	Robert Maltsberger	Owens Drilling	06-71	120	kcgrl	1,035	23.00	do	S,E	D,S	Open hole 20-120 ft.
* 710	30-02-18N 98-06-18W	do	do	12-82	200	kcgrl	1,020	12.40	04-15-86	S,E	Irr	Open hole 20-200 ft.
801	30-02-21N 98-04-58W	Skyline Acres Estates				kcgrl	1,198	279.6	04-16-86	S,E	PS	Obs. well.
*58-49-118	30-12-34N 97-58-18W	Mrs. F.J. Turck	S W Glass	1931	623	kcgrl	1,190			S,E	D	
405	30-10-40N 98-57-45W	Johnny Howeth				kcgr	985	171.4	04-24-86	S,E	PS	
58-49-406	30-10-41N 98-57-50W	Johnny Howeth	E. H. Glass	08-85	530	kcgr	1,015	50.0	04-24-86	S,E	PS	
407	30-10-40N 98-57-38W	Johnny Howeth	do	do	do	kcgr	1,040	75.57	04-30-86	N	N	
* 509	30-10-19N 98-56-38W	Kemp Hills Utility Corp.	do	12-23-84	1,060	kcs, kcho	980	313 297.6	12-24-84 04-25-86	S,E	PS	Obs. well, open hole 685-1,060 ft. DL reported yield 150 gpm.
* 704	30-08-21N 98-58-08W	Golden Wood West Water System	Byron Benot	-	530	kcgrl	1,041	393.4	do	S,E	PS	Est. yield 15 gpm.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Completed	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measurement	Method of Lift	Use of Water	Remarks
* 705	30-08-22N 98-58-02W	do	do	09-85	500	kcgrl	1,030	234.8	do	S,E	PS	Obs. well +2.2 - 500 ft. Est. yield 15 gpm.
* 706	30-08-22N 98-58-04N	do	do	02-86	700	kcs, kcho	1,030	-	-	S,E	PS	Obs. well perforated 480-700 ft. Est. yield 200 gpm.
* 707	30-08-19N 98-57-31W	Radiance WSC	F.A. Glass	11-05-82	900	kccc, kcho?	1,093	265 335.03	02-04-83 04-25-86	S,E	PS	Spotty steel tape +1.5 pvc 900 ft. DL. Est. 30 gpm.
* 808	30-09-34N 98-57-10W	Cordell Webb	Glass Tucker	10-19-84	420	kcgr	939	222.40	05-08-86	S,E	PS	Obs. well. Open hole 287-420 ft. DL. Est. yield 30-40 gpm.
* 57-101	30-07-00N 98-58-27W	M. O. Rogers	Harvy Harmon	-	110	kcgr	993	53.25	05-07-86	S,E	D,S	Obs. well, E-17 in Bulletin 5612. See Table 3 for additional water level data.
*58-57-401	30-02-17N 98-59-15W	Hays City Ranch	-	-	500	kcgr	963	193.57 206.15	01-04-32 05-07-86	S,E	D,S	Obs. well. See Table 3 for additional water level data.
909	30-00-32N 97-53-48W	Ky-Tex Properties Inc.	A.W. Gregg,Jr.	1950	850	kce,kcgr	830	216.00	04-16-86	S,E	PS	Obs. well.
68-08-102	29-59-11N 98-05-33	Wimberly WSC	Central Texas Drilling	1978	550	kcgrl,kccc	890	173.5	04-17-86	S,E	PS	Obs. well. DL. Est. yield 100 gpm.
* 103	29-59-01N 98-07-AW	-	-	01-30-84	500	kcgrl	990	-	-	S,E	PS	Obs. well. DL est. yield 100 gpm.

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Completed	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level Below Land-Surface Datum (ft)	Water Level Date of Measurement	Method of Lift	Use of Water	Remarks
58-57-101								63.24	11-04-37			
								52.09	01-08-40			
								51.59	02-26-40			
								52.44	03-25-40			
								51.25	04-29-40			
								50.67	05-24-40			
								50.32	06-24-40			
								56.50	08-26-40			
								53.21	09-27-40			
								53.42	10-30-40			
								18.5	01-30-41			
								5.26	03-28-41			
								8.65	05-31-41			
								51.86	08-08-41			
								54.00	11-18-41			
								52.33	04-10-42			
								48.18	12-04-42			
								51.42	03-30-43			
								51.99	09-09-43			
								34.46	04-28-44			
								53.02	08-23-44			
								50.56	12-21-44			
								50.6	05-22-45			

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Com- pleted	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measure- ment	Method of Lift	Use of Water	Remarks
								29.5	03-22-46			
								58.4	08-06-48			
								53.03	02-10-49			
								54.55	08-24-49			
								56.12	11-30-49			
								56.90	04-12-50			
								55.40	08-03-50			
								54.83	12-06-50			
								57.21	01-03-51			
								56.31	08-08-51			
								55.04	12-05-51			
								53.62	03-31-52			
								58.22	08-08-52			
								53.60	04-13-53			
								57.81	08-17-53			
								56.95	04-07-54			
								57.40	07-21-54			
								55.64	08-23-54			
								62.28	12-06-54			
								55.07	03-08-55			
								57.51	07-15-55			
								59.48	11-09-55			
								63.79	07-12-56			
								59.61	10-05-56			

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Com- pleted	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measure- ment	Method of Lift	Use of Water	Remarks
								62.18	11-09-56			
								59.34	01-07-57			
								57.42	03-08-57			
								52.99	05-09-57			
								47.32	07-16-57			
								6.07	11-18-57			
								13.98	01-10-58			
								3.14	03-11-58			
								8.65	05-12-58			
								54.08	07-03-58			
								9.90	11-13-58			
								58.84	11-08-71			
								57.57	09-13-71			
								52.40	01-31-72			
								50.30	06-05-72			
								16.90	02-06-73			
								8.64	07-24-73			
								13.57	02-11-74			
								39.30	07-18-74			
								6.75	02-10-75			

Table 4. Selected Water Well Inventory Data - Continued

Well	Latitude/ Longitude	Owner	Driller	Date Com- pleted	Depth of Well (ft)	Aquifer	Altitude of Land Surface Datum (ft)	Water Level: Below Land-Surface Datum (ft)	Water Level: Date of Measure- ment	Method of Lift	Use of Water	Remarks
57-63-804								208.00	01-25-38			
								213.12	03-01-38			
								214.76	03-31-38			
								172.9	04-28-38			
								218.2	06-23-38			
								218.34	06-21-38			
								219.76	08-30-38			
								221.98	09-29-38			
								226.80	12-12-38			
								226.01	01-25-39			
								224.62	03-01-39			
								226.60	03-29-39			
58-57-401								200.51	03-29-43			
								196.76	03-30-43			
								202.29	12-12-50			
								203.27	01-03-51			
								207.0	03-31-52			
								206.5	09-05-52			
								213.9	09-23-54			
								204.88	09-29-56			
								191.96	03-11-58			
								191.79	01-05-61			

Table 5. Chemical Analyses of Water Samples

Analyses are in milligrams per liter except percent sodium, specific conductance, pH, sodium adsorption ratio (SAR), and residual sodium carbonate (RSC).

Analyses by the Texas State Department of Health.

Aquifers: Kce, Edwards and Associated Limestones; Kct, Trinity Group; Kcgr, Glen Rose Limestone; Kcgru, upper member of the Glen Rose Limestone; Kcgrl, lower member of the Glen Rose Limestone; Kche, Hensell Sand Member of the Travis Peak Formation; Kccc, Cow Creek Limestone Member of the Travis Peak Formation; Kcs, Sligo Limestone Member of the Travis Peak Formation; Kcho, Hosston Sand Member of the Travis Peak Formation

State Well Number	Aquifer	Depth of Well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium* (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron	Dissolved solids	Total hardness as $CaCO_3$	Specific Conductance (Micromhos at 25°C)	pH	Percent Sodium	SAR	RSC
57-47-501	Kcho	81	02-27-80	--	0.1	75	25	2	--	285	40	15	0.0	5.0	0.0	302	285	--	7.1	1	0.0	--
502	Kcho	71	02-27-80	--	0.0	65	15	5	--	245	20	15	0.0	5.0	0.0	345	240	--	7.3	5	0.1	--
503	Kcho	81	02-27-80	--	0.0	64	10	20	--	220	45	15	0.0	5.0	0.0	265	210	--	7.4	18	0.6	--
55-401	Kcgrl,Kche Kccc	460	05-09-86	10	-	544	92	25	1.0	340	1,406	24	1.7	1.64	-	2,273	1,739	4,108	7.8			--
601	Kcgrl,Kche Kccc	340	05-09-86	13	-	182	125	51	15	359	722	45	2.8	.53	-	1,319	969	2,512	7.9	10	0.7	-
603	Kcgrl,Kche	480	06-16-77	12	-	180	138	35	16	399	690	43	3.5	0.4	-	1,314	1,020	1,680	7.6	7	0.4	-
			05-09-86	14	-	310	215	50	18	346	1,391	63	2.7	<.04	-	2,218	1,661	4,216	7.7	6	0.5	-
56-101	Kcgrl,Kche	500	08-04-76	11	-	145	115	35	13	455	470	40	3.2	1.3	-	1,057	830	1,450	7.6	8	0.5	-
			04-25-86	13	-	228	165	75	17	356	1,016	54	2.2	0.18	-	1,730	1,251	3,255	7.8	12	0.9	-
303	Kcgrl	606	08-01-84	12	0.18	244	148	36.0	1.5	368	922	37	3.4	.04	-	1,585	1,222	3,087	8.0	6	0.4	-
			05-08-86	12	-	220	172	40	1.6	381	958	36	3.4	.09	-	1,630	1,256	3,066	7.7	6	0.4	-
401	Kcgru	Spring	09-02-37	-	-	87	19	-	1	305	20	20	-	-	-	297	297	-	-	-	-	-
			04-25-86	11	-	102	19	11	2	362	32	21	0.3	6.60	-	381	336	750	7.8	7	0.2	-

Table 5. Chemical Analyses of Water Samples - Continued

State Well Number	Aquifer	Depth of Well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium* (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron	Dissolved solids	Total hardness as $CaCO_3$	Specific Conductance (Micromhos at 25°C)	pH	Percent Sodium	SAR	RSC
703	Kcgrl,Kccc Kcho	820	04-25-86	13	-	110	91	55	11	392	389	38	2.7	0.04	-	893	649	1,694	7.8	16	0.9	-
902	Kcs,Kcho	1,000	04-23-85	-	0.10	60	35	90	-	160	285	55	1.1	.10	.30	610	285	-	7.2	41	2.4	0
			04-22-86	14	-	101	73	132	13	329	471	77	1.3	<0.04	-	1,032	553	1,957	7.9	34	2.4	0
63-501	Kct	625	08-04-76	10	-	81	22	7	2.0	318	19	12	0.3	2.8	-	318	294	524	8.4	5	0.1	-
			04-18-86	10	-	83	26	7	2	353	30	13	0.5	1.42	-	345	314	668	7.9	5	0.1	-
57-63-502	Kcgrl	331	04-18-86	10	-	80	20	8	1	332	14	11	0.2	1.73	-	308	281	600	7.3	6	0.2	-
801	Kcgrl,Kccc	225	04-16-86	8	-	35	32	10	3	276	2	12	0.5	<0.01	-	236	219	471	7.9	9	0.2	0.1
804	Kcgrl,Kccc	810	11-02-37	-	-	-	-	-	-	293	43	16	-	-	-	-	-	-	-	-	-	-
	Kcho		05-08-86	11	-	101	15	18	1	365	25	15	0.4	10.68	-	376	313	725	7.9	11	0.4	0
905	Kcgrl	Spring	10-28-37	-	-	94	17	-	-	329	11	15	-	-	-		306	-	-	-	-	-
	Kccc	Jacob's Well	04-14-86	10	-	91	13	7	1	328	17	12	0.2	2.75	-	314	283	608	7.6	5	0.1	-
64-401	Kcgrl	280	05-08-86	13	-	58	44	6	2	351	30	15	1.0	<0.04	-	340	326	695	8.0	4	0.1	0
702	Kcgrl	400	04-14-86	10		83	20	7	1	340	17	12	0.2	1.9	-	318	290	620	7.9	5	0.1	-
704	Kcgrl,Kccc	450	04-14-86	10	-	88	18	7	1	343	17	12	0.2	1.51	-	322	297	624	7.6	5	0.1	-
709	Kcgrl	120	04-15-86	9		98	14	8	1	342	15	14	0.2	8.82	-	335	304	640	7.3	5	0.2	-
710	Kcgrl	200	04-15-86	9	-	94	13	7	1	338	13	13	0.2	3.72	-	319	291	620	7.7	5	0.1	-
58-49-118	Kcgrl	623	08-26-52	12	-	178	111	29	-	421	547	30	2.6	0.2	-	1,117	900	1,540	7.4	7	0.4	-
	Kcgrl	623	09-17-75	12	-	217	169	37	-	304	960	35	2.7	0.4	-	1,583	1,240	1,880	8.0	6	0.4	-
	Kcgrl	623	06-28-77	13	-	204	134	33	13	382	790	31	2.4	2.0	-	1,410	1,060	1,750	7.6	6	0.4	-
	Kcgrl	623	05-08-86	12	-	296	140	40	15	383	1,039	35	3.2	.09	-	1,755	1,315	3,276	7.7	6	0.4	-

Table 5. Chemical Analyses of Water Samples - Continued

State Well Number	Aquifer	Depth of Well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium* (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron	Dissolved solids	Total hardness as $CaCO_3$	Specific Conductance (Micromhos at 25°C)	pH	Percent Sodium	SAR	RSC
509	Kcs,Kcho	1,060	12-26-84		.13	130	70	60	-	260	460	40	1.0	.10	.10	889	605		7.3	18	1.0	-
		1,060	03-27-86	19	-	160	107	53	10	339	621	37	1	<0.04	-	1,166	840	1,320	8.3	12	.8	-
			03-28-86	19	-	156	107	56	14	338	608	38	1	<0.04	-	1,153	829	1,300	8.2	13	.8	-
704	Kcgrf	530	04-25-86	12	-	72	72	13	7	425	142	15	2.6	0.75	-	539	478	1,050	7.9	6	0.2	-
705	Kcgrf	500	04-25-86	12	-	79	29	7	2	360	27	12	.6	3.54	-	347	320	664	7.7	5	0.1	-
58-49-706	Ksc,Kcho	700	04-25-86	11	-	102	21	9	1	386	20	16	.2	5.85	-	375	343	735	7.6	5	0.2	-
707	Kccc,Kcho	900	11-05-82	14	-	66	40	7	2	367	31	11	0.6	0.84	-	351	328	679	7.8	4	0.1	-
808	Kcgr	420	05-08-86	12	-	216	169	50	16	367	967	41	3.1	<0.04	-	1,640	1,235	3,108	7.8	8	0.6	-
57-101	Kcgr	110	11-04-37	-	-	144	52		-	244	43	78	-	276	-		572	-	-	-	-	-
			05-07-86	13	-	93	28	7	2	394	30	12	0.3	0.71	-	378	350	750	8.0	4	0.1	0
401	Kcgr	500	11-04-37	-	-	358	170		-	366	1,330	24	-	-	-		1,600	-	-	-	-	-
			05-07-86	13	-	73	52	8	4	334	128	10	0.9	0.62	-	450	397	894	8.0	4	0.1	0
909	Kce,Kcgr	850	07-15-85	11	-	78	24	7	0.1	333	21	11	0.4	5.4	-	322	293	616	8.1	5	0.1	-
			04-16-86	12	-	81	21	6	1	339	14	11	0.3	6.87	-	319	291	516	7.7	4	0.1	-
68-08-103	Kcgrf	500	12-13-84	-	.10	80	44	26	7.0	406	39	57	1.1	0.1	-	454	381	912	7.5	13	0.5	-
			10-28-85	-	0.3	59	40	22	6.0	372	36	18	0.9	0.1	-	365	313	740	7.7	13	0.5	-
			04-15-86	14	-	58	39	21	0.6	368	34	17	0.9	.13	-	366	307	725	8.0	13	0.5	-