TEXAS DEPARTMENT OF WATER RESOURCES

REPORT 279

OCCURRENCE AND QUALITY OF GROUND WATER IN THE VICINITY OF BROWNSVILLE, TEXAS

By

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ABSTRACT

The City of Brownsville in 1972 requested technical and financial assistance from the Texas Water Development Board (now Texas Department of Water Resources) in regard to water-supply possibilities. In order for the Board to provide financial assistance, an evaluation of all possible water-supply sources was needed. This report is a description of the evaluation made of the availability and quality of ground water in the general area of the city.

The study encompasses an area of approximately 150 square miles (390 km^2). Information was collected on 168 existing wells, and 21 test holes were drilled by the City of Brownsville as a part of the study. Some 179 water samples were collected for chemical analysis. These included samples from each producing zone encountered in the 21 test holes. Two comprehensive pumping tests were conducted on existing high-capacity wells.

All data indicate three distinct producing zones within the area, with only the deep zone (150 to 225 feet or 46 to 69 m) capable of producing significant amounts of usable quality water. Generally, water quality within this zone deteriorates gradually from less than 1,000 milligrams per liter (mg/l) dissolved solids some 12 miles (19 km) west of Brownsville to more than 10,000 mg/l within the eastern part of the city.

At least 350,000 acre-feet (432 hm^3) of fresh to slightly saline water is calculated to be in storage within this deep zone in the study area. Water-quality maps indicate three areas that are feasible for development of additional ground water. Computer simulations of pumpage within these areas indicate that the development of more than 10 million gallons per day (34 million l/d) of water with less than 2,000 mg/l dissolved solids is possible without disastrous effects of dewatering the aquifer or deterioration of water quality.

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INTRODUCTION

Location and Extent of the Area

Brownsville, the county seat of Cameron County, is the southernmost city in Texas. The city lies on the United States border with Mexico, on the north bank of the Rio Grande about 25 miles (40 km) upstream from the Gulf of Mexico (Figure 1). Most of the city lies within the Rio Grande floodplain on the delta of the river.

Cameron County includes 896 square miles (2,321 km^2) and is bounded on the west by Hidalgo County, on the north by Willacy County, on the south by Mexico, and on the east by the Gulf of Mexico.

The study area lies within the Lower Valley area of the Gulf Coastal Plain physiographic province. Brownsville is one of the major points of entry to Mexico and is located 160 highway miles (260 km) south of Corpus Christi, 275 miles (442 km) south-southeast of San Antonio, 202 miles (325 km) southeast of Laredo, and 331 miles (533 km) south of Austin. Brownsville is over 800 miles (1,290 km) south of the northwest corner of the Texas Panhandle, the most northern part of the State.

The present study included the City of Brownsville and an area to the west along the Rio Grande. This area included about 150 square miles (390 km^2), bounded on the east side by Paredes Line Road (Farm Road 1847) and extending north to San Benito, west to Los Indios, and south to the Rio Grande (Figure 1).

Purpose and Scope

In 1972, the Public Utilities Board of the City of Brownsville requested that the Texas Department of Water Resources (then the Texas Water Development Board) conduct an inventory and evaluation of water-supply possibilities for the city. This was to include a determination of the availability and quality of ground-water supplies in the vicinity of Brownsville and an evaluation of the city's existing well field which consists of seven wells in the northwest part of Brownsville.

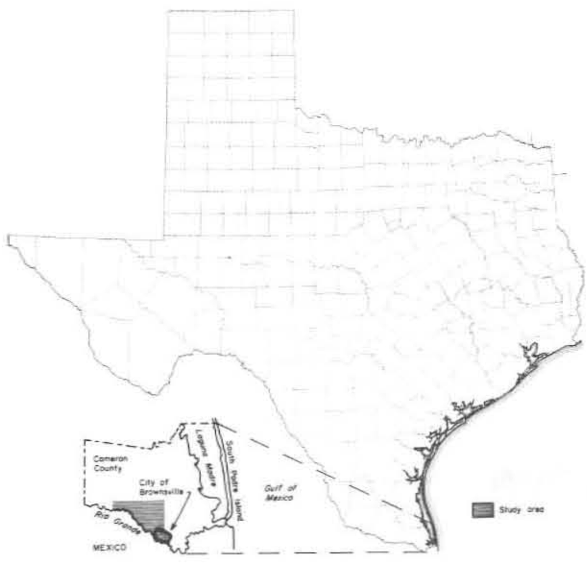


Figure 1.—Location of the Study Area

Since existing data on the area were sketchy and out-of-date, a detailed study of the entire ground-water situation was initiated in September 1972. Specific data on ground-water occurrence, availability, and quality were to be collected and reviewed and used to make recommendations on the possible development of a supplemental supply of ground water for the City of Brownsville. Thus, the specific purpose of the study was the collection of adequate data to provide the city with accurate recommendations.

The scope of the study included the determination of the location and extent of water-bearing strata and the quantity and quality of water available for development. This also included the determination of any possible problems which might occur as a result of heavy prolonged pumpage (especially the migration of poor quality water into the producing zone).

The project was part of a coordinated study of ground- and surface-water problems conducted for the City of Brownsville by the Department under the supervision of W. L. Ivey, formerly with the Texas Department of Water Resources. The ground-water portion of the study was conducted under the general direction of C. R. Baskin, Fred L. Osborne, Jr., and Dr. Tommy R. Knowles of the Department of Water Resources, and under the direct supervision of A. Wayne Wyatt, formerly with the Department.

Previous Investigations

During the late 1940's and 1950's, the U.S. Geological Survey collected data on ground-water availability and use within the Lower Rio Grande Valley, especially in conjunction with the ground water produced from alluvial deposits which were used as supplemental irrigation and public supplies. This work culminated in 1954 in the publication of Board of Water Engineers Bulletin 5403, "Ground-Water Resources of Cameron County, Texas," by O. C. Dale and W. O. George; and in 1960, Bulletin 6014, "Ground-Water Resources of the Lower Rio Grande Valley Area, Texas," by R. C. Baker and O. C. Dale was published. The latter bulletin covered Hidalgo, Starr, Willacy, and Cameron Counties.

General information on the area is included in the Texas Water Commission's Bulletin 6305, "Reconnaissance Investigation of the Ground-Water Resources of the Gulf Coast Region, Texas" (L. A. Wood and others), and 6502, "Reconnaissance Investigation of the Ground-Water Resources of the Lower Rio Grande Basin, Texas," by R. C. Baker.

Several studies on Tertiary and Quaternary geology of the region are listed in the Selected References section of this report.

Climate

The lower Rio Grande Valley has a semitropical, subhumid climate. In Cameron County, the growing season average 341 days. There is a mean annual temperature of 74 °F (23 °C), with an average July maximum of 95 °F (35 °C) and an average January minimum of 51 °F (11 °C). A record minimum of 12 °F (-11 °C) was recorded at Brownsville in February 1899, and a record maximum of 104 °F (40 °C) in September 1947.

Yearly rainfall at Brownsville averaged 26.1 inches (66.3 cm) for the 77-year period from 1900 to 1976. The maximum yearly total of 60.06 inches (152.5 cm) was recorded in 1886 and the minimum of 8.88 inches (22.6 cm) in 1870. The yearly rainfall at Brownsville is shown on Figure 2.

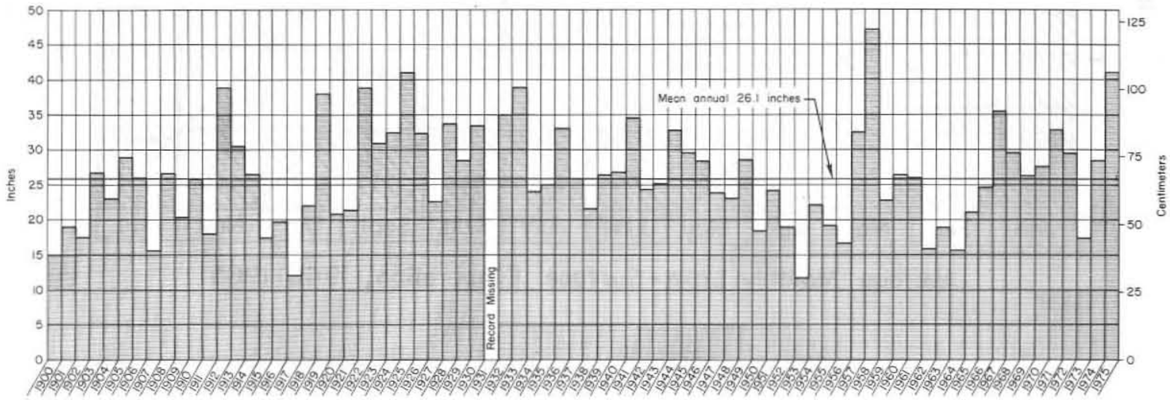


Figure 2.—Yearly Rainfall at Brownsville, 1900-1976 (From Records of National Weather Service)

Evaporation records for the 26-year period from 1940 to 1965 show an average annual gross lake-surface evaporation of about 56 inches (142 cm). The average annual net lake-surface evaporation (average annual gross lake-surface evaporation less the average annual effective rainfall) is about 30 inches (76 cm).

The average monthly distribution of rainfall and the average monthly distribution of gross and net lake-surface evaporation are shown on Figure 3.

Topography and Drainage

The study area lies within the West Gulf Coast section of the Coastal Plain physiographic province. Most of the area is a part of the low-lying, delta portion of the Rio Grande floodplain. The land surface is gently rolling to flat, sloping gradually toward the coast and the river. The area is crossed by many extremely sinuous waterways locally called resacas. These are the abandoned, former courses of the Rio Grande and its tributaries. Other meander scars or abandoned river beds also exist and are evidenced by elongated, curved but often unconnected low-lying areas which are subject to frequent flooding.

Before the construction of International Falcon Dam and Reservoir and other lakes on the Rio Grande, the entire lower valley area was subject to flooding during times of high river flow. A

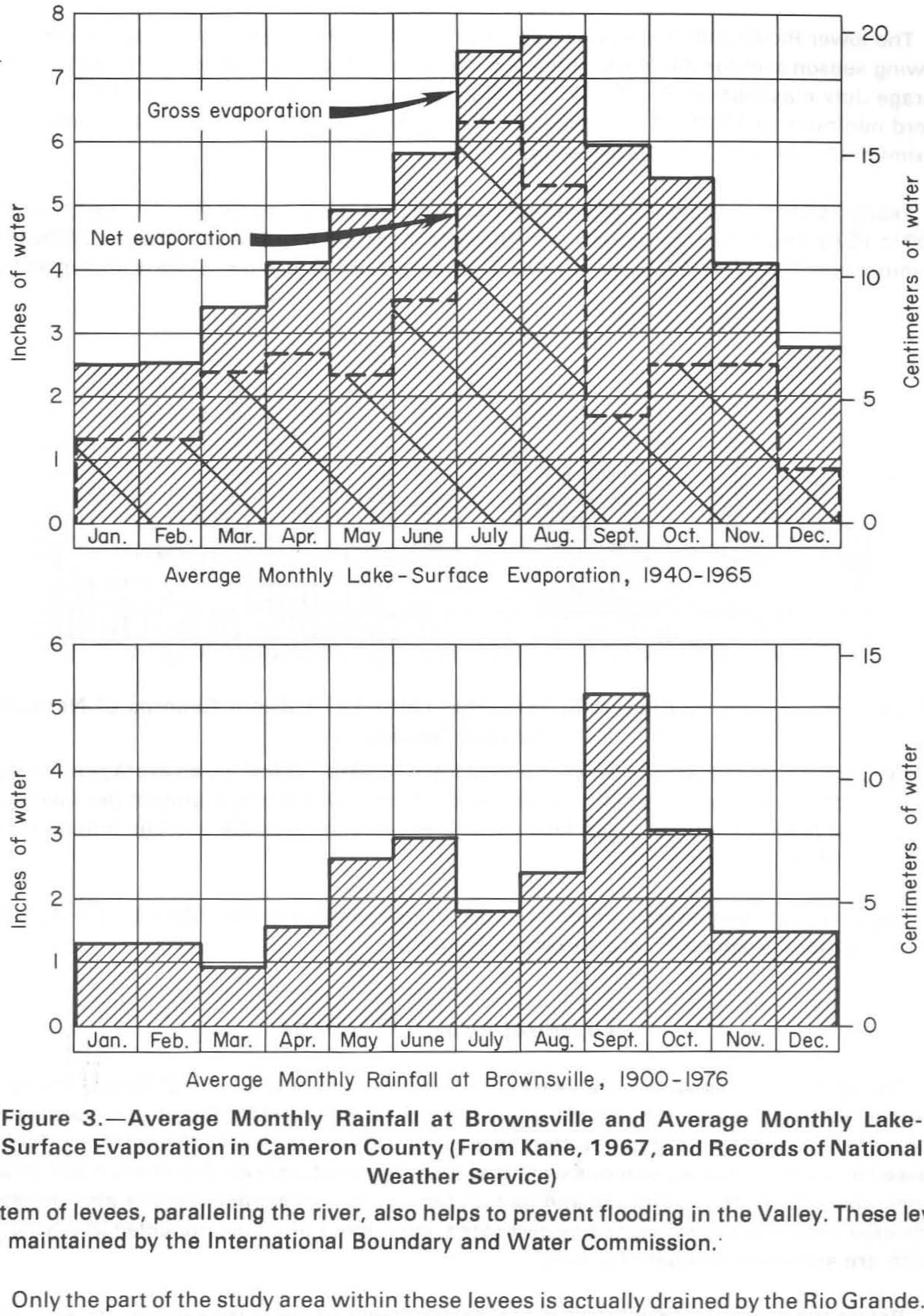


Figure 3.—Average Monthly Rainfall at Brownsville and Average Monthly Lake-Surface Evaporation in Cameron County (From Kane, 1967, and Records of National Weather Service)

system of levees, paralleling the river, also helps to prevent flooding in the Valley. These levees are maintained by the International Boundary and Water Commission.

Only the part of the study area within these levees is actually drained by the Rio Grande. The area outside of the natural and artificial levees is drained by the numerous resacas, including the Resaca del Rancho Viejo and the Resaca de los Cuates. These eventually empty into either the several lakes or bays along the Laguna Madre or into the Laguna Madre itself. Many small dams along each of the resacas hold much of the water in storage except during times of high rainfall and runoff. Additional drainage is induced over much of the area artificially, however, by means of a system of drainage canals. The high water table and relatively poor natural drainage has interfered with agriculture, especially in conjunction with irrigation practices, making the system of drainage canals necessary.

History, Population, and Economy

The Brownsville and Cameron County area has been a part of almost every phase of the discovery and development of Texas. Some of the first explorers of the Western Hemisphere landed at the mouth of the Rio Grande in 1520 and pushed inland about 18 to 20 miles (29 to 32 km). Between 1720 and 1747, several attempts were made to settle the area, but all failed. In the period from 1758 to 1761, several large ranches were set up by Spanish people from Mexico. A trade center was established at the present site of Matamoros and Brownsville. The area continued as a part of the Mexican State of Tamaulipas until 1836 when the Rio Grande was claimed as the southern boundary of the newly formed Republic of Texas. During the Mexican War of 1845, after Texas became part of the United States, several major battles were fought in the Brownsville area (these included the Battle of Palo Alto and the Battle of Resaca de la Palma). The first settlement by anglos also began in 1845 when Fort Brown was constructed at the present site of Brownsville.

Cameron County was created and organized in 1848 with Brownsville as the county seat. The county originally consisted of 3,300 square miles (8,550 km^2) taken from Nueces County. It was later reduced to 896 square miles (2,321 km^2) by the creation of Kenedy and Willacy Counties.

During the War between the States, Brownsville became a thriving city as a major overseas shipping point for the southern States. A steady stream of cotton moved out and supplies moved in avoiding the Federal blockade of other southern ports. The last land battle of the war was won by Confederate forces at Palmito Ranch near Brownsville in May 1865, several weeks after Appomattox.

Slow population growth continued within the area until accelerated by the two world wars during the twentieth century. This rapid growth, combined with increased tourism and the construction of Port Brownsville, has made Brownsville the major city of the Lower Rio Grande Valley.

In the census of 1860, Cameron County had a population of 6,028, which increased to 10,999 in 1870. Growth continued at about the same rate through the early 1880's but then population stabilized until after 1900. From 1900 to 1920, county population more than doubled, from 16,095 to 36,662, and it doubled again by 1930 to 77,540. By 1950, the population had reached 125,170, and it climbed to 151,098 in 1960. In 1970, however, the county population had dropped to 140,368.

In 1860, the City of Brownsville had a population of 2,734. Steady growth has continued until the present. The 1970 population was 52,522.

The City of Brownsville and the study area have a broad-based economy with major contributions from agribusiness, shipping, manufacturing, and tourism.

Citrus fruits and vegetables are the major crops, and cotton and grain sorghum are also important. There is renewed interest in growing sugarcane in the area. The long growing season allows double and even triple cropping. Over 150,000 acres (60,700 hm^2) is irrigated in Cameron County from both surface-water and ground-water sources. Yearly farm income averages over $40 million in the county with three-fourths from fruit, vegetables, cotton, and grain sorghum.

Port Brownsville, completed in 1936 with a 17-mile (27-km) ship channel connecting with the Gulf of Mexico, has contributed greatly to the economy of Brownsville. Serving not only the Texas part of the Lower Rio Grande Valley, but northeastern Mexico and Monterrey as well, the Port handles not only foreign shipping but is the southern end point of the Gulf Intracoastal Waterway. A combined total of 4,911,267 short tons was handled in 1969. The major import is crude petroleum and the principal export is grain. The Port Brownsville ship channel also serves the Brownsville shrimp fleet and harbor. Manufacturing in Brownsville includes representatives of the machinery and chemical industries. The shrimp fleet at Port Brownsville is a large one and there are large seafood plants in the area. About $62 million was added to the economy of Cameron County in 1970 by manufacturing. Retail trade was more than $91 million in Brownsville during 1967.

One of the fastest growing facets of Brownsville's economy is the mushrooming tourist and winter vacation industry. The city is one of the major gateways to Mexico, and increasing numbers of both Mexican and United States tourists are crossing the international bridges every year. Many retired people spend the entire winter in the area, and an increasing number are making the Lower Rio Grande Valley their permanent home. The warm semitropical climate and the proximity to the Gulf of Mexico and Mexico have made Brownsville an ideal retirement and winter vacation center.

Well-Numbering System

The numbers assigned to wells and springs in this report conform to the statewide well-numbering system used by the Texas Department of Water Resources. Each well and spring is assigned a seven-digit number to facilitate record keeping and locating the well within the State. This system is based on division of the State into quadrangles formed by degrees of latitude and longitude, and repeated subdivision of these quadrangles into smaller ones as illustrated in Figure 4.

The largest quadrangle, a one-degree quadrangle, is divided into sixty-four 7½-minute quadrangles, each of which is further divided into nine 2½-minute quadrangles. Each one-degree quadrangle in the State has been assigned a number for identification. The 7½-minute quadrangles are numbered consecutively from left to right beginning in the upper left hand corner of the one-degree quadrangle, and the 2½-minute quadrangles within the 7½-minute quadrangle are similarly numbered. The first two digits of a well number identify the one-degree quadrangle, the third and fourth digits identify the 7½-minute quadrangle, the fifth digit identifies the 2½-minute quadrangle, and the last two digits designate the order in which the well was inventoried within the 2½-minute quadrangle.

On the well-location map of this report (Figure 13), the one-degree quadrangles are indicated by open-block numerals 88 and 89, the 7½-minute quadrangles are labeled near their corners, and the last three digits of each well number are shown at the well location.

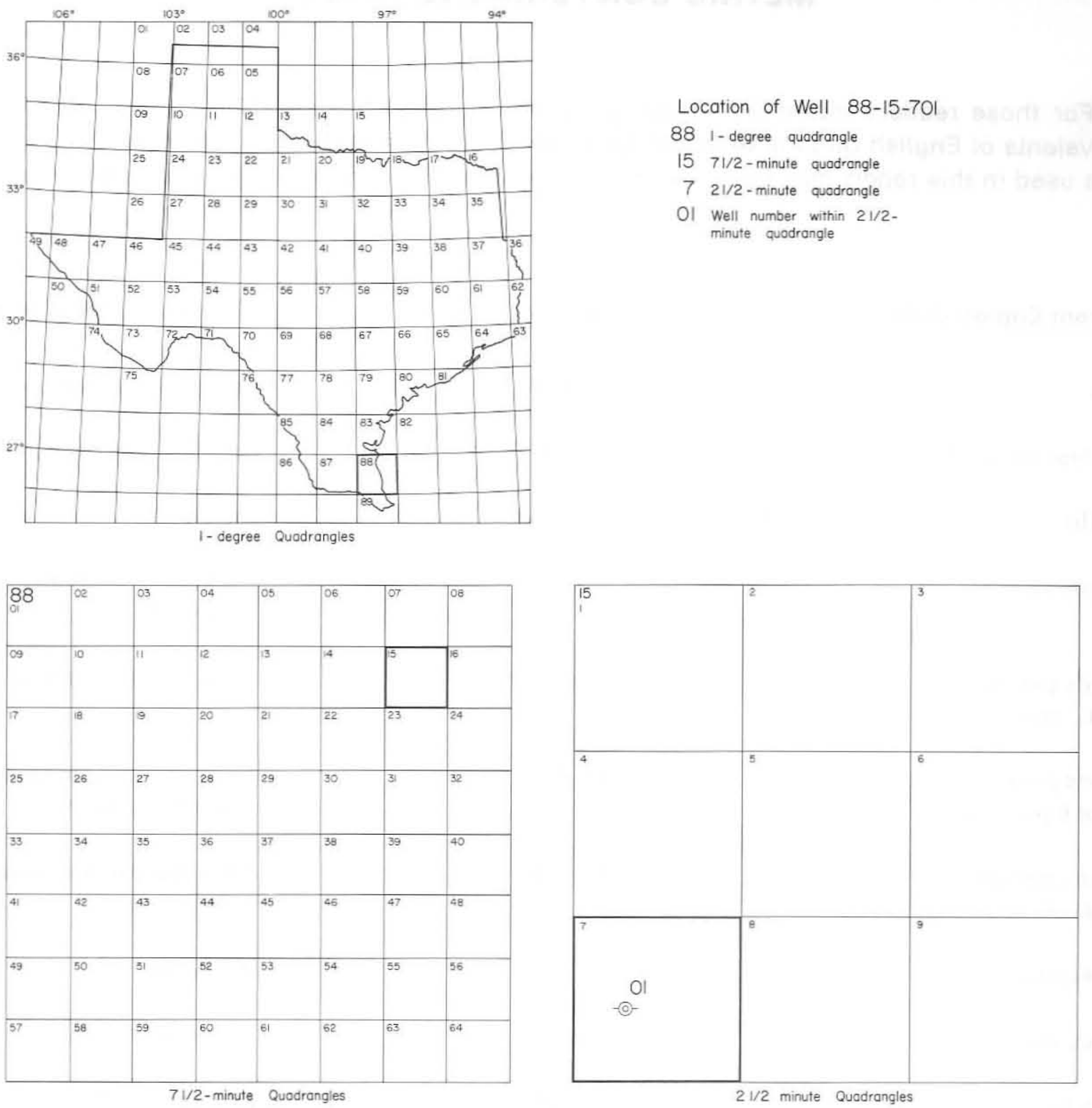


Figure 4.—Well Numbering System

Acknowledgements

The author would like to recognize the invaluable assistance provided by many people during the course of this study. Special thanks are due to Jack Coffee, Candy Hernandez, and Moe Hastings of the Public Utilities Board of the City of Brownsville.

Appreciation is expressed to the many farmers, ranchers, water well drillers, businessmen, and other individuals who generously provided information or cooperated in the collection of data for this report.

Appreciation is also expressed to personnel of the City of Brownsville, the Agricultural Stabilization and Conservation County Committee, and other private, local, county, state, and federal agencies which furnished aid and information.

METRIC CONVERSIONS TABLE

For those readers interested in using the International System (SI) of Units, the metric equivalents of English units of measurement are given in parentheses in the text. The English units used in this report may be converted to metric units by the following conversion factors:

From English units	Multiply by	To obtain metric units
acres	.4047	square hectometers (hm^2)
acre-feet (acre-ft)	.001233	cubic hectometers (hm^3)
feet (ft)	.3048	meters (m)
feet per mile (ft/mi)	.189	meters per kilometer (m/km)
gallons per minute (gal/min)	.06309	liters per second (l/s)
gallons per day per square foot [(gal/d)/ft^2]	40.74	liters per day per square meter [(l/d)/m^2]
gallons per day per foot [(gal/d)/ft]	12.418	liters per day per meter [(l/d)/m]
horsepower (electric) hp	746	watts (w)
inches (in)	2.54	centimeters (cm)
miles (mi)	1.609	kilometers (km)
million gallons per day (million gal/d)	3.785	million liters per day (million l/d)
square miles (mi^2)	2.590	square kilometers (km^2)

To convert degrees Fahrenheit to degrees Celsius use the following formula:

$$°C = 0.556\ (°F-32)$$

GEOLOGY AS RELATED TO THE OCCURRENCE OF GROUND WATER

General Stratigraphy and Structure

The study area lies within the Rio Grande embayment on the delta of the Rio Grande. Recent fluvial and deltaic sediments are at the surface throughout Cameron County. Several thousand feet of similar, loosely consolidated or unconsolidated fluvial, deltaic, and shallow marine deposits underlie the study area. Several generally recognizable geologic units of late Tertiary and early Quaternary age produce fresh to slightly saline water to the north and northwest of the study area. These units, which include the Oakville Sandstone, Goliad Sand, and Lissie Formation, are not easily definable in the subsurface within the immediate vicinity of Brownsville, however. The interval which corresponds to these beds contains only water of very poor quality within the study area.

These complexly interbedded deposits of clay, silt, sand, and gravel make up a system dipping gently to the east toward the Gulf of Mexico. Within this system, the percentage of fine sediments increases to the east, and individual beds or interbedded intervals thicken to the east. This causes a steepening of dip of these beds toward the Gulf. The actual dip is extremely hard to determine because of the interbedded nature of the deposits, but it should be considerably less than 50 feet per mile (10 m/km), perhaps 20 feet per mile (4 m/km).

This gentle homocline is further modified within the lower coastal area by several low-profile salt domes similar to those common throughout most of the Texas Gulf Coastal area. Because of the extreme thickness of overlying sediments, most of the salt domes within the Rio Grande embayment do not show much penetration and there is little surface evidence. Some minor faulting also occurs within the general area. However, within the immediate study area there is no evidence of either salt domes or faulting.

Physical Characteristics and Water-Bearing Properties of the Lower Rio Grande Valley Aquifer

The Lower Rio Grande Valley aquifer or aquifer system, within the study area, is made up of all or part of the Goliad Sand, the Lissie Formation, the Beaumont Clay, and various Recent alluvial deposits. Because of similarities within these units, especially in the most eastern part of the Lower Valley (which includes the Brownsville area), boundaries between these units are difficult to recognize. The complex vertical and horizontal intergradations of sand and gravel units also make the entire sequence act as one aquifer, at least on a regional scale. Therefore, in a narrow band along the river in southeastern Starr County, in south and east Hidalgo County, and in west and southeast Cameron County, the entire water-bearing sequence, which extends from the surface down to 400 or 500 feet (120 or 150 m), is considered as a unit called the Lower Rio Grande Valley aquifer. Regionally, this aquifer is equivalent to the Gulf Coast aquifer as named in some previous studies (Texas Water Development Board, 1977).

This whole sequence of rocks, from the Goliad Sand through the Recent alluvium, is made up of clay, silt, sand, and gravel, mostly of fluvial or deltaic origin. Some small amounts of shallow marine clay may be present locally within the Lissie Formation and the Beaumont Clay. Generally, usable quality water is restricted to the upper 500 feet (150 m) of the section. In the study area, no fresh to slightly saline water (containing less than 3,000 milligrams per liter dissolved solids) is known to occur at depths greater than about 300 feet (90 m), and within the city limits of Brownsville 225 feet (69 m) is the maximum depth of occurrence. Therefore, it seems that, at least within the study area, producing zones of fresh to slightly saline water are confined to the deposits of Pleistocene and Recent age, and the section which correlates with the Goliad Sand, Lissie Formation, and Beaumont Clay contains only relatively small amounts of saline water.

In and around Brownsville, the aquifer is made up of thick accumulations of river floodplain and delta deposits. The resulting system consists of complexly interbedded clay, silt, sand, and gravel beds. The clays and silts generally are laid down in sheet deposits of varying thickness. A few relatively widespread sheetlike beds of very fine sand can also be recognized. Generally, however, the beds of sand are tabular or linear in form. This elongate nature is even more apparent in the beds made up of coarser sand and gravel. This arrangement is the result of the partial restriction of sand and gravel deposition to the buried former stream courses.

The preponderance of finer material was readily apparent in samples taken during the drilling of the 21 test holes for the study. In all of the test holes, most of the material coarser than fine sand was confined to the depth interval between 150 and 225 feet (46 and 69 m). Beds of coarse sand and fine gravel of varying thickness are found at this interval over most of the study area, and this seems to be the only interval capable of producing large amounts of water in the vicinity of Brownsville. There also seems to be gradual lessening of coarser material toward the Gulf, even in the 150 to 225 foot (46 to 69 m) interval, and in the southeastern test holes (89-04-903 and 89-05-701) the section consisted almost exclusively of fine sand and clay.

GENERAL GROUND-WATER HYDROLOGY

In the Lower Rio Grande Valley aquifer, ground water occurs under a variety of conditions which range from pure water-table to artesian conditions. The water throughout the aquifer system, however, conforms to the fundamental hydraulic principles as outlined by Meinzer, Todd, and others (See Selected References).

Hydrologic Cycle

The complicated system of movement and processes through which the earth's water travels from the oceans, through the atmosphere, to the land surfaces, and back to the sea, is called the hydrologic cycle. This cycle is graphically illustrated in Figure 5. Water for any use, whatever the source, is captured in transit and ultimately, after use, is returned to the hydrologic cycle. Thus each use of water adds a loop to the hydrologic cycle.

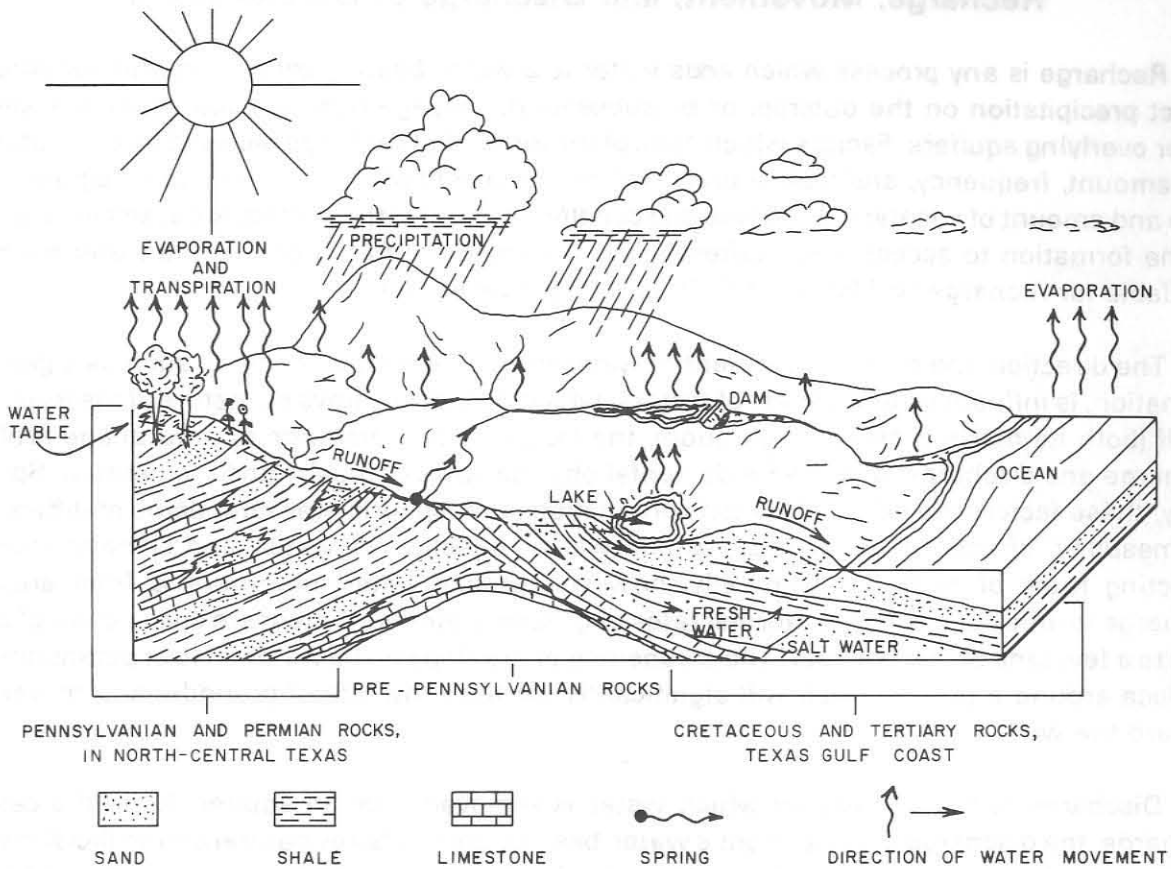


Figure 5.—The Hydrologic Cycle

Source and Occurrence of Ground Water

The ultimate source of most ground water is precipitation. This may be through direct precipitation on the outcrop of the aquifer, downward seepage from overlying beds, or loss from surface waterways where they cross the outcrop. The small percentage of total precipitation which seeps through the soil and reaches the water table is called ground water. The water table is the top of the zone within which the voids or pore spaces which make up the aquifer are saturated or filled with water.

Ground water is said to occur under either water-table (unconfined) or artesian (confined) conditions. Under water-table conditions, the top of the saturated zone is exposed to only the pressure of the atmosphere. When a well taps a water-table aquifer, the top of the water in the well will stand level with the top of the zone of saturation. Artesian conditions exist when the entire thickness of the aquifer is saturated and the top of an aquifer is bounded by a bed through which water will pass only with difficulty. The source of water in the artesian aquifer, usually the outcrop area, is generally at a higher elevation, and the force of gravity on the water that has infiltrated down through the aquifer imparts an added pressure to the water. When a well taps an artesian aquifer, the water will stand at some point above the top of the aquifer. If the land surface at the well is sufficiently lower than the land surface at the aquifer's outcrop area, water will flow from the well. In many cases, however, conditions may exist which cause an aquifer to have characteristics somewhere between those of an ideal water-table aquifer and those of an ideal artesian aquifer.

Recharge, Movement, and Discharge of Ground Water

Recharge is any process which adds water to a water-bearing zone or aquifer, whether by direct precipitation on the outcrop, or by subsequent seepage from surface streams, lakes, or other overlying aquifers. Factors which control the amount of recharge received by an aquifer are the amount, frequency, and type of precipitation, the extent of the outcrop, the topography, the type and amount of vegetation, the type and conditions of soil in the outcrop area, and the capacity of the formation to accept water (often, when an aquifer is full, a part of the water normally available for recharge will be passed off as rejected recharge).

The direction and rate of movement of water through a porous medium, such as a geologic formation, is influenced by a variety of factors, which include the physical nature of the formation itself (both its makeup and configuration), the locations and amounts of natural and artificial recharge and discharge, and the fundamental physical laws of gravity and momentum. Specifically, these factors include surface tension, friction, atmospheric pressure, paths of differential permeability, effects of heavy local withdrawal or injection of water, and climatic changes affecting rates of recharge. Generally, however, ground-water movement is from areas of recharge to areas of discharge. Normal rates of ground-water movement are on the order of a few feet to a few tens of feet per year. The steepening of the slope of the water table or potentiometric surface around a pumped well will significantly increase the rate of ground-water movement toward the well.

Discharge is the process by which water is removed from an aquifer. As in the case of recharge, the discharge of water from a water-bearing unit is also by natural and artificial means. Natural discharge occurs as leakage, transpiration by plants, and by evaporation. Artificially, water is discharged through wells by pumpage.

Hydraulic Characteristics of Aquifers

The capacity of an aquifer to hold, transmit, or yield water to wells depends on several characteristics which include porosity and coefficients of permeability, transmissibility, and storage. These factors will vary not only from aquifer to aquifer but from place to place within an aquifer. Therefore, an aquifer may be more productive in some areas than in others.

Porosity

Porosity is a measure of the total empty space within a formation expressed as a percentage of the total volume of the formation. It varies not only with the shape and size of the particles which comprise an aquifer, but also with the sorting of grain sizes and types, and with the amount of compaction and cementation the sediments have undergone. Generally, deeper aquifers have undergone a greater degree of compaction and cementation and, therefore, usually have a lower porosity than shallow aquifers with similar particle shapes, sizes, and sorting of grains. The porosity of sedimentary materials ranges from zero to greater than 50 percent. Some representative ranges are given in the following table (Todd, 1959, p. 16):

Material	Porosity (percent)
Soils	50-60
Clay	45-55
Silt	40-50
Medium to coarse mixed sand	35-40
Uniform sand	30-40
Fine to medium mixed sand	30-35
Gravel	30-40
Gravel and sand	20-35
Sandstone	10-20
Shale	1-10

Permeability

Permeability is a measure of the ability of sediments or other rocks to transmit water. It depends not only on the size and number of pore spaces or voids within the rock, but also on the degree of interconnection of these voids. The coefficient of permeability is generally expressed as the number of gallons of water moving in 1 day through a vertical section of an aquifer 1 foot square and having a hydraulic gradient of 45 degrees. Meinzer and Wenzel (1942, p. 453) state that the U.S. Geological Survey has measured coefficients of permeability of natural earth materials ranging from about 0.0002 to more than 90,000 gallons per day per square foot [0.0081 to more than 3,700,000 $(l/d)/m^2$].

Transmissibility

Transmissibility is a measure of an aquifer's ability to transmit water and it varies from area to area within an aquifer depending on its thickness. The coefficient of transmissibility is generally defined as the number of gallons of water that will move in 1 day through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness of the aquifer, with a hydraulic gradient of 45 degrees. Thus, the coefficient of transmissibility is equal to the field coefficient of permeability times the saturated thickness of the aquifer.

Storage

The coefficient of storage is a measure of the capacity of an aquifer to yield water. It is defined as the volume of water that is released from or taken into storage by an aquifer per unit surface area of the aquifer per unit change in the component of head normal to that surface (Todd, 1959, p. 31).

Under artesian conditions, water is yielded due to the compression of the sediments and expansion of the water when the potentiometric surface is lowered by pumping. Under water-table conditions, however, the coefficient of storage is equal to the specific yield. The coefficient of storage is generally much smaller for aquifers that are under artesian conditions than those under water-table conditions. Also, because of these differences, a well pumping from an artesian aquifer will produce a large cone of depression in the potentiometric surface in a very short time, while a well pumping from a water-table aquifer will develop a smaller cone of depression in the water table over a much longer time. Ferris and others (1962) indicate that, in general, the range of coefficients of storage for artesian aquifers is from about 0.00001 to 0.001, and the range for water-table aquifers from about 0.05 to 0.30.

Development of Ground Water

Ground-water supplies for domestic and livestock, irrigation, industrial, and municipal uses are often preferable, where available, to surface-water supplies. Several factors control the development of ground water for each use, however.

For irrigation supplies, the most important factors are water quality and the amount of ground water available for development. It is especially critical in irrigation to be able to supply large quantities of water within relatively short time periods. In aquifers which do not supply large enough quantities to individual wells, several wells pumped together may often supply sufficient water for irrigation.

Development of ground water for public supply also requires large quantities of water, but the time factor is not so critical. Water for public supplies may be built up in times of slack usage to take care of peak usage periods. Water quality is critical in municipal water supplies, however. Ground water for public supply is usually developed using well fields (several wells in one general area which pump into central tanks or pipelines). These well fields are generally located in areas where relatively large amounts of good quality water may be obtained. Often, however, especially in some areas of north-central, west, and south Texas, ground-water supplies of rather limited quantities and of poor quality have been developed for public use because of the lack of any better supply from either ground-water or surface-water sources.

Most industrial uses of ground water depend on water quality. This is especially true of "process water" (water that comes into contact with, or is incorporated into, manufactured products). If ground water meets the quality requirements of an industry, it is often preferred over surface water because the quality of ground water from any one supply source is usually very constant. The temperature of ground water from any one source is also usually constant making ground water useful in industrial cooling processes.

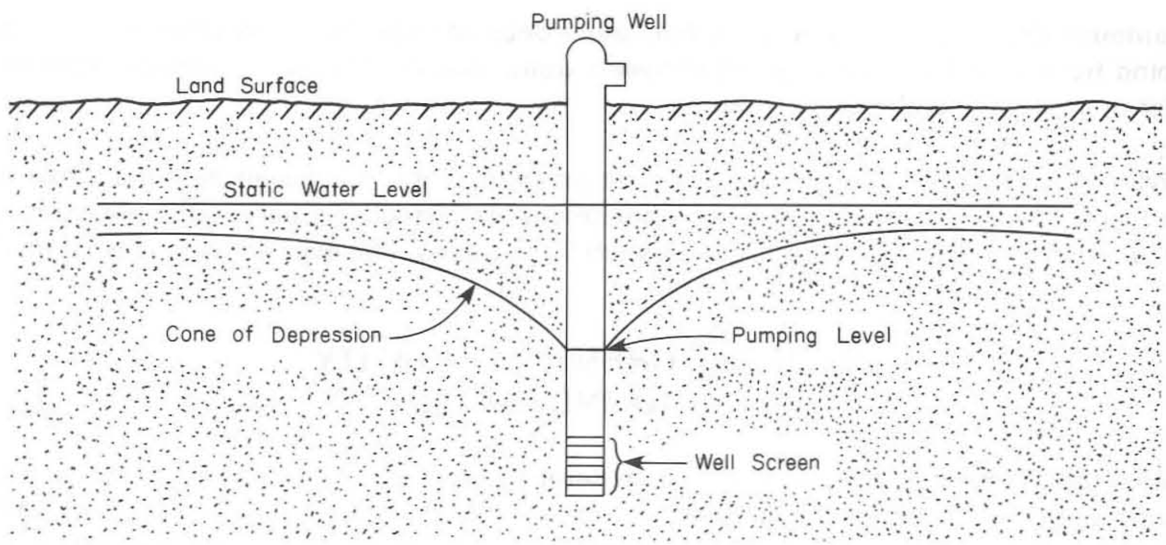
The many recent advances in desalination processes (especially flash distillation and reverse osmosis processes) have made the development of supplies of poor quality ground water more feasible. In areas where sources of good quality water are limited or nonexistent, this is especially important. Cost of these processes is still so high, however, that they would usually be limited to industrial or public-supply development.

In domestic and livestock supply, the amount of water or capacity of wells is generally not of prime importance. As with municipal supplies, the water may be pumped during times of slack usage and stored for periods of peak use. Also, as in public supplies, water quality is extremely important, but in areas of water scarcity ground-water supplies of poor quality may be developed because of a lack of any better dependable sources.

Changes in Water Levels

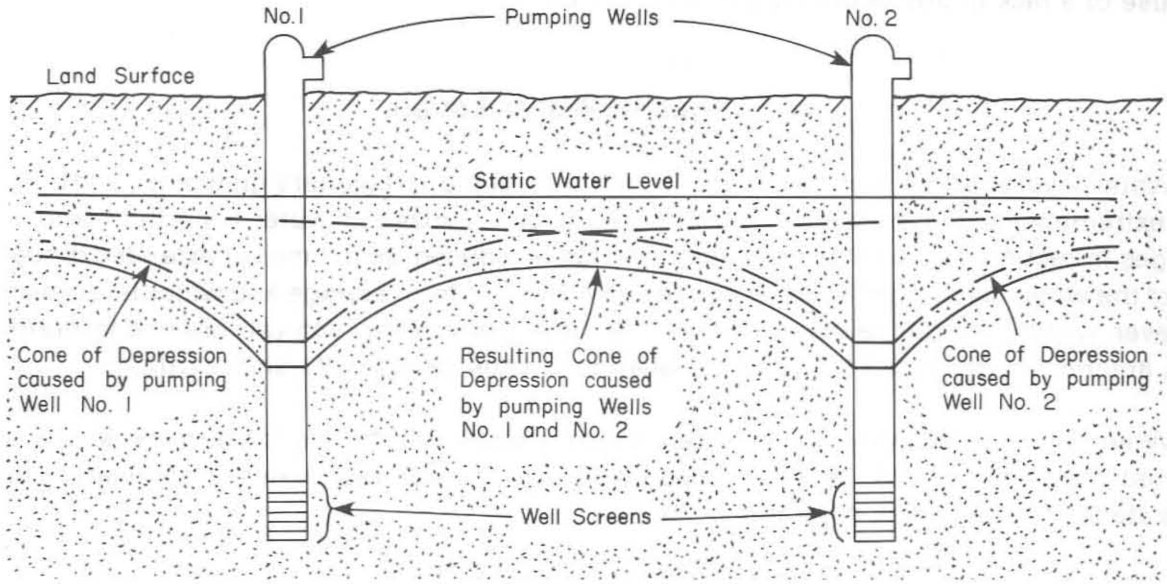
Water-level changes may be due to many causes, some of regional significance and others of only extremely local significance. The most significant causes of water-level fluctuations are changes in recharge or discharge. When recharge is reduced, as in times of extended drought, a part of the water discharged from an aquifer is withdrawn from storage and water levels decline. However, when adequate rainfall resumes, the volume of water which was drained from storage in an aquifer during drought may be replaced and water levels will rise accordingly.

When a well is pumped, water levels in the vicinity are drawn down in the shape of an inverted cone with its apex at the pumped well. This cone of depression in the water table is illustrated in the following diagram.



The development of growth of this cone depends on the aquifer's coefficients of transmissibility and storage and on the pumping rate. As pumping continues, the cone expands and will continue to do so until it intercepts a source of replenishment capable of supplying sufficient water to satisfy the pumping demand. This source can be either intercepted natural discharge or induced recharge. If the quantity of water received from these sources is sufficient 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 salvageable natural discharge is less than the amount of water pumped from wells, water is removed from storage in the aquifer to supply the deficiency and water levels continue to decline.

Where intensive development has taken place in ground-water reservoirs, each well superimposes its own individual cone of depression on the cones of neighboring wells. This results in the development of a regional cone of depression. When the cone of one well overlaps the cone of another, interference occurs, and an additional lowering of water levels occurs as the wells compete for water by expanding their cones of depression. The effects of interference between pumping wells are illustrated in the following diagram.



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.

Water levels in some wells, especially those completed in artesian aquifers, have been known to fluctuate in response to such phenomena as changes in barometric pressure, tidal force, and earthquakes. The magnitude of such fluctuations, however, is usually very small.

GENERAL CHEMICAL QUALITY OF GROUND WATER

All ground water contains dissolved mineral constituents. The type and concentration depends upon the source, movement, and environment of the ground water. Water derived from precipitation is relatively free of mineral matter, but because water has considerable solvent power, it dissolves minerals from the soil and rocks through which it passes. Therefore, the differences in the chemical character of ground water reflect, in a general way, the nature of the geologic formations and the soils that have been in contact with the water. The concentration of dissolved solids generally increases with depth, especially where the movement of the water is restricted. Rocks deposited under marine conditions will contain brackish or highly mineralized water unless flushing by fresh water has been accomplished. This flushing action will occur in the outcrop area and to a limited distance downdip, depending in part upon the permeability of the rocks.

The chemical quality of ground water that has not been artificially altered is relatively constant, as is the temperature of ground water, which makes it highly desirable for many uses.

Included among the factors determining the suitability of ground water as a supply are the limitations imposed by the intended use of the water. Criteria have been developed to cover most categories of water quality, including bacterial content, physical characteristics, and chemical constituents. Water-quality problems associated with the first two categories can usually be alleviated economically, but the removal of undesirable minerals dissolved in water is often very difficult and expensive. The source and significance of the principal dissolved-mineral constituents occurring in ground water are summarized in Table 1.

Table 1.—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 than 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 mg/l (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

Table 1.—Source and Significance of Dissolved-Mineral Constituents and Properties of Water—Continued

Constituent or Property	Source or Cause	Significance
Nitrate NO_3—Continued		in infant feeding (Maxcy, 1950, p. 271). Nitrate 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.
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 recommends 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.
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 drinking water standards recommends a pH greater than 7.

For many purposes the dissolved-solids content constitutes a major limitation on the use of water. A general classification of water by Winslow and Kister (1956, p. 5) based on dissolved-solids content in parts per million (ppm) 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. Up to concentrations of about 7,000, these units are essentially identical. The analyses in this report are reported in mg/l. Only a few exceed 7,000 mg/l; to calculate these in parts per million, a density correction must be made using the following formula:

$$\text{Parts per million} = \frac{\text{Milligrams per liter}}{\text{Specific gravity of the water}}$$

Relationship of Water Quality to Use

Irrigation

The suitability of water for irrigation purposes depends not only on the chemical quality of the water, but also on soil composition and texture, irrigation practices, types of crops grown, climate, drainage, and the quantity of water applied. In consideration of the quality of water for irrigation, both the concentration and composition of the dissolved constituents are important. The chemical characteristics that seem to be most important in evaluating the quality of water for irrigation are: (1) the relative proportion of sodium to the other cations (called the percent sodium), (2) the sodium-adsorption ratio (the relative activity of sodium ions in exchange reactions with the soil, as compared with calcium and magnesium ions), (3) the total concentration of soluble salts (usually expressed as the specific conductance), (4) the amount of residual sodium carbonate, and (5) the concentration of boron.

The U.S. Salinity Laboratory Staff (1954, p. 69-82) proposed a system of classification that is commonly used for judging the suitability of water for irrigation use. The classification is based on plotting the salinity hazard as measured by the electrical conductivity (specific conductance) against the sodium hazard as measured by the sodium-adsorption ratio (SAR). This classification is illustrated in Figure 6. This figure indicates that waters pumped from the Lower Rio Grande

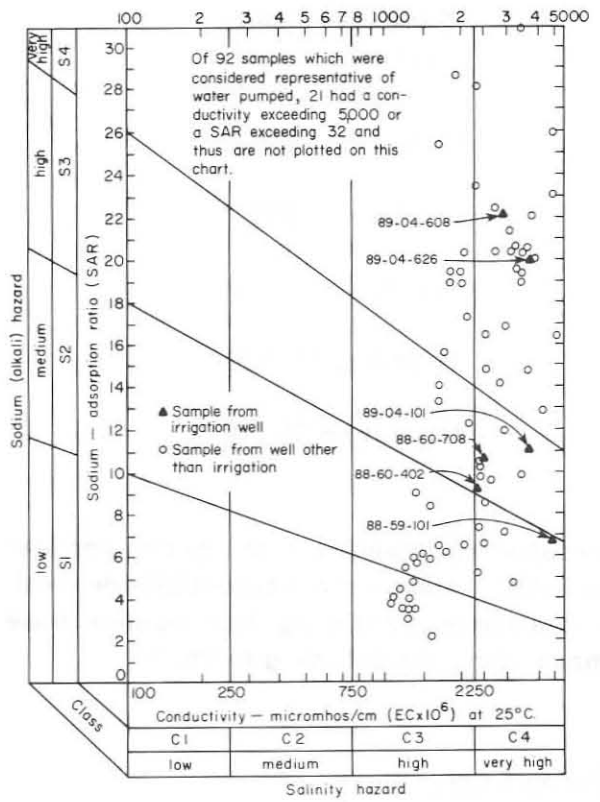


Figure 6.—Classification of Lower Rio Grande Valley Aquifer Waters for Irrigation (After U.S. Salinity Laboratory Staff, 1954, p. 80)

Valley aquifer fall in two salinity hazard classes which are high (C3) and very high (C4). Additionally, the plot shows that waters from the aquifer have sodium hazard classes which range from low (S1) through very high (S4). Based on this information, it is recommended that any waters considered for irrigational purposes to be thoroughly evaluated by experts.

In general, water with low salinity and sodium hazards is suitable for all crops. Water with a high salinity or sodium hazard is unsuitable for continuous irrigation of crops, except for those crops which have a high salinity tolerance and only then under certain ideal soil and drainage conditions. The percent sodium and sodium-adsorption ratio are used to express the relative amount of sodium ions in the water as compared to the amount of calcium and magnesium ions. When water with a high SAR and high percent sodium is placed upon soils which are tight and do not drain well, the sodium ions in the water will replace calcium and magnesium ions in the soil. This tends to make the soil highly plastic and will hinder tilling operations and lower the permeability of the soil.

The residual sodium carbonate (RSC) factor is used in assessing the quality of water for irrigation because excessive sodium carbonate concentrations cause soils to break down and lose their permeability, restricting the movement of air and water. Alkali soils will develop and the soil will lose its ability to support plant life. Wilcox (1955, p. 11) gives the following limits for RSC for irrigation waters: above 2.6 me/l (milliequivalents per liter) is not suitable for irrigation, 1.25 to 2.6 me/l is marginal, and water containing less than 1.25 me/l probably is safe.

The salinity hazard to growing plants is twofold. The first effect of high concentrations of dissolved solids in irrigation water is to disrupt the osmotic exchange of water between the plants and the soil. This osmotic exchange usually consists of water being taken into the plant's root systems, coming from relatively low concentrations of minerals in the soil water to relatively high concentrations within the plant. When the concentration in the soil becomes too high, the plants may lose water, wilt, and even die.

The second effect is the danger of high concentrations of some ions which are toxic to plants. Chloride and sulfate are probably the most injurious ions that are often found in high concentrations in ground water.

Boron in irrigation water is essential to plant growth, but only in very small amounts. A deficiency of boron may seriously injure plants, but on the other hand concentrations as low as 1 mg/l may harm plants which are sensitive to boron. A striking example of this is that lemons show definite and, at times economically important injury when irrigated with water containing 1 mg/l of boron, while alfalfa will make maximum growth with water containing 1 to 2 mg/l of boron. The following table is often used as a guide in rating irrigation water in relation to boron content (Scofield, 1936):

Permissible Limits for Boron of Several Classes of Irrigation Water

Classes of Water		Sensitive crops	Semitolerant crops	Tolerant crops
Rating	Grade	(mg/l)	(mg/l)	(mg/l)
1	Excellent	< 0.33	< 0.67	< 1.00
2	Good	0.33 to 0.67	0.67 to 1.33	1.00 to 2.00
3	Permissible	0.67 to 1.00	1.33 to 2.00	2.00 to 3.00
4	Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
5	Unsuitable	> 1.25	> 2.50	> 3.75

Under most normal conditions of irrigation, however, it is not the quality of the irrigation water that directly affects the growing plants, it is the chemical quality and characteristics of the soil solution (the soil and the water contained in it). The soil solution always contains a higher concentration of minerals than the applied irrigation water, generally 4 to 8 times as much; and in tight soils and fields with poor drainage, irrigation with water of high or even moderate salinity and sodium hazards will only cause further concentration of the problems. Sandy soils with relatively high permeabilities and good drainage will allow the excess mineral content to be flushed or leached out by application of large amounts of water. Because of this, water of even very poor quality may be used for irrigation if the soil conditions are right and care is taken to select crops with high tolerances for the minerals contained in the water.

Industrial

Water that is suitable for industrial use may not be acceptable for human consumption, and different standards may apply for each type of industry. Ground water used for industry may be classified into four principal categories: cooling water, boiler water, process water, and water used for secondary recovery of oil by water injection.

Although cooling water is usually selected on the basis of its temperature and source of supply, its chemical quality is also significant. Any characteristic that may adversely affect the heat-exchange surfaces is undesirable. Substances such as magnesium, calcium, iron, and silica may cause the formation of scale. Another objectionable feature that may be found in cooling water is corrosiveness caused by calcium and magnesium chlorides, sodium chloride in the presence of magnesium, acids, and oxygen and carbon dioxide gases.

Boiler water used for production of steam requires high quality-of-water standards, since extreme temperature and pressure conditions intensify the problems of corrosion and incrustation. Under these conditions the presence of silica is particularly undesirable as it forms a hard scale or incrustation.

Water coming in contact with, or incorporated into, manufactured products is termed "process water" and is subject to a wide range of quality requirements. These requirements involve physical, biological, and chemical factors. Water used in the manufacture of textiles must be low in dissolved-solids content and free of iron and manganese, which could cause staining. The beverage industry normally requires water free of iron, manganese, and organic substances.

Water used for injection in the secondary recovery of oil is generally that water taken from the oil reservoir. However, this water, usually brine, must generally be supplemented in order to meet the requirements of volume. Careful control must be exercised over the injected water with regard to suspended solids, dissolved gases, microbiological growths, and mineral constituents. Suspended solids in the water, of course, can cause plugging of the reservoir. Hydrogen sulfide, carbon dioxide, and oxygen all have corrosive effects on well equipment, and oxygen reacting with the metallic ions, primarily iron, will cause plugging of the reservoir. Organisms such as iron bacteria, algae, and fungi also have an effect of plugging the reservior or pumping equipment, and the sulfate reducers have a corrosive effect. Insofar as the mineral constituents are concerned, iron and manganese are undesirable as they cause plugging in injection wells. Sulfates are of interest from a standpoint of deposition. Water that is high in sulfate should not be mixed with water containing appreciable amounts of barium, because this would result in formation of barium sulfate which has a very low solubility. The pH value is also significant when corrosion control and the solubilities of calcium carbonate and iron are considered. The higher the pH, the more difficult it is to maintain iron in solution and to keep calcium scale from forming.

Public Supply

Through the years, the U.S. Public Health Service established standards for drinking water to be used on common carriers engaged in interstate commerce. These standards were designed primarily to protect the traveling public. Prior to June 1977, they were used extensively to evaluate public water supplies. According to these standards, chemical constituents should not have been present in the water supply in excess of the listed concentrations except where more suitable supplies are not available. Some of the standards initially adopted by the U.S. Public Health Service (1962, p. 7-8) were as follows:

Substance	Concentration (mg/l)
Chloride (Cl)	250
Fluoride (F)	(*)
Iron (Fe)	.3
Manganese (Mn)	.05
Nitrate (NO_3)	45

Substance	Concentration (mg/l)
Sulfate (SO_4)	250
Total dissolved solids	500

* When fluoride was present naturally in drinking water, the concentration could not average more than an appropriate upper limit which ranged from 0.8 to 1.7 mg/l depending upon the annual average of maximum daily air temperatures.

As the first step in setting national standards for drinking water quality and to implement the 1974 Safe Drinking Water Act, the U.S. Environmental Protection Agency (1975) issued drinking water standards on December 10, 1975. The standards apply to all public water systems as of June 1977. These standards are now enforced in Texas by the Texas Department of Health.

The standards which relate to municipal supplies consist of two types, primary and secondary standards (Texas Department of Health, 1977). Primary standards deal with dissolved mineral constituents and regulations affecting the health of system customers. Secondary standards deal with the esthetic qualities of the water. As defined by the Texas Department of Health, municipal systems to which primary and secondary standards selectively apply are classified as three types 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 for 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 defined as any public water system which is not a community water system.

Maximum limits for dissolved minerals set in the primary standards which are applicable to community water systems are as follows:

Contaminant	Maximum level (mg/l)
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	.01

Contaminant	Maximum level (mg/l)
Chromium (Cr^6)	0.05
Lead (Pb)	.05
Mercury (Hg)	.002
Selenium (Se)	.01
Silver (Ag)	.05
Nitrate (as NO_3)	45
Nitrate (as N)	10

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.

The maximum permitted level of fluoride still varies according to the annual average of the maximum daily air temperatures. However, the maximum permitted levels have changed. In the Brownsville area, the maximum limit is 1.4 mg/l.

In addition to the previously stated requirements, limits are set on various organic chemicals and coliform bacteria. Maximum levels for coliform bacteria apply to community and non-community water systems. The organic chemicals include endrin, lindane, toxaphene, 2, 4-D, etc., which are pesticides, and these apply to community water systems. 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.

The recommended secondary standards which are applicable to all public water systems are as follows:

Constituent	Maximum level
Chloride (Cl)	300 mg/l
Color	15 color units
Copper (Cu)	1.0 mg/l
Corrosivity	Non-corrosive
Foaming agents	.5 mg/l

Constituent	Maximum level	
Hydrogen sulfide (H_2S)	0.05	mg/l
Iron (Fe)	.3	mg/l
Manganese (Mn)	.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 were 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.

Water having concentrations of chemical constituents in excess of the recommended limits may be objectionable for many reasons. Brief explanations for these objections, as well as the significance of most of the constituents, are made in Table 1. Additional comments regarding some of the constituents follow.

According to Maxcy (1950, p. 271), water containing nitrate in excess of 45 mg/l has been related to the incidence of infant cyanosis (methemoglobinemia or "blue baby" disease). A high nitrate concentration is often, but not always, indicative of pollution from organic matter, commonly human or livestock wastes. Iron and manganese in excessive concentrations cause reddish-brown or dark-gray precipitates, which stain clothing and plumbing fixtures. Sulfate in water in excess of 250 to 300 mg/l may produce a laxative effect and may have a gypsiferous taste. Water containing chloride exceeding 250 to 300 mg/l may have a salty taste. Fluoride in concentrations of about 1 mg/l may reduce the incidence of tooth decay, but excessive concentrations may cause teeth to become mottled (Dean, Arnold, and Elvove, 1942, p. 1155-1159).

Domestic and Livestock

Ideally, waters used for rural domestic purposes should be as free of contaminants as those used for municipal purposes; however, often this is not economically possible. At present, there are no controls placed on private, domestic or livestock wells. In general, the chemical constituents of waters 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)	1.4*
Iron (Fe)	.3
Manganese (Mn)	.05
Nitrate (as N)	10
Nitrate (as NO_3)	45
Sulfate (SO_4)	300
Dissolved solids	1,000

* Maximum fluoride content based on annual average of maximum daily air temperatures of 84.6 °F (29.2 °C).

Many areas of 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.

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 dissolved solids providing these waters contain mostly sodium and chloride (Hem, 1970, p. 324). Waters 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	Maximum dissolved-solids concentration (mg/l)
Poultry	2,860
Hogs	4,290
Horses	6,435
Cattle (dairy)	7,150
Cattle (beef)	10,000
Adult sheep	12,900

Changes in Chemical Quality

One of the major assets of ground-water supplies is the general uniformity of chemical quality and temperature. Increased demands on an aquifer caused by heavy pumpage, however, may impose new hydrologic conditions on the aquifer which in turn may bring about alteration of the chemical quality of the water produced. This can be dramatically illustrated by the aquifers along the Texas Gulf Coast. The aquifer called the Gulf Coast aquifer consists of several hundred feet of interbedded sands, silts, and shales which dip generally southeast under the Gulf. Under normal conditions, the hydrostatic pressure of fresh water being added to the aquifer's outcrop area keeps the salt water, which occurs far downdip under the Gulf, pushed back and an interface is formed between the two waters. Heavy pumpage along the coast, however, can sufficiently lower the hydrostatic pressure so that salt water invades the zones that formerly contained fresh water. This type of problem is often found in coastal aquifers.

Water stratification within an aquifer may also cause a problem. Often water quality may vary vertically within an aquifer, and usually the poorer quality water will be found lower in the formation. Heavy development and pumping of an aquifer with this type of stratification may bring drastic changes in the quality of water produced as the amount of better quality water is reduced and more and more of the poorer quality water is brought into the wells.

Aquifers are also in danger of contamination from other sources, including man's activities. This is true of all aquifers, but especially of shallow water-table aquifers. Municipal and domestic sewage systems (including septic tanks), the wastes from barnyards and feedlots, industrial wastes, and oil-field brine that is improperly handled or disposed of can enter into ground water and render it unfit for most uses.

Treatment of Water

Water that does not meet the requirements of a municipal or industrial user commonly can be treated by various methods so that it will become usable. Treatment methods include softening, aeration, filtration, cooling, dilution or the blending of poor and good quality waters, and addition of chemicals. In extreme cases, various desalinization processes may be used. These include distillation, reverse osmosis, freezing, electrodialysis, and ion exchange. Although still very expensive, the reverse osmosis and distillation processes have been made increasingly effective and economical during the past few years.

OCCURRENCE AND QUALITY OF GROUND WATER IN BROWNSVILLE AND VICINITY

In Brownsville and vicinity, fresh to saline ground water is produced from alluvial deposits of Pleistocene and Recent (Quaternary) age. Recent alluvial deposits lie at the surface throughout the study area and over most of Cameron County. These fluvial and deltaic sediments are underlain by several thousand feet of very similar but older Quaternary and Tertiary deposits. Regionally, the erratic horizontal and vertical intergradations of beds allow this entire system to interact. Locally, however, individual sand beds or lenses are effectively separated. There is a wide range in water quality within the system, and extreme quality variations occur within very short distances both horizontally and vertically. Within most of the study area, water of usable quality that has been found occurs within the upper 300 feet (91 m) of the section. This system of interbedded clay, silt, sand, and gravel has been designated as the Lower Rio Grande Valley aquifer.

During the course of this study, 168 wells were inventoried (Table 2). All of these wells produce from rocks of the Lower Rio Grande Valley aquifer except for a few oil and gas tests which were inventoried for use of their electric logs. A total of 21 test holes were drilled by the City of Brownsville in conjunction with this study. Electric, gamma ray, and other types of logs were run on these test holes, and 15 of the test holes were cased for use as water level and water quality observation wells. An additional seven irrigation test holes were also inventoried.

Of the remaining wells, 132 were in use during the study. The uses or former uses of the wells are as follows:

Domestic and livestock	55
Industrial	8
Irrigation	55
Public supply	14

The locations of all wells are shown on Figure 13.

A total of 179 water samples were collected from 87 of the wells and test holes during the study. Several duplicate samples were taken from some wells at various time intervals, especially during the pumping tests conducted for the study. These also included samples collected from several depth intervals within the test holes drilled in conjunction with the study. Chemical analyses were performed on these samples by the Texas Department of Health laboratories. These analyses and historical analyses from previous studies and other sources are listed in Table 5.

The wide range in chemical quality of water from the Lower Rio Grande Valley aquifer within the study area is indicated in the table which follows. The table shows the number of analyses within certain ranges of dissolved-solids content and includes analyses collected from the shallow producing zones in the test holes.

Range in dissolved solids (mg/l)	Number of analyses	Percent of total analyses	Cumulative percent
1,000 or less	12	10.9	10.9
1,001 to 2,000	38	34.5	45.4
2,001 to 3,000	23	20.9	66.3
3,001 to 4,000	9	8.2	74.5
4,001 to 5,000	6	5.5	80.0
5,001 to 10,000	15	13.6	93.6
more than 10,000	7	6.4	100.0

The dissolved-solids content of all water samples collected during the study ranged from a minimum of 552 mg/l to a maximum of 37,800 mg/l. Similar variations occur in the concentrations of the individual mineral constituents, especially chloride, sulfate, and sodium as shown below, in mg/l:

Silica	1 to 50	Sulfate	69 to 6,700
Calcium	8 to 1,050	Chloride	62 to 17,900
Magnesium	6 to 1,480	Fluoride	0.6 to 5.6
Sodium	59 to 10,800	Nitrate	0.4 to 14.0
Bicarbonate	17 to 740	Boron	0.5 to 12.6

Iron 0.002 to 21.0

Almost all of the samples contained higher concentrations of chloride, sulfate, and total dissolved solids than is recommended by the Texas Department of Health and the U.S. Environmental Protection Agency under the provisions of the Safe Drinking Water Act of 1974.

In drilling the 21 test holes for the study, each significant producing zone was tested and a water sample collected for chemical analysis. Generally, either two or three producing zones were encountered in each hole.

Shallow Zone.—Within and immediately to the west of Brownsville, there is a shallow water producing zone which occurs at depths of less than 75 feet (23 m). This zone produces limited amounts of very poor quality ground water. Sand thicknesses within this zone are very erratic and the zone probably is not present throughout the entire study area. Eight analyses were run on water from this zone. The content of dissolved solids ranged from 1,170 to 37,800 mg/l. The following table shows the concentrations of selected constituents from these eight analyses representing the shallow zone:

Well	Producing interval (ft)	Chloride (mg/l)	Sulfate (mg/l)	Sodium (mg/l)	Dissolved solids (mg/l)
88-60-806	16-39	17,900	6,300	10,800	37,800
89-04-210	22-45	3,160	2,270	2,330	8,700
89-04-211	46-80	2,500	2,550	2,060	8,000
89-04-302	29-37	209	247	375	1,170
89-04-627	24-46	6,400	6,700	5,800	20,400
89-04-630	22-45	1,310	1,530	1,610	5,000
89-04-632	0-25	990	1,740	1,250	4,750
89-05-405	22-45	6,320	5,200	5,170	18,100

Well 89-04-302 is about 20 feet (6 m) from the Water Conservation and Improvement District No. 6 canal which carries Rio Grande water to Olmito and Los Fresnos, and probably received surface water from leaks in the canal. Because of the great difference in quality of water in this shallow zone and in underlying zones, it seems that, at least locally, the shallow zone is effectively separated hydrologically. Any change in the hydraulic balance, however, might tend to cause some migration of water between the zones. The very poor quality water contained in the shallow zone may be attributed to several sources. Among these are sea water blown from the Gulf of Mexico during tropical storms and hurricanes, leaching of minerals deposited on the salt flats, and the concentration of minerals caused by evaporation and plant usage of the water through osmosis and transpiration.

Middle Zone.—Between depths of 75 and 150 feet (23 and 46 m), most of the test holes penetrated one or more water-bearing sand beds which will be referred to as the middle zone. Much like in the shallow zone, occurrence and thickness of individual sand beds was very erratic as would be expected in this type of sediments. General conclusions on the quality of water produced from this middle zone can be drawn, however. Fifteen water samples for chemical analyses were collected from the zone during the test hole drilling program. In addition, seven samples were analyzed which came from existing wells producing from sands in this zone. The occurrence and thickness of sand within this interval seemed much more erratic than in the upper zone. Perhaps because of this, variations in water quality also seemed highly erratic. Generally, however, concentrations of dissolved solids and chloride appear to increase to the east and southeast. Ranges of concentration of the major chemical constituents in water samples from the middle zone were as follows, in mg/l:

Silica	20 to 50	Sulfate	210 to 5,240
Calcium	8 to 680	Chloride	112 to 5,730
Magnesium	6 to 392	Fluoride	1.0 to 2.7
Sodium	259 to 3,860	Nitrate	0.4 to 15.0
Bicarbonate	282 to 660	Boron	0.8 to 12.5

The concentration of dissolved solids ranged from 1,180 to 13,450 mg/l and iron from 0.04 to 7.15 mg/l. Of the nine samples in which dissolved solids exceeded 5,000 mg/l, only those from two wells, 89-04-209 and 89-05-102, were from sands in excess of 100 feet (30 m) in depth. It seems probable that most of the sand beds within this middle zone which produce ground water with relatively high concentrations of dissolved solids, sodium, chloride, and sulfate may be in more or less direct hydraulic contact with the beds in the shallow zone which contain highly mineralized water. Thus, the middle zone may represent a transitional interval between the shallow zone containing highly saline water in the area just west of Brownsville and a deep zone which contains water that is generally of much better quality within this area.

Deep Zone.—All of the major wells (irrigation, industrial, and public supply) and most of the smaller capacity domestic and livestock wells in the study area produce water from sand and gravel beds in the 150 to 225 foot (46 to 69 m) depth interval which will be referred to as the deep zone. In the northwestern part of the area, a few wells do produce ground water of relatively good quality from still deeper zones. Well 88-60-708, for example, produces water containing less than 2,000 mg/l dissolved solids from the 250 to 271 foot (76 to 83 m) interval. In the area just to the west of the City of Brownsville and within the city limits, however, only minor amounts of very poor quality ground water occur at depths greater than 225 feet (69 m).

Samples from 75 wells and test holes which were completed at depths greater than 150 feet (46 m) were collected and analyzed during this study. In test hole 89-04-631, samples were collected from two producing zones deeper than 150 feet (46 m). The dissolved-solids content in the 76 analyses representing the deep zone ranged from a minimum of 770 mg/l to a maximum of 11,900 mg/l, and the number of analyses within certain salinity ranges was as follows:

Range in dissolved solids (mg/l)	Number of analyses	Percent of total analyses	Cumulative percent
1,000 or less	11	14.5	14.5
1,001 to 2,000	27	35.5	50.0
2,001 to 3,000	21	27.6	77.6
3,001 to 4,000	5	6.6	84.2
4,001 to 5,000	4	5.3	89.5
5,001 to 7,500	5	6.6	96.1
7,501 to 10,000	2	2.6	98.7
more than 10,000	1	1.3	100.00

Ranges of concentration for individual mineral constituents in the analyses of water from the deep zone are as follows, in mg/l:

Silica	1 to 46	Bicarbonate	17 to 640
Calcium	16 to 510	Sulfate	171 to 2,080
Magnesium	14 to 370	Chloride	83 to 5,430
Sodium	127 to 3,260	Fluoride	0.6 to 3.5
Boron	0.5 to 6.6	Nitrate	0.4 to 7.0
Iron	0.002 to 9.0		

A definite regional pattern is present in the quality distribution of ground water produced from the deep zone, as shown in Figures 7, 8, and 9. They show lines connecting equal concentrations of dissolved solids, chloride, and sulfate, respectively. Essentially the same pattern of distribution is readily discernable on each of the three maps. The best quality water is found in the most westerly part of the study area along the Rio Grande. Here several wells produce water containing less than 1,000 mg/l dissolved solids from sand and gravel beds within the deep zone. Concentrations of sulfate, chloride, and sodium are also generally very low relative to concentrations in water from wells to the east and northeast. From this relatively limited area of good quality water, the salinity of ground water produced from the deep zone increases steadily toward the southeast, east, northeast, and north, especially in the concentrations of sodium, sulfate, chloride, and dissolved solids. This increase is generally gradual toward the east at least into the western part of the City of Brownsville. From the city well field in the northwest part of the city, however, significant salinity increases take place within very short distances to the northeast,

east, and southeast. Water produced from city well 5 (well 89-04-616) contained a chloride concentration of 670 mg/l, sodium concentration of 730 mg/l, and dissolved-solids concentration of 2,370 mg/l in a sample collected May 3, 1973. Water produced from about the same depth interval from test hole 8 (89-05-102), which is located 3.1 miles (5.0 km) northeast of city well 5, was more than twice as saline as the water from city well 5. Test hole 1 (89-05-404), located at City Water Plant Number 2 about 3.5 miles (5.6 km) east of city well number 5, and test hole 13 (89-04-903), located in Amigoland only 2.6 miles (4.2 km) south-southeast of city well 5, show even more drastic deterioration in the quality of water produced from the same zone. The following table shows the concentrations of chloride, sulfate, sodium, and dissolved-solids from city well 5, these three test holes, and other wells and test holes which indicate the rapid worsening in ground-water quality from the west side of the City of Brownsville toward the north, east, and southeast.

Well	Date of sample	Sodium (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Dissolved Solids (mg/l)
89-04-616	May 3, 1973	730	670	560	2,370
89-04-631	Apr. 21, 1973	1,650	1,320	2,300	5,930
89-04-903	Apr. 21, 1973	3,260	3,080	5,430	11,900
89-05-101	Oct. 19, 1972	1,790	1,660	2,070	6,200
89-05-102	Mar. 24, 1973	1,530	1,260	1,870	5,200
89-05-201	Oct. 17, 1972	2,150	1,680	2,980	7,500
89-05-404	Apr. 23, 1973	2,430	1,470	4,230	9,070
89-05-701	Apr. 19, 1973	2,340	1,530	3,760	8,490

From this table it is apparent that the increase in chloride concentration is much more drastic than the increase in sodium or sulfate concentration, as might be expected if this increase is a result of mixing with sea water. This increase probably continues from Brownsville toward the Laguna Madre and the Gulf of Mexico, as several test holes which had previously been drilled between Brownsville and Port Isabel and Boca Chica were reported to yield only highly saline water.

GROUND-WATER AVAILABILITY IN THE LOWER RIO GRANDE VALLEY AQUIFER

Occurrence

Within the Lower Rio Grande Valley aquifer, ground water occurs within the pore spaces of the various unconsolidated or very slightly consolidated beds of clay, silt, sand, and gravel which make up the aquifer. Even though the entire section is usually saturated to within a few inches or at most a few feet of the land surface, little or no water can be derived from much of the section. The extremely small pore spaces in the clay and silt portions of the section prevent the movement of sufficient quantities of water to a well, even though the clay may contain much more water than nearby sands. Therefore, most wells are completed in beds of sand or gravel.

Because of the highly complex nature of the system of deltaic and fluvial sediments which make up the Lower Rio Grande Valley aquifer, the character of individual beds often changes quickly, both laterally and vertically. The complex intergradation and interfingering of the beds of the various sediment types (clay, sand, silt, gravel) not only control the availability of water to wells, but also cause significant changes in water quality over very short distances.

Recharge, Movement, and Discharge

Recharge of water to the Lower Rio Grande Valley aquifer is derived from rainfall on the outcrop and from seepage of surface waters where the Rio Grande and other streams (mostly resacas or meander scars) cross the outcrop of sediments with relatively high permeability. In the immediate vicinity of the City of Brownsville, the shallow water-producing zone, which is less than 75 feet (23 m) in depth, contains extremely poor quality water (dissolved-solids content in excess of 30,000 mg/l in one sample). This indicates that in this immediate area direct downward percolation of precipitation is not the prime source of recharge to the major producing zone which contains better quality water between depths of 150 and 225 feet (46 and 69 m). Surface-water flow records for the Rio Grande indicate that there are significant water losses, especially during drought conditions, between Brownsville and the upstream measuring stations. Water-level data, as shown on Figure 10, indicate that the Rio Grande is losing water from a point near the City of Landrum to the west edge of the City of Brownsville. It seems probable that these streamflow losses are the source of much of the recharge to the major producing zone (deep zone) of the Lower Rio Grande Valley aquifer within the study area. Water-quality maps (Figures 7, 8, and 9) also show possible indications of recharge of water of better quality, particularly in three areas. The first is at Villa Nueva, the Los Fresnos Pump Station, and the settling basin just north of the Los Fresnos Pump Station. Recharge by river water in this area is a possible explanation of the seemingly isolated area of better quality water outlined on Figure 11 as Area 3. The second area is just east and northeast of San Pedro. The third area is at Los Indios in the westernmost part of the study area. Here two large settling basins seem to be losing river water to the deep zone. Recharge from this source seems to be at least partially responsible for the good quality of water in the deep zone in Area 1 of Figure 11.

Generally speaking, ground-water movement is in the direction of slope of the potentiometric surface as determined from water levels in wells and is from areas of recharge to areas of discharge. Within the Lower Rio Grande Valley aquifer, movement of ground water is generally to the southeast and east toward the coast (Figure 10). The gradient of the potentiometric surface is generally less than 10 feet per mile (2 m/km). Heavy withdrawals, however, would probably cause some reversal of the normal direction of flow and might easily lead to updip migration of poor quality water. Additionally, deterioration of existing well casing or lack of adequate casing might also allow upward migration of water under artesian pressure into overlying beds that may be under lower artesian pressure or water-table conditions.

Water is removed from the Lower Rio Grande Valley aquifer by both natural and artificial discharge. Natural discharge in this area is generally confined to underflow and local return flow to the Rio Grande (there is possibly some springflow, but only in very limited amounts), underflow toward and under the coast, and, of course, evaporation and transpiration losses. Losses from evapotranspiration are probably significant in the study area, because of the relatively low precipitation rate, the high rate of evaporation, and the high water table. Artificially, water is discharged through wells by pumping.

Losses of artesian pressure in the vicinity of heavily pumped wells may also allow increased downward percolation of water from upper zones into the pumped zone. This may be a problem where casing has deteriorated and saline water is present in upper zones. This may lead to water-quality problems, especially in the eastern part of the study area where very poor quality water overlies the major producing zone.

Aquifer Characteristics

Various calculation of the hydraulic characteristics of the sands and gravels which make up the Lower Rio Grande Valley aquifer have been performed in the past. These indicate a wide range in transmissibility, permeability, and storage coefficients for these sediments. Tests conducted by U.S. Geological Survey personnel on wells belonging to the City of Harlingen indicated an average of 54,000 (gal/d)/ft [671,000 (l/d)/m] for the coefficient of transmissibility, 900 (gal/d)/ft^2 [36,700 (l/d)/m^2] for the coefficient of permeability, and 0.00044 for the coefficient of storage.

Two comprehensive pumping tests were conducted on wells producing from the Lower Rio Grande Valley aquifer during this study. These tests were analyzed using the leaky artesian formula (Walton, 1962). The first of these tests was conducted using one of the City of Brownsville public supply wells (city well 5, which is well 89-04-616) as a pumping well. Other nearby city wells and two cased test holes (drilled for this study) were used as water-level observation wells for the test. Data from this test indicate an average aquifer coefficient of transmissibility of 80,000 (gal/d)/ft [993,000 (l/d)/m] and an average coefficient of storage of 0.000025. All of these wells were slotted within the 150 to 200 foot (46 to 61 m) depth interval and are within the City of Brownsville's well field in the northwest part of the city.

The second pumping test was conducted using an irrigation well, 88-60-708, located about 8 ½ miles (13.7 km) northwest of the city well field, as the pumped well. Several nearby irrigation wells and one test hole drilled for the study were used as water-level observation wells during the test. Average aquifer coefficients calculated from the results of this test were transmissibility, 100,000 (gal/d)/ft [1,240,000 (l/d)/m] and storage, 0.0016.

Well Construction and Yields

Many existing wells within the study area are used for domestic or livestock supply. These wells were generally drilled with a rotary rig and are cased with small diameter, 3 to 5 inch (7.6 to 12.7 cm), steel or plastic casing. A few are equipped with factory manufactured screens, but most are either torch or hacksaw slotted. The steel casing deteriorates rapidly, especially in areas where very poor quality water occurs in the shallow zone. Most of these wells are equipped with 1/3, 1/2, or 3/4 horsepower electric jet or submersible pumps which produce 10 gallons per minute (0.63 l/s) or less. In the future, plastic casing would be preferable, unless the steel casing is cemented through the shallow water-bearing zones. Factory screens should also be used because of the extremely fine sands encountered in most of the area.

Larger capacity wells have been constructed in several ways, depending on the intended use. Most irrigation wells were drilled 12 to 20 inches (30.5 to 50.8 cm) in diameter and cased with 10 to 18 inch (25.4 to 45.7 cm) steel casing. This casing was usually torch slotted within the producing interval. Occasionally, these irrigation wells were gravel packed. Public supply wells were drilled with similar diameters and were almost always gravel packed. Public supply wells were usually completed with factory screens. Both irrigation and public supply wells are usually equipped with large-capacity turbine pumps powered with electricity or butane. Motor horsepower ranges from 10 to more than 80 (7,500 to more than 59,700 w). Production capacity ranges up to about 2,500 gallons per minute (158 l/s) with an average rate of about 1,000 gallons per minute (63 l/s).

All future large capacity wells (irrigation, industrial, or public supply) should be drilled with a large diameter, possibly in excess of 20 inches (50.8 cm), especially through the shallow water-producing zone which usually contains poor quality water. Large-diameter surface casing should be set and cemented through this zone. The well could then be completed at a diameter slightly smaller than the surface casing. High-capacity wells should be underreamed with the producing horizon, and equipped with factory screens selected according to grain-size analyses of formation samples from the producing zones. All wells should be gravel packed using a graded gravel of optimum size as indicated by grain-size analyses of samples from the producing zone. In general, pump sizes should be selected to keep the capacity of individual wells below 1,000 gallons per minute (63 l/s). Some typical well constructions are illustrated on Figure 12.

Availability

Large amounts of ground water are contained in the Lower Rio Grande Valley aquifer within the study area. Useful production of much of this water is impractical, however, not only because of the poor quality of much of the water, but also because of severe limitations in the yields of wells completed in the shallow and middle zones of the aquifer.

At least 350,000 acre-feet (432 hm^3) of fresh to slightly saline ground water (containing less than 3,000 mg/l dissolved solids) is in storage within the deep zone of the aquifer. This total was derived using the area within the 3,000 mg/l dissolved solids contour on Figure 7 which is about 100 square miles (259 km^2), a net sand and gravel thickness of about 35 feet (11 m) in the deep zone within this area, and a conservative figure for porosity of 15 percent. A relatively large part of this water should be available for development from the aquifer on a continuing basis.

In order to determine what effects heavy prolonged pumpage would have on the aquifer, a series of computer simulations were conducted using a well field drawdown model, IMAGEW-1 (Texas Water Development Board, 1973). Using the aquifer characteristics calculated from the pumping tests performed for the study, simulations were run using the present city wells, other more ideally located wells within the western part of Brownsville, and several irrigation wells located about 8 miles (12.9 km) to the west of the city as producing wells. The series of simulations included rates of pumpage for each set of wells varying from 1.5 million to 9.0 million gallons per day (5.7 million to 34.1 million l/d).

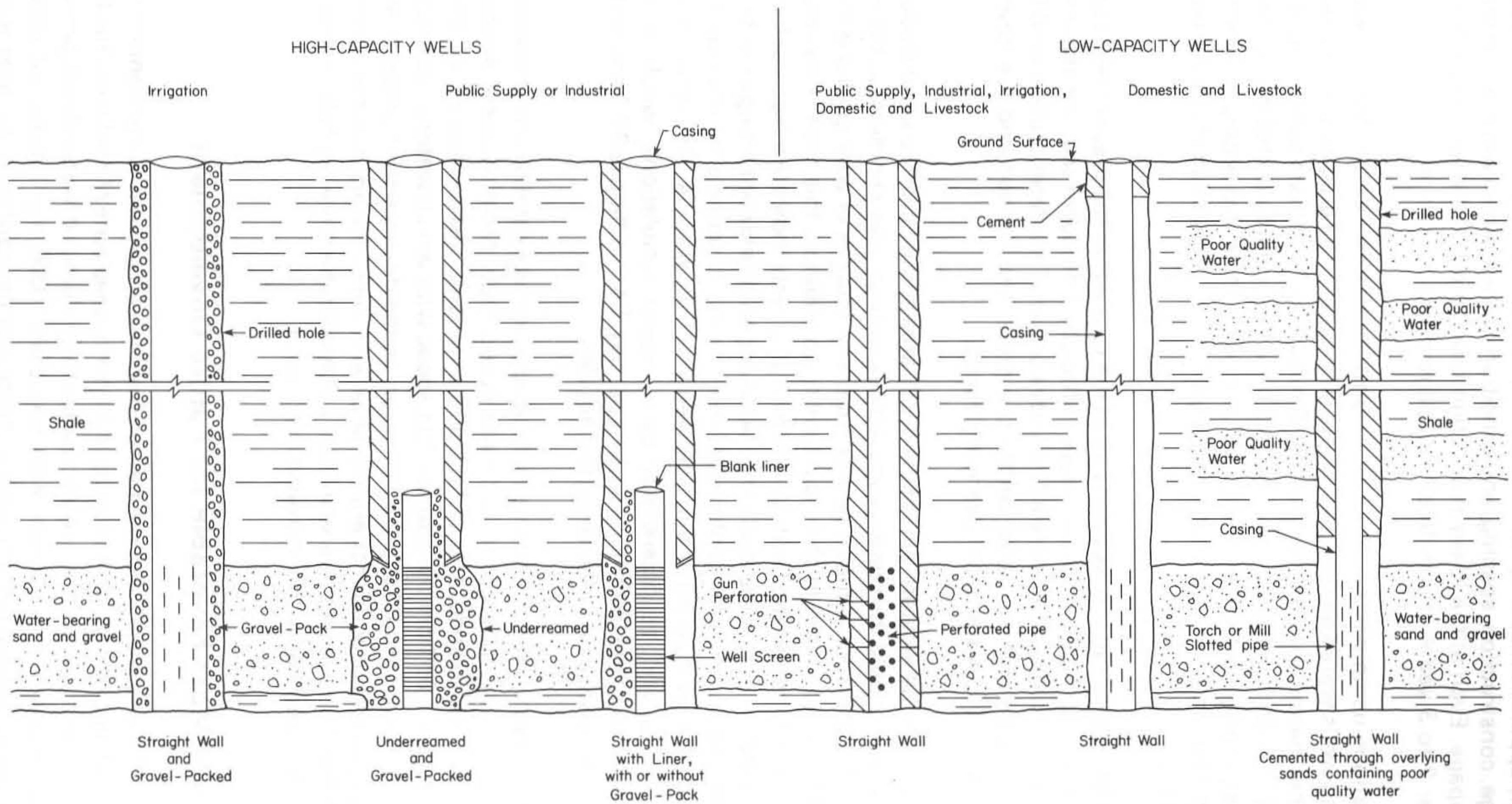


Figure 12

Typical Well Construction Used to Produce Water From Sand and Gravel in Brownsville and Vicinity

It was immediately apparent that the present city well field of Brownsville was not suitable for long-term use. The age, construction, spacing, and condition of these seven wells would preclude prolonged heavy pumpage. Even at the lower production rates, projected water levels fell below the pump setting after 2 to 3 years of simulated pumpage using the city well field.

Additional simulations using wells laid out in a north-south line through the city well field were conducted. These wells were spaced 2,000 feet (610 m) apart. The gradual development of a well field laid out in this manner could supply from 1.5 million to 7.5 million gallons per day (5.7 million to 28.4 million l/d). With optimum spacing, only six wells could be drilled within this area, and after 7 to 10 years the projected water levels would be below the pump settings in the present city wells and the decline of water levels would seriously affect the production of water from wells completed in the deep zone.

Any well field developed within the western part of the city, either the present wells or wells drilled with optimum spacing, would probably cause sufficient drawdown to bring about significant deterioration of water quality after only a few years of use. This deterioration could result from updip migration of poor quality water within the producing horizon and the downward percolation of very poor quality water from overlying zones.

A well field developed in the western part of the study area should provide several additional benefits, however. Not only should the water produced over a large area contain less than 2,000 mg/l dissolved solids, but the area is much farther from any sources of poor quality water that might eventually lead to deterioration in chemical quality. In addition, this area is also closer to probable areas of recharge from the Rio Grande, and pumping tests indicate a high coefficient of transmissibility in the western part of the study area. An elongated field containing at least 8 to 10 wells could be developed within the area containing fresh to slightly saline ground water and still maintain spacing of 2,000 feet (610 m) or more between individual wells. This would minimize interference between wells and, as determined by computer simulations, would allow the production of at least 9.0 million to 10.0 million gallons per day (34.1 million to 37.9 million l/d) on a long-term basis without disastrous effects on the aquifer.

Since the aquifer is practically full and in a state of approximate equilibrium, any significant increase in pumpage should bring about an increase in recharge. Most recharge seems to be derived directly from the Rio Grande; therefore, there should almost always be an adequate source to replace water removed from the aquifer. The speed with which water is replenished to the aquifer at pumping locations would depend, however, on the distance from areas of recharge to areas of pumpage as well as the aquifer characteristics, and computer simulations indicate that after initiation of additional pumpage there would be a considerable time lag before water-level drawdowns in wells are modified by the increased recharge.

Areas Most Favorable for Future Development

On Figure 11, broad areas have been delineated from which ground water containing less than 2,000 mg/l of dissolved solids can be developed from the deep zone of the Lower Rio Grande Valley aquifer. Area 1 on this map is the first choice for future ground-water development. Not only is much of the area underlain by water with less than 1,000 mg/l dissolved solids, but computer simulations and pumping tests of wells indicate that the aquifer in this area is capable of yielding in excess of 10 million gallons per day (37.9 million l/d) over a prolonged period. In addition, this area is located at some distance from any known sources of poor quality water. Also, the area is favorably located along the Rio Grande, which is thought to be the prime source of recharge to the aquifer, and the configuration of the contours on the water-quality and water-level maps (Figures 7, 8, 9, and 10) seem to indicate that the aquifer is receiving additional recharge from the lakes or settling basins located just northeast of Los Indios.

Areas 2 and 3, also outlined on Figure 11, are not as desirable for future development as Area 1 because of their limited extent and proximity to areas containing poor quality water. Both areas, however, offer suitable sites for the development of ground water.

Bordering the southeast edge of Area 3, a small region within the western part of the City of Brownsville might also be suitable for limited and short-term development. This region includes the city well field and extends to the northeast and southwest. Ground water which might be produced from this area should initially have less than 2,500 mg/l of dissolved solids. The quality might soon deteriorate, however, because of the proximity of this area to areas containing water of much poorer quality.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Large amounts of ground water are in storage in the upper 225 feet (69 m) of the Lower Rio Grande Valley aquifer within the immediate vicinity of Brownsville. In this area, the aquifer may be considered to consist of three more or less separate producing zones, which can generally be differentiated both by water-producing characteristics (transmissibility, net sand thickness, particle sizes, etc.) and chemical quality of the produced water. These zones include a shallow zone (0 to 75 feet deep, or 0 to 23 m) and a middle zone (75 to 150 feet or 23 to 46 m) which produce only limited amounts of ground water, often of poor quality. The quality of water produced from the shallow zone is especially poor over much of the area; two wells produced water with dissolved-solids concentrations in excess of 20,000 mg/l. The deep zone (150 to 225 feet or 46 to 69 m) is capable of producing large amounts of water, and over much of the study area the produced water contains dissolved-solids concentrations of less than 3,000 mg/l.

Although the availability of ground water from the deep zone in the Brownsville area is also restricted by water-quality problems, at least 350,000 acre-feet (432 hm^3) of fresh to slightly saline ground water is estimated to be in storage in the deep zone of the Lower Rio Grande Valley aquifer within the study area. The high transmissibility of the sands and gravels within this zone should allow the development of a large part of this water for irrigation use, and with proper treatment, possibly including desalination in some areas, for municipal and industrial supplies as well.

Because of the extremely complex nature of the aquifer, future ground-water development should be based on a program of preliminary test-hole drilling and test pumping, chemical analyses of water from the various sands, optimum well completion, and the spacing of wells to avoid large concentrated withdrawals of ground water in small areas.

Since the aquifer is at present essentially in a state of equilibrium, any significant increase in ground-water withdrawals should result in increased recharge of surface water into the aquifer, both directly from the Rio Grande and the numerous resacas, and from the several municipal and irrigation district lakes or holding basins. A considerable time lag should be evident between initiation of additional pumpage and modification of resulting drawdowns by the increased recharge, however.

If at all possible, most future development of large-capacity wells, especially for public supply, should be confined to Areas 1, 2, and 3, as outlined on Figure 11, with Area 1 being the most preferred. Development from these areas should at least minimize the updip migration of very poor quality water which is contained within the deep zone in the east and north parts of the study area.

Extreme care should be exercised in the drilling, casing, and completion of wells in the region, especially in areas where the shallow zone (0 to 75 feet deep, or 0 to 23 m) contains highly mineralized water. All wells should be cemented through the upper water-bearing zones that are not intended to be developed. Use of plastic casing in small-diameter wells would also help to minimize deterioration of casing by these highly saline waters and the possible resulting contamination of better quality water in the main producing zone.

All new large-capacity wells, especially those for municipal supply, should be underreamed and gravel packed. Because of the extremely fine, well sorted sands which occur through much of the section in this area, factory manufactured screens should be placed in all new wells. If at all possible formation samples should be analyzed to determine the optimum slot size to prevent the abrasive fine sands from entering the wells. Many wells and pumps have been lost in the past as a result of torch or hacksaw slotted casing.

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Table 2.--Records of Wells and Test Holes

All wells are drilled unless otherwise noted in the remarks column.
Water Level : Reported water levels are given in feet; measured water levels are given in feet and tenths of feet.
Method of lift and type of power: C, cylinder; Cf, centrifugal; E, electric; G, gasoline, oil, butane, or diesel engine; N, none; Sub, submersible; T, turbine; W, windmill. Number indicates horsepower.
Use of water : D, domestic; Ind, industrial; Irr, irrigation; J, jet; N, none; P, public supply; S, livestock.
Water-bearing unit : LRGV, Lower Rio Grande Valley aquifer.

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
* 88-59-101	Oscar Thiems	A & T Drilling Co.	1952	168	12	168	LRGV	51	27.6 3/	Sept. 12, 1957	T,E, 50	Irr	Yearly observation well. Yield 886 gal/min by U.S. Geological Survey measurement. 1/	F-83
102	Jack Garrett	do	1952	394	12	200	do	49	18.9 3/	July 24, 1952	T,G, 72	Irr	Yearly observation well. 2/	F-46
* 103	Emil Kaufman	Waldrey & Morrow	1944	151	3	151	do	51	6	Jan. 1944	J,E, 1	D	--	K-1
104	B. F. Morrow	A & T Drilling Co.	1952	163	12	162	do	50	--	--	T,G, 72	Irr	1/	F-50
* 105	C. D. Echols	Odie Gilliland	1953	164	2	164	do	53	--	--	J,E, 1	D	1/	--
106	V. E. Morrow	A & T Drilling Co.	1952	257	12	256	do	49	--	--	T,G, 72	Irr	Reported yield 900 gal/min.	F-47
107	C. D. Echols	do	1962	169	12	169	do	51	137	Oct. 27, 1962	T,G, 75	N	Unused irrigation well. 1/	
201	D. H. Palmer	Virdell Drilling Co.	1952	166	12	166	do	49	17.7 3/	Aug. 19, 1952	T,B, 75	Irr	1/	F-44
202	T. Kawamara	Tom Wilkinson	1952	346	12	346	do	52	29.4 3/	Sept. 12, 1957	T,B, 55	Irr	Yearly observation well. 1/	F-68
203	Able Suarez	--	1956	160	12	160	do	50	--	--	T,B, 60	Irr	--	--
* 204	W. D. Todd	Powell Drilling Co.	1968	166	2	166	do	50	--	--	J,E, 1-1/2	D	--	--
205	do	A & T Drilling Co.	1952	185	12	185	do	47	20 15.4	1952 Sept. 25, 1972	T,G, 65	Irr	Reported yield 800 gal/min. 1/	K-5
206	T. Oyama	Tom Wilkinson	1952	200	12	200	do	53	20	1952	T,G, 145	Irr	Reported yield 1,000 gal/min. 1/	F-54
207	T. Date	Tom Wilkinson	1952	200	12	200	do	52	--	--	T,G, 75	Irr	1/	F-75
208	Herman Johnson	do	1952	194	12	194	do	52	22.1	June 25, 1952	T,G, 65	Irr	Reported yield 800 gal/min. 1/	F-81
209	George Oyama	do	1952	201	12	201	do	53	26.4	do	T,G, 145	Irr	Reported yield 994 gal/min. 1/	F-80
210	Ray McDonald	do	1952	212	12	206	do	47	--	--	T,G, 65	Irr	Reported yield 850 gal/min. 1/	F-55
301	G. W. McCain	do	1952	180	12	180	do	44	10 30 15.6	1952 May 1954 Mar. 2, 1959	T,G, 75	Irr	1/	F-57

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
88-59-302	Guadalupe Garza	Powell Drilling Co.	1968	120	2	103	LRGV	40	15	Apr. 16, 1968	J,E, 1/2	D	Not presently used, no electricity. 1/	--
303	John Scaief	--	1952	165	12	165	do	48	--	--	T,G, 55	N	Former irrigation well.	--
304	George W. Gamble	A & T Drilling Co.	1948	464	14	328	do	47	22	1948	T,G, 55	Irr	2/	F-63
305	G. W. McCain	do	1948	310	12	310	do	45	--	--	T,G, 54	Irr	Reported yield 450 gal/min. 2/	F-62
306	do	Tom Wilkinson	1952	386	12	385	do	46	19	1952	T,E, 75	Irr	Reported yield 1,750 gal/min. 1/	F-61
401	Tom Tanamachi	Gene Liberty	1952	160	12	160	do	55	16.3 3/	Mar. 2, 1959	T,B, 145	Irr	Yearly observation well. Reported yield 900 gal/min.	K-15
402	Steve Gallaway	do	1952	160	10	160	do	52	10.1	Sept. 28, 1972	T,G, 50	Irr	Reported yield 650 gal/min.	K-17
403	Edward E. Billings	--	1957	176	12	176	do	57	13.5	Oct. 18, 1972	T,E, 50	Irr	--	--
404	Ricardo Aquilar	Tom Wilkinson	1952	174	12	174	do	55	13.0	Sept. 20, 1972	T,G, 50	Irr	Yield 560 gal/min by U.S. Geological Survey measurement.	K-16
405	M. de los Santos	do	1952	184	12	184	do	49	--	--	T,G, 65	Irr	1/	K-14
* 502	O. W. Tucker	do	1952	200	12	200	do	45	18.9 3/	Sept. 4, 1952	T,G, -	Irr	Yearly observation well. Reported yield 770 gal/min. 1/	K-11
* 503	B. H. Barlow	Powell Drilling Co.	1968	150	2	150	do	46	16	Apr. 29, 1968	J,E, 2	D	1/	--
* 504	R. C. Carmichael	Odie Gilliland	1972	150	2	150	do	48	15	Mar. 5, 1972	J,E, 1	D	--	--
505	Johnny T. Pitts	A & T Drilling Co.	1953	177	16	175	do	45	--	--	T,G, 50	N	Former irrigation well. 1/	--
506	Bent M. Crawford	O. B. Martin	1952	184	12	184	do	45	32	1970	T,G, 50	Irr	--	--
507	Mary E. Coakley	Tom Wilkinson	1952	199	12	199	do	46	6.0	Oct. 17, 1952	T,G, 50	N	Former irrigation well. 1/	K-13
508	L. C. Poth	A & T Drilling Co.	1948	290	14	290	do	48	18	1948	T,G	N	Former irrigation well. 2/	K-3
601	-- Furukawa	do	1953	190	12	190	do	48	32 34 19	May 1954 Aug. 30, 1957 Mar. 2, 1959	T,G	Irr	1/	K-52
602	La Paloma School	--	1939	150	2	150	do	46	--	--	N	N	Former school supply. Sandpoint well.	K-23
* 603	R. L. McGarr	Odie Gilliland	1969	172	2	172	do	49	19	Oct. 7, 1969	J,E, 3/4	D	1/	--
604	Robert N. Jonies	--	1952	180	20	180	do	45	11.5	Oct. 16, 1972	T,E, 50	Irr	--	--
* 605	Island Farms, Inc.	--	1952	200	5	200	do	45	17.3	Oct. 19, 1972	S,E, 3	Ind	Supplies feedlot.	--

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
88-59-607	G. B. Smith	A & T Drilling Co.	1952	174	16	174	LRGV	47	20 25	May 5, 1952 May 1954	T,E, 50	Irr	Reported yield 950 gal/min. 1/	K-10
* 701	J. W. Meadows	Odie Gilliland	1963	170	2	170	do	55	15	Sept. 28, 1972	J,E, 1	D	--	--
702	do	A & T Drilling Co.	1952	173	12	173	do	41	15.1	do	T,G, 70	N	Former irrigation well. Yield 868 gal/min by U.S. Geological Survey measurement. 1/	K-18
801	Jack Garrett	do	1952	306	--	--	do	47	--	--	N	N	Irrigation test hole. 2/	K-21
* 901	Encantada School	--	1934	750	2	--	do	47	18	Apr. 17, 1941	N	N	Abandoned.	K-28
* 902	Ernesto Garcia	Powell Drilling Co.	1970	170	2	170	do	45	22	Dec. 4, 1970	J,E	D	1/	--
* 903	Pablo Escamille	Odie Gilliland	1971	175	2	175	do	46	28 16.9	July 30, 1971 Sept. 19, 1972	J,E, 1/2	D,S	1/	--
* 904	Carlos Zepeda	do	1968	169	2	169	do	43	16	Apr. 9, 1968	J,E, 3/4	S	1/	--
* 905	do	do	1968	175	2	167	do	47	17	Apr. 2, 1968	J,E, 1	Ind	1/	--
* 906	Dionicio Esparza	do	1967	172	2	172	do	49	32	May 14, 1967	J,E, 1	D	1/	--
* 907	do	do	1968	176	2	176	do	47	16	Apr. 5, 1968	J,E, 3/4	D	1/	--
* 908	Mrs. R. T. Leal	do	1966	183	2	183	do	51	35	May 31, 1966	J,E, 3/4	D	1/	--
909	Irima Garcia	do	1970	178	2	175	do	46	18	Dec. 20, 1969	J,E, 3/4	D	1/	--
* 910	Salvador Perez	do	1968	156	2	148	do	50	17	Apr. 6, 1968	J,E, 1	D	1/	--
911	Jose Escamilla	Henry Cleveland	1952	295	20	295	do	49	--	--	T,G, 85	Irr	2/	K-25
912	Lee Joe Wood	do	1952	260	16	260	do	51	33	Apr. 1954	T	Irr	1/	K-51
913	Carlos Zepeda	do	1952	275	12	275	do	48	--	--	T,E, 50	Irr	Reported yield 850 gal/min. 2/	K-27
* 60-101	Louis Stanley	do	1952	174	12	174	do	40	27.4 3/	Sept. 12, 1957	J,E	D,S	Yearly observation well. (Former irrigation well. Yield with 75 hp turbine 700 gal/min by U.S. Geological Survey measurement. 1/	F-78
* 102	Pilar Cabrera	Odie Gilliland	--	200	2	--	do	34	--	--	J,E, 3/4	S	--	--
* 401	J. G. Ballinger	A & T Drilling Co.	1951	204	14	204	do	34	12.3 3/	Mar. 2, 1959	T,E, 75	Irr	Yearly observation well. Yield 2,097 gal/min by U.S. Geological Survey measurement. 1/	--
* 402	Sam Porter Corp.	do	1953	200	16	200	do	44	--	--	T,E, 75	Irr	--	--
403	Pilar Cabrera	Henry Cleveland	1952	303	20	303	do	49	--	--	T,G, 97	Irr	2/	K-6

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
88-60-404	E. A. Brady	A & T Drilling Co.	1953	186	16	186	LRGV	35	28	July 3, 1957	T, E, 75	Irr	2/	K-54
405	Rice Tract Community Well 1	Russell Plantation	1955	9,552	--	--	--	--	--	--	N	N	Oil test hole. 2/	K-57
406	Lyle and Smith	A & T Drilling Co.	1953	360	16	360	LRGV	38	30	July 3, 1957	T, E	Irr	2/	K-55
501	Barreda Estate	Tom Wilkinson	1952	235	12	235	do	42	7.5	Sept. 21, 1972	T(N)	N	Former irrigation well	K-7
* 502	Jim Brooks	Odie Gilliland	1970	166	2	166	do	35	8	Aug. 1970	J, E	D	--	--
503	A. H. Fernandez	Tom Wilkinson	1952	302	12	299	do	35	11.4	Oct. 11, 1972	N	N	Former irrigation well. Yield with turbine pump 696 gal/min by U.S. Geological Survey measurement. 1/	L-11
504	L. F. Wilkinson	Otto Walk	--	300	2	300	do	30	--	--	J, E, 1-1/2	D, S	Sandpoint well.	L-9
505	Pilar Cabrera	Tom Wilkinson	1952	203	12	302	do	35	18.9	Oct. 1952	T, G, 65	N	Former irrigation well.	L-12
506	F. Y. Wingate	O. N. Gilliland	1943	164	6	164	do	38	--	--	Cf, E, 1/3	D, Irr	--	L-2
507	John Prentiss	Tom Wilkinson	1952	173	4	170	do	37	20	1952	J, G, 40	Irr	Reported yield 350 gal/min.	L-7
508	L. F. Wilkinson	do	1949	170	12	170	do	33	14	July 22, 1952	T, G, 55	Irr	--	L-4
509	A. H. Fernandez	Adams Gardens Drilling Co.	1952	205	12	186	do	35	--	--	T, G, 65	N	Drilled for irrigation, but never used. 2/	L-10
* 701	Ben Benson	Tom Wilkinson	1950	290	14	290	do	39	25.6 3/	Sept. 12, 1957	T, G	N	Yearly observation well. Former irrigation well. Yield 847 gal/min by U.S. Geological Survey measurement.	K-31
702	Carlos Watson	A & T Drilling Co.	1951	276	12	276	do	41	24.5 3/	Aug. 20, 1952	T, G, 70	N	Historical observation well. Former irrigation well. Reported yield 900 gal/min. 1/	K-41
* 703	N. Costillano	Odie Gilliland	1968	169	2	165	do	42	20	Dec. 18, 1968	J, E, 3/4	S	1/	--
704	Dr. McCamy	A & T Drilling Co.	1946	280	12	--	do	39	--	--	T	N	Former irrigation well.	K-30
* 705	Victor Guajardo	Odie Gilliland	1968	196	2	188	do	44	--	--	J, E, 3/4	D	1/	--
706	J. T. Canales	Luis Tamez	1949	250	10	250	do	43	18.1	Sept. 22, 1972	T(N)	N	Former irrigation well.	K-35
707	L. T. Boswell	Fred Fielder	1948	286	8, 6	286	do	42	18.3	do	T(N)	N	do	K-36
* 708	Sam-Porter Corp.	A & T Drilling Co.	1953	271	16	250	do	44	31.0 3/	July 3, 1957	T, E, 75	Irr	Measured yield 1,100 gal/min. Pumped well in pump test May 10, 1973. 2/	K-56
* 709	Valley Christian Camp	do	--	270	8	200	do	35	--	--	J, E	P	Supplies camp and swimming pool.	K-29
710	J. T. Canales	Fred Fielder	1949	302	10, 8	302	do	45	--	--	T, B	N	Former irrigation well. 1/	K-34
711	L. T. Boswell	do	1948	279	8	--	do	37	--	--	N	N	do	K-32
712	Ben Benson	A & T Drilling Co.	1950	300	14	284	do	40	20	1950	T, B	Irr	Reported yield 868 gal/min. 1/	K-33

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
88-60-713	L. T. Boswell	A & T Drilling Co.	1947	345	12	--	LRGV	43	--	--	T,B, 145	Irr	Reported yield 900 gal/min. 2/	K-37
714	Pilar Cabrera	Tom Wilkinson	1948	286	16	286	do	42	24.0	June 26, 1952	T,B, 135	Irr	--	K-38
715	Mrs. Raul Tijerina	Luis Tamez	1949	310	10,8	310	do	44	--	--	T,B	Irr	--	K-39
718	Jesus Costellano	Raul Tijerina	1949	280	8	280	do	41	--	--	T,E, 4	Irr	Rerported yield 600 gal/min.	K-50
* 719	Sam-Porter Corp.	Rader Water Well Co.	1973	275	4-1/2	253	do	44	15.8 3/	May 3, 1973	N	N	Test hole, observation well drilled for this study. Used as observation well in pump test (See Table 4). 1/ 2/	--
801	R. Grand-Lienard	A & T Drilling Co.	1951	280	12	280	do	38	--	--	T,E, 50	Irr	Reprted yield 700 gal/min. 2/	L-14
802	Balbino Rego	Tom Wilkinson	1952	311	16	311	do	35	23	June 17, 1952	T,G, 159	Irr	Reported yield 1,045 gal/min. 1/	L-13
803	R. O. Thuem	do	1949	296	12	296	do	39	--	--	T,G, 159	Irr	--	L-15
804	A. H. Fernandez	Adams Gardens Drilling Co.	1952	174	12	174	do	35	24.0	July 8, 1952	T,E, 75	N	Drilled for irrigation, but not used because of salty water. 2/	L-16
805	Porter & Wentz	A & T Drilling Co.	1953	318	--	--	do	--	--	--	N	N	Irrigation test hole. 2/	L-39
* 806	Valley International Prop.	Rader Water Well Co.	1973	198	N	N	do	32	--	--	N	N	Test hole drilled for this study. Plugged and abandoned. Well depth measured. 1/ 2/	--
* 901	Jimmy Woodard	Odie Gilliland	1972	180	2	--	do	31	10.7	Oct. 16, 1972	J,E	D	--	--
* 902	Chester Wheelock	Rader Water Well Co.	1973	204	N	N	do	29	6.5	Apr. 8, 1973	N	N	Test hole drilled for this study. Plugged and abandoned. Originally drilled to 260 feet. 1/ 2/	--
* 61-701	Mae Dean Corp.	Odie Gilliland	--	240	2	--	do	17	.8	Oct. 16, 1972	N	N	Former livestock well. Replaced well L-17 of Bulletin-6014.	--
* 702	Rigoberto Cuellar	do	1972	180	2	--	do	17	--	--	J,E, 1-1/2	D,S	--	--
* 89-04-101	J. T. Canales	Fred Fiedler	1950	328	8,5	328	do	44	30.2 3/	June 27, 1962	T,G	Irr	Yearly observation well.	K-47
102	do	Luis Tamez	1949	275	10,8	274	do	45	16.4	Sept. 22, 1972	T,G, 65	N	Former irrigation well.	K-40
103	Raul Lopez	Tom Wilkinson	1950	275	14	275	do	40	15.3	do	T(N)	N	do	K-43
104	do	A & T Drilling Co.	1947	276	8	265	do	39	22	1947	T,B, 65	Irr	1/	K-45
* 105	Alberto Rodriquez	Odie Gilliland	1969	202	2	--	do	41	18	Aug. 30, 1969	J,E	D	1/	--
* 106	Marcos Zavala	do	1968	200	2	--	do	39	18	Apr. 24, 1968	J,E	D	1/	--
* 107	Catholic Church	do	1968	212	2	212	do	43	20	Dec. 27, 1968	J,E	P	Well originally drilled to 232 feet. 1/	--
* 108	Antonio Salizar	do	1970	212	2	--	do	42	20	June 1, 1970	J,E	D	1/	--
* 109	Amendo Suarez	do	1970	208	2	208	do	40	20	June 12, 1970	J,E	D	1/	--

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
* 89-04-110	Mrs. Raul Lopez	Powell Drilling Co.	1970	187	2	187	LRGV	41	20	June 24, 1970	J,E	D	1/	--
* 111	Rudy Garza	Odie Gilliland	1970	188	2	--	do	49	48	Sept. 11, 1970	J,E	D	1/	--
* 112	R. Rego	do	1969	212	2	--	do	43	35	Oct. 30, 1969	J,E	D	1/	--
* 113	Pasqual Rodriques	do	1971	190	2	190	do	45	70	Aug. 20, 1971	J,E	D	1/	--
* 114	Villa Nueva School	do	1939	192	1-1/2	--	do	44	--	--	J,E	P	Supplies school.	--
115	Charles Russell	Virdell Drilling Co.	1952	237	12	237	do	43	--	--	T	N	Former irrigation well. 1/	K-46
201	Carlos Watson	Raul Tijerina	1950	220	10	220	do	40	21.0	Aug. 20, 1952	T(N)	N	Former irrigation well.	K-42
202	A. H. Fernandez	A & T Drilling Co.	1951	305	--	--	do	41	--	--	N	N	Irrigation test hole. 1/	L-21
203	do	do	1951	230	14	230	do	38	20	1951	T,G	Irr	1/	L-20
204	Mrs. Alice Mayer	Tom Wilkinson	1951	245	12	245	do	38	17	Aug. 19, 1952	T,G, 97	Irr	1/	L-22
205	Porter & Wentz	A & T Drilling Co.	1957	211	16	211	do	31	--	--	T,E, 75	Irr	2/	L-40
206	do	do	1957	225	16	225	do	32	--	--	T,E, 75	Irr	--	L-41
207	George H. Bingley	do	1952	190	12	190	do	33	13	Aug. 28, 1952	T,G, 145	Irr	1/	L-23
* 208	Water Conservation and Improvement District No. 6	Rader Water Well Co.	1973	200	4-1/2	200	do	42	15.4 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this study. 1/ 2/	--
* 209	do	do	1973	200	4-1/2	200	do	31	5.9 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this study. Originally drilled to 205 feet. 1/ 2/	--
* 210	Valley International Properties	do	1973	220	N	N	do	30	--	--	N	N	Test hole drilled for this study. 1/ 2/	--
* 211	do	do	1973	235	N	N	do	36	--	--	N	N	do	--
* 301	Jo Jennings	Odie Gilliland	1966	177	2	177	do	26	16	Apr. 20, 1966	J,E, 3/4	D	1/	--
* 302	Mrs. F. Ceyanes	do	1970	37	2	37	do	31	10	Oct. 1, 1970	J,E	D	1/	--
* 303	Robin Pate	do	1970	180	2	180	do	23	18	June 2, 1970	J,E	P	1/	--
304	Floyd Hoel	Tom Wilkerson	1953	260	12	260	do	28	16	Apr. 1954	T,G	N	Former irrigation well, slotted 215-260 feet.	L-42
* 305	Rigoberto Cuellar	Odie Gilliland	1972	180	2	--	do	32	--	--	J,E, 1	Ind	Supplies truck garage.	--
306	M. G. Ortiz	--	1929	165	3	155	do	22	--	--	J,E	D,S	--	L-24
307	H. B. Fleming	do	1945	204	4	204	do	29	9 20	Sept. 1945 Aug. 1954	J,E	D,S	1/	L-25
* 308	Texas Parks and Wild-life Dept.	Rader Water Well Co.	1973	211	4-1/2	210	do	35	8.2 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this study. 1/ 2/	--
* 309	A. Garcia	do	1973	220	4-1/2	200	do	32	9.6 3/	do	N	N	do	--

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
89-04-501	Lloyd E. Horn	Powell Drilling Co.	1969	189	2	189	LRGV	38	12	July 16, 1969	J, E	D	1/	--
502	Floyd Condit	do	1970	153	2	153	do	38	16	Mar. 26, 1970	J, E	D	1/	--
* 503	George Allala	do	1968	191	2	191	do	35	16	Sept. 20, 1968	J, E	D	Originally drilled to 210 feet. 1/	--
* 504	Abelando T. Garza	do	1969	185	2	185	do	38	14	May 6, 1969	J, E	D	Originally drilled to 195 feet. 1/	--
* 505	Mrs. Fred Rusteberg, Jr.	do	1969	202	2	200	do	35	--	--	J, E	D	Originally drilled to 220 feet. 1/	--
* 506	Hector Cascos	Odie Gilliland	1969	178	2	178	do	36	19	Nov. 24, 1969	J, E	D	1/	--
* 507	Lloyd E. Horn	Powell Drilling Co.	1971	185	5, 2	185	do	38	15	June 4, 1971	J, E	D	1/	--
* 508	Dr. Vital Longoria	do	1969	200	2	--	do	37	15	Sept. 29, 1969	J, E	D, S	Originally drilled to 208 feet. 1/	--
* 509	Carmen Gin	--	--	200	--	--	do	48	--	--	J, E	Ind	--	--
* 510	Jimmy Hollon	Rader Water Well Co.	1973	195	4-1/2	193	do	40	14.4 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this study.	--
601	City of Brownsville	Virdell Drilling Co.	1953	198	12	198	do	34	23 18.2	Sept. 30, 1953 Sept. 11, 1957	T, E, 75	P	City of Brownsville well 7. 1/ 2/	L-37
* 602	do	do	1953	200	12	200	do	36	22.4 3/	Sept. 30, 1953	T, E, 75	P	Yearly observation well. City of Brownsville well 8. 2/	L-38
* 603	do	do	1953	193	12	193	do	33	21.8	do	T, E	P	City of Brownsville well 4. Used as observation well in pump test of City well 5. 1/ 2/	L-34
604	Pete Rocha	Powell Drilling Co.	1969	192	2	192	do	30	--	--	J, E	D	1/	--
605	M. M. Hernandez	do	1970	160	2	160	do	31	12	Dec. 3, 1970	J, E	D	Originally drilled to 170 feet. 1/	--
* 606	Mary Wallace	Odie Gilliland	1969	190	2	190	do	27	9	Aug. 15, 1969	J, E	Ind	1/	--
607	Tom Foutch	A & T Drilling Co.	1967	212	2-1/2	212	do	32	17	May 1969	N	N	Drilled to supply Gulf service station, but not used. Well plugged. 1/	--
* 608	Valley International Golf Course	do	1969	228	12	228	do	33	18.7	Sept. 26, 1972	T, E, 25	Irr	Supplies golf course. Measured yield 600 gal/min. 1/	--
* 609	Armours Food Co.	do	1966	200	8	189	do	36	20	Jan. 14, 1966	Sub, E, 15	Ind	Supplies meat packing plant. 1/	--
* 610	Win Mobil Homes	Powell Drilling Co.	1970	197	2	197	do	25	9	May 21, 1970	J, E	P	Supplies mobile home park. 1/	--
* 611	Dr. H. A. Miller	Odie Gilliland	1970	127	2	127	do	34	17	May 20, 1970	J, E, 1-1/2	D	1/	--
* 612	Judge G. T. Sharpe	do	1970	104	2	--	do	--	16	May 21, 1970	J, E, 1	D	1/	--
* 613	Reta Thomas	Powell Drilling Co.	1971	180	2	180	do	27	11	Aug. 11, 1971	J, E	D	Originally drilled to 190 feet. 1/	--
* 614	Peter Knutson	Odie Gilliland	1970	147	2	147	do	35	17	Mar. 2, 1970	J, E	P, Ind	1/	--
* 615	Mrs. Frankie Foreman	do	1969	197	2	197	do	31	19	May 11, 1969	J, E, 3/4	D	1/	--
* 616	City of Brownsville	Virdell Drilling Co.	1953	197	12	197	do	34	20.6 3/	Sept. 30, 1953	T, E, 75	P	City of Brownsville well 5. Used as pumping well in pump test (Table 4). Yearly observation well. 1/	L-35

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
89-04-617	City of Brownsville	Virdell Drilling Co.	1953	203	12	203	LRGV	34	21.1	Sept. 30, 1953	T,E, 75	P	City of Brownsville well 6. Used as observation well in pump test of City well 5. Measured yield 1,100 gal/min. 1/ 2/	L-36
618	do	do	1952	203	20,12	196	do	34	14.3	Oct. 23, 1952	T,E, 75	P	City of Brownsville well 2. Used as observation well in pump test of City well 5. 2/	L-30
619	do	do	1953	194	12	194	do	33	--	--	T,E, 75	P	City of Brownsville well 3. 1/ 2/	L-33
620	do	Texas Water Supply Corp.	1952	200	20,12	198	do	35	14	July 1952	T,E, 75	N	Formerly City of Brownsville well 1. Abandoned. 2/	L-29
621	do	do	1952	503	--	--	do	38	--	--	N	N	Test hole drilled for public supply. 1/ 2/	L-32
622	P. J. Davis	The Texas Co.	1950	12,053	--	--	--	33	--	--	N	N	Oil test hole. 2/	L-28
* 623	Mr. McDaniel	--	--	100	2	--	LRGV	37	--	--	J,E	Ind	Supplies retail store.	--
* 624	James Haywood	Odie Gilliland	1968	195	2	--	do	36	17	July 30, 1968	J,E	D,S	1/	--
* 625	George A. Lopez	Powell Drilling Co.	1970	190	2	--	do	30	16	Dec. 22, 1970	J,E	D	1/	--
* 626	Vance Wilson	--	1972	180	4	180	do	30	--	--	J,E	D,Irr	--	--
* 627	City of Brownsville	Rader Water Well Co.	1973	195	4-1/2	195	do	37	10.7 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this report. Used as observation well in pump test (See Table 4). Originally drilled to 207 feet. 1/ 2/	--
* 628	M. J. Tipton, Sr.	do	1973	207	4-1/2	203	do	33	11.4 3/	do	N	N	Test hole, observation well drilled for this report. 1/ 2/	--
* 629	City of Brownsville	do	1973	307	4-1/2	196	do	37	11.0 3/	do	N	N	Test hole, observation well drilled for this report. Used as observation well in pump test (See Table 4). Well depth measured. 1/ 2/	--
* 630	Pedro Rocha	do	1973	204	4-1/2	202	do	30	10.4 3/	Apr. 18, 1973	N	N	Test hole, observation well drilled for this report. Well depth measured. 1/ 2/	--
* 631	City of Brownsville	do	1973	228	N	N	do	31	--	--	N	N	Test hole drilled for this report. Plugged and abandoned. Well depth measured. 1/ 2/	--
* 632	Del Mar Motel	--	1973	25	N	N	do	30	--	--	N	N	Sand point wells used for dewatering excavation for new swimming pool.	--
901	City of Brownsville	Texas Water Supply Corp.	1952	300	--	--	do	35	--	--	N	N	Test hole for public supply. 2/	P-1
* 902	do	Rader Drilling Co.	1973	226	4-1/2	220	do	31	22.2 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this study. Water-level recorder installed Oct. 20, 1973. 1/ 2/	--
* 903	Robert Mathers	do	1973	202	N	N	do	30	--	--	N	N	Test hole drilled for this study. Plugged and abandoned. Well depth measured. 1/ 2/	--
* 05-101	Mando Joe Guerra	Odie Gilliland	1972	180	2	--	do	20	--	--	J,E	D,S	--	--
* 102	Joe A. Bestiero	Rader Water Well Co.	1973	205	4-1/2	204	do	19	0.0 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this study. 1/ 2/	--
* 201	Enrique Valentin Est.	--	--	230	2	--	do	14	--	--	Cf 3/4	N	Abandoned. Water very salty.	--

See footnotes at end of table.

Table 2.--Records of Wells and Test Holes--Continued

	Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diam-eter (in.)	Casing: Depth (ft)	Water bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks	Old Well Number From Bulletin 6014
	89-05-401	-- Mogel	-- Keith	--	225	2	--	LRGV	23	3.8	Oct. 18, 1972	N	N	Abandoned domestic well, water too salty.	--
*	402	Jo and Fred Wagner	--	1957	212	2	--	do	31	--	--	Cf 1/2	D		--
	403	-- Fleming	Ted Pursley	1946	211	10	211	do	28	--	--	N	N	Test drilled for irrigation, but water too salty. 1/	L-27
*	404	City of Brownsville	Rader Water Well Co.	1973	240	4-1/2	205	do	30	11.1 3/	Apr. 2, 1973	N	N	Test hole, observation well drilled for this study.	--
*	405	do	do	1973	243	4-1/2	224	do	29	9.0 3/	Apr. 16, 1973	N	N	Test hole, observation well drilled for this study. Well depth measured.	--
*	701	do	do	1973	225	N	N	do	26	--	--	N	N	Test hole drilled for this study. Plugged and abandoned.	--

* Chemical analysis of water from this well in Table 5.
1/ Driller's log of well in Table 3.
2/ Electric or gamma ray log available in files of the Texas Department of Water Resources.
3/ Additional water-level measurements in Table 4.

Table 3.—Drillers' Logs of Wells

	THICKNESS (FEET)	DEPTH (FEET)

Well 88-59-101

Owner: Oscar Thieme
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	6	6
Clay	24	30
Sand and clay	65	95
Clay	10	105
Sand	30	135
Clay	20	155
Gravel	13	168

Well 88-59-104

Owner: B. F. Morrow
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	6	6
Sand	19	25
Clay	35	60
Sand with clay streaks	40	100
Sand	20	120
Clay	4	124
Sand and gravel	39	163

Well 88-59-105

Owner: C. D. Echols
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	4	4
Clay	26	30
Sand (salty)	20	50
Clay	70	120
Fine sand	14	134
Clay	12	146
Sand and gravel	11	157
—	7	164

Well 88-59-107

Owner: C. D. Echols
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface	6	6
Sand with clay streaks	56	62
Broken sand and clay	31	93
Sand	49	142
Gravel with sand streaks	7	149
Clay	2	151
Gravel	16	167
Clay	2	169

Well 88-59-201

Owner: D. H. Palmer
Driller: Virdell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Sand with streaks of clay	26	26
Sand	8	34
Clay, yellow	8	42
Sand, black, fine grained	16	58
Clay with streaks of sand	22	80
Sand, black, fine grained	15	95
Clay, blue	10	105
Sand	5	110
Clay, blue	5	115
Gravel	51	166

Well 88-59-202

Owner: T. Kawamar
Driller: Tom Wilkinson

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	10	10
Sand	19	29
Clay	17	46
Sand	59	105
Clay	16	121
Sand	13	134

Table 3.—Drillers' Logs of Wells—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well 88-59-202—Continued		
Gravel, sandy, and clay	16	150
Clay	3	153
Sand	28	181
Clay	15	196
Sand	15	211
Clay	7	218
Sand with some gravel	69	287
Gravel	59	346
Well 88-59-205		
Owner: W. D. Todd Driller: A & T Drilling Company		
Surface soil	6	6
Sand	165	171
Gravel	14	185
Well 88-59-206		
Owner: T. Oyama Driller: Tom Wilkinson		
Surface soil	6	6
Clay	32	38
Sand	8	46
Clay, sandy	13	59
Sand	112	171
Gravel	22	193
Clay	7	200
Well 88-59-207		
Owner: T. Date Driller: Tom Wilkinson		
Surface clay	8	8
Sand	56	64
Clay	51	115
Sand	22	137
Clay	3	140
Gravel	60	200
Well 88-59-208		
Owner: Herman Johnson Driller: Tom Wilkinson		
Surface soil	17	17
Sand	33	50
Clay	10	60
Sand	45	105
Clay	16	121
Sand	29	150
Gravel	42	192
Clay	2	194
Well 88-59-209		
Owner: George Oyama Driller: Tom Wilkinson		
Surface soil	15	15
Sand	21	36
Clay	53	89
Sand with clay streaks	31	120
Sand and clay	31	151
Clay	15	166
Gravel	31	197
Clay	4	201
Well 88-59-210		
Owner: Ray McDonald Driller: Tom Wilkinson		
Surface clay	18	18
Sand	38	56
Clay	33	89
Sand	30	119
Clay	19	138
Sand	10	148
Gravel	57	205
Clay	7	212

Table 3.—Drillers' Logs of Wells—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well 88-59-301		
Owner: G. W. McCain Driller: Tom Wilkinson		
Surface soil	15	15
Sand	40	55
Clay	55	110
Sand	10	120
Gravel	60	180
Well 88-59-302		
Owner: Guadalupe Garza Driller: Powell Drilling Company		
Topsoil	2	2
Clay, gray	24	26
Sand, gray	27	53
Clay, brown	45	98
Sand, gray and brown	15	113
Clay, blue	7	120
Well 88-59-306		
Owner: G. W. McCain Driller: Tom Wilkinson		
Surface soil	15	15
Sand	14	29
Clay	10	39
Sand	13	52
Clay	28	80
Sand	11	91
Clay	7	98
Sand	25	123
Clay	13	136
Gravel	15	151
Clay	87	238
Clay, sandy	6	244
Sand with shale streaks	30	274
Clay	16	290

	THICKNESS (FEET)	DEPTH (FEET)
Well 88-59-306—Continued		
Sand	15	305
Clay	15	320
Gravel, fine, with sand	65	385
Clay, hard	1	386
Well 88-59-405		
Owner: M. de los Santos Driller: Tom Wilkinson		
Clay	29	29
Sand	32	61
Clay	31	92
Clay, sandy	30	122
Sand	23	145
Gravel	38	183
Clay	1	184
Well 88-59-502		
Owner: O. W. Tucker Driller: Tom Wilkinson		
Surface soil and clay	29	29
Clay	61	90
Clay and sand	10	100
Clay	21	121
Clay, sandy	19	140
Gravel	58	198
Clay	2	200
Well 88-59-503		
Owner: B. H. Barlow Driller: Powell Drilling Company		
Clay, brown	48	48
Sand, brown	32	80
Clay, brown	20	100
Sand, gray-brown	46	146
Gravel (½ to ¾ inch)	4	150

	THICKNESS (FEET)	DEPTH (FEET)
Well 88-59-505		
Owner: Johnny T. Pitts Driller: A & T Drilling Company		
Surface	6	6
Clay	14	20
Sand and clay	33	53
Clay	49	102
Sand and clay streaks	13	115
Clay	10	125
Sand	20	145
Clay and hard streaks	4	149
Sand and gravel	4	153
Gravel and sand streaks	22	175
Clay	2	177
Well 88-59-507		
Owner: Mary E. Coakley Driller: Tom Wilkinson		
Surface soil	10	10
Clay	65	75
Sand	42	117
Clay	30	147
Sand	3	150
Gravel	49	199
Well 88-59-601		
Owner: —Furnkawa Driller: A & T Drilling Company		
Surface soil	6	6
Sand	24	30
Clay	37	67
Sand and clay	51	118
Clay	40	158
Gravel	32	190
Well 88-59-603		
Owner: R. L. McGarr Driller: Odie Gilliland		
Topsoil	5	5
Clay	36	41
Sand (salty)	22	63
Clay	89	152
Sand	13	165
Gravel	7	172
Well 88-59-607		
Owner: G. B. Smith Driller: A & T Drilling Company		
Surface soil	7	7
Clay	3	10
Sand	16	26
Clay	34	60
Sand	35	95
Clay	30	125
Sand and gravel	49	174
Well 88-59-702		
Owner: J. W. Meadows Driller: A & T Drilling Company		
Surface soil	8	8
Sand	18	26
Clay	10	36
Sand	50	86
Clay	38	124
Sand	8	132
Clay	8	140
Sand	10	150
Gravel	23	173

Table 3.—Drillers' Logs of Wells—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well 88-59-902		
Owner: Ernesto Garcia Driller: Powell Drilling Company		
Clay, gray	12	12
Clay, brown	16	28
Silt, brown	7	35
Clay, brown	11	46
Silt, gray	6	52
Clay, brown	48	100
Sand, fine gray	58	158
Clay, mixed in sand, fine, gray	4	162
Gravel (½ inch)	8	170
Well 88-59-903		
Owner: Pablo Escamille Driller: Odie Gilliland		
Topsoil	3	3
Clay	37	40
Sand (fair water)	9	49
Clay	111	160
Sand and gravel	15	175
Well 88-59-904		
Owner: Carlos Zepeda Driller: Odie Gilliland		
Topsoil	4	4
Clay	35	39
Sand	11	50
Clay	55	105
Sand	10	115
Clay	33	148
Fine sand	12	160
Gravel	9	169
Well 88-59-905		
Owner: Carlos Zepeda Driller: Odie Gilliland		
Topsoil	4	4
Clay	34	38
Sand	13	51
Clay	57	108
Sand	9	117
Clay	46	163
Sand and gravel	12	175
Well 88-59-906		
Owner: Dionicio Esparza Driller: Odie Gilliland		
Topsoil	6	6
Clay	57	63
Sand (water is fair)	27	90
Shale and clay streaks	75	165
Sand and rock	7	172
Well 88-59-907		
Owner: Dionicio Esparza Driller: Odie Gilliland		
Topsoil	4	4
Clay	34	38
Sand	17	55
Clay	51	106
Sand	9	115
Clay	40	155
Sand	13	168
Gravel	8	176
Well 88-59-908		
Owner: Mrs. R. T. Leal Driller: Odie Gilliland		
Topsoil	8	8
Clay	7	15

Table 3.—Drillers' Logs of Wells—Continued

Well 88-59-908—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Sand	23	38
Clay	34	72
Sand	10	82
Clay	43	125
Sand	20	145
Clay	15	160
Sand	7	167
Rock and gravel	14	181
Loose pea gravel	2	183

Well 88-59-909

Owner: Irima Garcia
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Clay	20	20
Fine sand	8	28
Hard clay	12	40
Fine sand	8	48
Clay	5	53
Medium sand	6	59
Clay	3	62
Fine sand	6	68
Clay	97	165
Sand and gravel	13	178

Well 88-59-910

Owner: Salvador Perez
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	4	4
Clay	36	40
Sand	15	55
Clay	53	108
Sand	7	115
Clay	25	140
Sand	16	156

Well 88-59-912

Owner: Lee Joe Wood
Driller: Henry Cleveland

	THICKNESS (FEET)	DEPTH (FEET)
Clay	70	70
Sand	25	95
Clay	10	105
Sand	12	117
Clay	18	135
Sand	20	155
Clay	9	164
Gravel	40	204
Clay	2	206
Sand and gravel	21	227
Clay	11	238
Gravel	22	260

Well 88-60-101

Owner: Louis Stanley
Driller: Henry Cleveland

	THICKNESS (FEET)	DEPTH (FEET)
Clay	24	24
Sand, broken	16	40
Shale	45	85
Sand	5	90
Shale, clay	70	160
Gravel	12	172
Shale	2	174

Well 88-60-401

Owner: J. G. Ballinger
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	6	6
Sand	12	18
Clay	77	95
Sand	63	158
Gravel	32	190
Sand	14	204

Table 3.—Drillers' Logs of Wells—Continued

Well 88-60-503

Owner: A. H. Fernandez
Driller: Tom Wilkinson

	THICKNESS (FEET)	DEPTH (FEET)
Clay	15	15
Sand	20	35
Clay	101	136
Sand	28	164
Gravel, sandy	12	176
Clay, imbedded gravel	9	185
Clay	28	213
Sand	31	244
Gravel	55	299
Clay	3	302

Well 88-60-702

Owner: Carlos Watson
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	16	16
Sand	38	54
Clay with sand streaks	114	168
Sand	10	178
Sand and gravel	18	196
Clay	12	208
Sand	22	230
Sand and gravel	10	240
Clay	5	245
Sand and gravel	29	274
Clay	2	276

Well 88-60-703

Owner: N. Costiliano
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	5	5
Clay	25	30
Fine sand (a little salty)	30	60
Fine brown sand	20	80

Well 88-60-703—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Clay	72	152
Sand	12	164
Rocks and gravel	5	169

Well 88-60-705

Owner: Victor Guajardo
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	6	6
Clay	19	25
Sand	30	55
Clay	50	105
Sand	15	120
Clay	55	175
Sand and gravel	21	196

Well 88-60-710

Owner: J. T. Canales
Driller: Fred Fielder

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	16	16
Sand	24	40
Sand and clay	125	165
Gravel	15	180
Clay	13	193
Gravel	109	302

Well 88-60-711

Owner: L. T. Boswell
Driller: Fred Fielder

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	12	12
Clay	42	54
Sand	109	163
Sand and gravel	33	196
Clay	12	208
Sand and gravel	31	239
Clay	3	242

Table 3.—Drillers' Logs of Wells—Continued

Well 88-60-711—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Sand and gravel	24	266
Clay	13	279

Well 88-60-712

Owner: Ben Benson
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	12	12
Sand	58	70
Clay	56	126
Sand	8	134
Clay	20	154
Sand	12	166
Sand and gravel	19	185
Clay	26	211
Sand and gravel	21	232
Clay	2	234
Sand and gravel	48	282
Sand	18	300

Well 88-60-719

Owner: Sam-Porter Corp.
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil	1	1
Clay	7	8
Sand with clay streaks at 60 to 70 feet	77	85
Clay and sand streaks	10	95
Clay with sand streak at 120 feet	55	150
Sand and gravel	30	180
Clay	15	195
Sand and gravel (large gravel at 240 to 265 feet)	75	270
Clay or tight sand	5	275

Well 88-60-802

Owner: Balbino Rego
Driller: Tom Wilkinson

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	29	29
Clay	6	35
Sand	54	89
Clay	31	120
Clay, sandy	25	145
Sand	5	150
Gravel	61	211
Clay	30	241
Clay, with sand streaks	24	265
Gravel	46	311

Well 88-60-806

Owner: Valley International Properties
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil	1	1
Brown clay	19	20
Fine brown sand	18	38
Clay with broken spots (sands?) at 65 and 90 feet	82	120
Sand with clay streaks	15	135
Clay and sand streaks	15	150
Sand with hard streaks, possibly gravel	15	165
Broken clay and sand streaks	30	195
Clay with hard streaks	5	200

Well 88-60-902

Owner: Chester Wheelock
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Black soil	2	2
Brown to red broken clay	58	60
Sand with clay streaks	25	85
Broken clay and sand streaks	20	105

	THICKNESS (FEET)	DEPTH (FEET)
Well 88-60-902—Continued		
Brown clay	20	125
Sand with clay streaks	57	182
Sand and gravel	18	200
Sand with clay streaks	60	260

Well 89-04-101

Owner: J. T. Canales
Driller: Fred Fielder

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil and sand	25	25
Clay and sand	171	196
Sand	6	202
Gravel	28	230
Clay	44	274
Sand	54	328

Well 89-04-104

Owner: Raul Lopez
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	8	8
Clay, sandy	162	170
Sand and gravel	63	233
Clay	7	240
Sand and gravel	34	274
Clay	2	276

Well 89-04-105

Owner: Alberto Rodriquez
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	3	3
Clay	25	28
Sand	17	45
Clay	11	56
Sand	9	65
Clay	45	110
Sand	12	122

Well 89-04-105—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Clay	58	180
Sand and gravel	22	202

Well 89-04-106

Owner: Marcos Zavala
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	5	5
Clay	16	21
Sand	29	50
Clay	97	147
Sand rock	43	190
Rock and gravel	10	200

Well 89-04-107

Owner: Catholic Church
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	5	5
Clay	25	30
Sand	16	46
Clay	58	104
Fine sand	12	116
Clay	74	190
Sand and gravel	42	232

Well 89-04-108

Owner: Antonio Salizar
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	5	5
Clay	30	35
Sand (fair)	15	50
Clay	140	190
Sand and gravel	15	205
Gravel	7	212

Table 3.—Drillers' Logs of Wells—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-109		
Owner: Amendo Suarez Driller: Odie Gilliland		
Topsoil	5	5
Clay	31	36
Sand (water fair)	14	50
Clay	140	190
Sand and gravel	18	208
Well 89-04-110		
Owner: Mrs. Raul Lopez Driller: Powell Drilling Company		
Clay, gray, brown, tan—in order	27	27
Sand, gray to tan	19	46
Clay, gray	80	126
Sand and silt, gray	50	176
Sand	9	185
Gravel (½ inch)	2	187
Well 89-04-111		
Owner: Rudy Garza Driller: Odie Gilliland		
Topsoil	5	5
Clay	56	61
Sand	9	70
Clay	10	80
Sand	21	101
Clay	25	126
Sand	14	140
Clay	29	169
Sand and gravel	19	188
(did not go to bottom of strata)		
Well 89-04-112		
Owner: R. Rego Driller: Odie Gilliland		
Clay	22	22
Sand	24	46
Well 89-04-112—Continued		
Clay	19	64
Sand	3	68
Clay	60	128
Sand	5	133
Clay	14	147
Sand	5	152
Clay	28	180
Sand rock	15	195
Gravel	17	212
Well 89-04-113		
Owner: Pasqual Rodriques Driller: Odie Gilliland		
Topsoil	3	3
Clay	37	40
Sand (fair) water	14	54
Clay	114	168
Sand and gravel	22	190
(did not go to bottom of gravel)		
Well 89-04-115		
Owner: Charles Russell Driller: Virdell Drilling Company		
Surface sand and clay	26	26
Sand with small gravel	22	48
Clay	22	70
Sand with clay streaks	10	80
Gravel, fine, with sandy clay streaks	15	95
Sand, fine grained, with streaks of clay	45	140
Clay	5	145
Sand, fine grained, with streaks of clay	30	175
Gravel, small	20	195
Gravel, large	40	235
Clay	2	237

	THICKNESS (FEET)	DEPTH (FEET)

Well 89-04-202

Owner: A. H. Fernandez
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	6	6
Sand	46	52
Clay	25	77
Sand	16	93
Clay, sand streaks	74	167
Sand and gravel	47	214
Sand, clay streaks	39	253
Clay	52	305

Well 89-04-203

Owner: A. H. Fernandez
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	7	7
Clay, sandy	10	17
Sand	22	39
Clay	25	64
Sand, clay streaks	29	93
Clay	95	188
Gravel, sand streaks	40	228
Sand	2	230

Well 89-04-204

Owner: Mrs. Alice Mayer
Driller: Tom Wilkinson

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	4	4
Clay	64	68
Sand	22	90
Clay	15	105
Sand	50	155
Clay	10	165
Sand and clay	31	196
Gravel	49	245

Well 89-04-207

Owner: George H. Bingley
Driller: A & T Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	6	6
Clay	24	30
Sand	25	55
Clay	20	75
Sand	27	102
Clay	33	135
Sand	10	145
Clay	14	159
Sand	20	179
Gravel	11	190

Well 89-04-208

Owner: Water Conservation and
Improvement District Number 6
(City of Brownsville arranged drilling)
Owner: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Sandy soil	14	14
Brown and gray silty clay with some caliche	19	33
Streaks of fine brown sand and yellow clay	32	65
Fine brown sand	37	102
Streaks of sand and clay	33	135
Fine gray-brown sand	16	151
Fine sand with streaks of clay	25	176
Coarse dark sand and fine gravel	19	195
Salmon colored clay	10	205

Well 89-04-209

Owner: Water Conservation and
Improvement District Number 6
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	3	3
Broken tan and gray clay with some fine brown sand and selenite crystals	17	20

Table 3.—Drillers' Logs of Wells—Continued

Well 89-04-209—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Fine gray sand	17	37
Brown, tan, yellow, and gray clay and silty clay with a few streaks of fine sand and some selenite crystals	76	113
Fine dark gray sand	9	122
Brown and yellow silty clay	37	159
Streaks of sand and gravel	38	197
Brown clay	8	205

Well 89-04-210

Owner: Valley International Properties
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil	2	2
Clay	20	22
Sand	28	50
Clay with sand streaks, very broken formation	65	115
Fine gray to brown sand	18	133
Clay with some sand streaks	27	160
Gray sand	35	195
Sand and gravel	20	215
Clay	5	220

Well 89-04-211

Owner: Valley International Properties
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil	1	1
Brown clay	47	48
Sand with some clay	32	80
Sand and clay streaks	30	110
Clay	25	135
Sand with clay streaks	10	145
Clay with some sand streaks	30	175
Sand and gravel with some clay	50	225
Broken clay	10	235

Well 89-04-301

Owner: Jo Jennings
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	8	8
Clay	23	31
Sand	11	42
Clay	63	105
Sand	22	127
Clay	23	150
Sand	27	177

Well 89-04-302

Owner: Mrs. F. Ceyanes
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	4	4
Clay	23	27
Fine sand	10	37

Well 89-04-303

Owner: Robin Pate
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	5	5
Clay	25	30
Soft muck	10	40
Clay	125	165
Coarse sand	15	180

Well 89-04-307

Owner: H. B. Fleming
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Soil, clay	149	149
Sandstone	2	151
Clay, white	19	170
Sand, hard and soft streaks, gravel	34	204

Table 3.—Drillers' Logs of Wells—Continued

Well 89-04-308

Owner: Texas Parks and Wildlife Department
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil	1	1
Broken clay and sand	19	20
Fine brown sand	35	55
Clay with sand streaks	15	70
Sand	20	90
Clay with sand streaks	30	120
Clay	15	135
Sand and clay streaks	10	145
Clay with sand streaks	40	185
Sand and gravel	20	205
Clay with hard streaks	10	215

Well 89-04-309

Owner: A. Garcia
(City of Brownsville arranged drilling).
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil	1	1
Clay with sand streak at 60 feet	72	73
Sand with clay streaks at 75 and 90 feet	22	95
Clay with sand streaks	80	175
Sand and gravel	20	195
Clay with hard streaks	10	205
Clay with soft streaks	15	220

Well 89-04-501

Owner: Lloyd E. Horn
Driller: Powell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Silt, light brown	8	8
Sand, fine, dark	29	37
Mixed sand and clay	38	75
Sand, coarse, light gray	30	105
Clay, light gray	31	136
Sand, coarse, light gray	53	189

Well 89-04-502

Owner: Floyd Condit
Driller: Powell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Clay, tan	6	6
Sand, gray	32	38
Clay, tan	52	90
Sand, gray	12	102
Silt, gray	18	120
Sand, clay mixed, tan	10	130
Clay, tan	6	136
Sand, tan	17	153

Well 89-04-503

Owner: George Allala
Driller: Powell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Clay, gray	75	75
Sand, gray	26	101
Clay, brown	79	180
Sand, gray	20	200
Clay, gray	10	210

Well 89-04-504

Owner: Abelando T. Garza
Driller: Powell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Clay, light	52	52
Silt, dark	19	71
Clay, light	69	140
Sand, dark	50	190
Clay, light	5	195

Well 89-04-505

Owner: Mrs. Fred Rusteberg, Jr.
Driller: Powell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Clay, light	26	26
Sand, gray	4	30
Clay, tan	30	60
Sand, dark	20	80
Clay	25	105

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-505—Continued		
Mixed silt and clay	25	130
Clay	10	140
Sand gray	62	202
Clay, dark	18	220

Well 89-04-506

Owner: Hector Cascos
Driller: Odie Gilliland

	THICKNESS (FEET)	DEPTH (FEET)
Clay	15	15
Sand	27	42
Clay	18	60
Sand	20	80
Clay	25	105
Sand	10	115
Clay	11	126
Course sand	21	147
Clay	8	155
Sand	23	178

Well 89-04-507

Owner: Lloyd E. Horn
Driller: Powell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Clay	16	16
Sand	24	40
Clay	36	76
Sand	39	115
Clay and sand mixed	30	145
Sand	40	185

Well 89-04-508

Owner: Dr. Vital Longoria
Driller: Powell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Clay, tan	14	14
Sand, gray-dark	40	54
Sand, tan	101	155

Well 89-04-508—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Clay, tan	5	160
Sand, tan	48	208

Well 89-04-510

Owner: Jimmy Hollon
(City of Brownsville arranged drilling)
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil and clay	5	5
Fine brown and gray sand	30	35
Tan to brown clay	35	70
Sand and clay streaks	5	75
Clay	10	85
Fine brown sand	10	95
Brown to tan clay	35	130
Fine light colored clay	55	185
Clay with soft streaks	10	195

Well 89-04-601

Owner: City of Brownsville
Driller: Virdell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	3	3
Sand	7	10
Clay	18	28
Sand	23	51
Clay	26	77
Sand	33	110
Clay with sand streaks	38	148
Sand	20	168
Gravel	28	196
Clay	2	198

Well 89-04-603

Owner: City of Brownsville
Driller: Virdell Drilling Company

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	4	4
Clay	30	34

Table 3.—Drillers' Logs of Wells—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-603—Continued		
Sand	11	45
Clay	27	72
Sand	45	117
Clay	52	169
Gravel	21	190
Clay	3	193
Well 89-04-604		
Owner: Pete Rocha Driller: Powell Drilling Company		
Clay, gray	10	10
Silt, tan and gray	36	46
Clay, dark	119	165
Sand, coarse, gray	27	192
Well 89-04-605		
Owner: M. M. Hernandez Driller: Powell Drilling Company		
Clay, light tan	18	18
Sand, gray	32	50
Granulated clay, brown and gray	14	64
Clay, brown	11	75
Sand, gray	15	90
Clay, tan	30	120
Sand, gray	10	130
Sand and clay mix	20	150
Sand, gray	20	170
Well 89-04-606		
Owner: Mary Wallace Driller: Odie Gilliland		
Topsoil	5	5
Clay	26	31
Soft muck sand	9	40
Clay	135	175
Sand	15	190

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-607		
Owner: Tom Foutch Driller: A & T Drilling Company		
Surface	6	6
Sand	34	40
Clay and sand	68	108
Sand	12	120
Clay	71	191
Sand and gravel	20	211
Clay	1	212
Well 89-04-608		
Owner: Valley International Golf Course Driller: A & T Drilling Company		
Surface soil	8	8
Clay	60	68
Sand	129	197
Sand and small gravel	29	226
Clay	2	228
Well 89-04-609		
Owner: Armours Food Company Driller: A & T Drilling Company		
Surface	6	6
Clay	12	18
Sand and clay streaks	29	47
Sand	2	49
Clay	27	76
Sand and clay streaks	32	108
Clay and sand streaks	32	140
Sand and clay streaks	24	164
Fine gravel	12	176
Clay	10	186
Gravel	11	197
Clay	3	200

Table 3.—Drillers' Logs of Wells—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-610		
Owner: Win Mobil Homes Driller: Powell Drilling Company		
Clay, brown	8	8
Silt, brown	6	14
Clay, brown	76	90
Sand and silt, gray	60	150
Clay, gray	20	170
Sand, gray	15	185
Sand and gravel (fine)	10	195
Gravel (1 inch)	2	197
Well 89-04-611		
Owner: Dr. H. A. Miller Driller: Odie Gilliland		
Topsoil	5	5
Clay	70	75
Fine sand	25	100
Clay	10	110
Coarse sand	17	127
Well 89-04-612		
Owner: Judge G. T. Sharpe Driller: Odie Gilliland		
Topsoil	6	6
Clay	44	50
Fine sand (salty)	20	70
Clay	13	83
Sand	21	104
Well 89-04-613		
Owner: Reta Thomas Driller: Powell Drilling Company		
Clay, brown	11	11
Clay, gray	19	30
Clay, brown	75	105
Sand, brown	10	115

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-613—Continued		
Clay, gray	48	163
Sand, gray	27	190
Sand	?	?
Well 89-04-614		
Owner: Peter Knutson Driller: Odie Gilliland		
Topsoil	5	5
Clay	70	75
Fine sand	45	120
Clay	10	130
Coarse sand	17	147
Well 89-04-615		
Owner: Mrs. Frankie Foreman Driller: Odie Gilliland		
Topsoil	6	6
Clay	10	16
Fine sand, brown (water fair)	14	30
Clay	10	40
Sand, gray	10	50
Clay	55	105
Fine sand	21	126
Clay and shale	44	170
Fine sand	19	189
Sand and gravel	8	197
Well 89-04-616		
Owner: City of Brownsville Driller: Virdell Drilling Company		
Topsoil	4	4
Sand and clay	6	10
Clay	20	30
Sand	12	42
Clay	30	72
Sand	62	134

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-616—Continued		
Clay	36	170
Gravel	25	195
Clay	2	197
Well 89-04-617 Owner: City of Brownsville Driller: Virdell Drilling Company		
Topsoil	4	4
Clay	28	32
Sand	9	41
Clay	32	73
Sand	78	151
Clay	15	166
Gravel	34	200
Clay	3	203
Well 89-04-619 Owner: City of Brownsville Driller: Virdell Drilling Company		
Topsoil	4	4
Clay	26	30
Sand	16	46
Clay	26	72
Sand	28	100
Sand and clay	34	134
Clay	36	170
Gravel	22	192
Clay	2	194
Well 89-04-621 Owner: City of Brownsville Driller: Texas Water Supply Corp.		
Surface soil	15	15
Sand, fine grained, with streaks of wood	24	39
Clay, gumbo	13	52
Sand, with streaks of clay	46	98
Well 89-04-621—Continued		
Clay	54	152
Sand, fine grained	44	196
Clay and sand	19	215
Clay, sand streaks	127	342
Sand, clay streaks	36	378
Clay	24	402
Sand and gravel, fine grained	65	467
Shale	21	488
Sand	15	503
Well 89-04-624 Owner: James Haywood Driller: Odie Gilliland		
Topsoil	6	6
Clay	44	50
Fine sand	20	70
Clay	13	83
Medium sand	15	98
Clay	5	103
Sand	9	112
Clay	49	161
Fine sand	14	175
Medium sand	5	180
Rock and gravel	15	195
Well 89-04-625 Owner: George A. Lopez Driller: Powell Drilling Company		
Clay, brown	21	21
Sand, gray	19	40
Silt and clay mix, brown and gray	46	86
Clay, brown	69	155
Sand, fine, gray	18	173
Gravel, pea size	5	178
Sand, tight pack, gray	12	190

Table 3.—Drillers' Logs of Wells—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-627		
Owner: City of Brownsville Driller: Rader Water Well Company		
Brown surface soil	5	5
Broken clay, brown, gray, tan, and yellow, with some selenite crystals	27	32
Sand with clay streaks	8	40
Broken, plastic and silty clay, tan, yellow, and red	22	62
Very fine brown sand with clay streaks	43	105
Sand	50	155
Clay with some sand streaks	5	160
Sand and gravel	30	190
Light silty clay	17	207
Well 89-04-628		
Owner: M. J. Tipton, Sr. (City of Brownsville arranged drilling) Driller: Rader Water Well Company		
Brown and gray silty clay soil	5	5
Brown, gray, yellow, and tan clay and silty clay, with a few streaks of fine sand and some selenite crystals	67	72
Streaks of fine to medium sand and tan silty clay	38	110
Gray, brown, and red silty clay	30	140
Brown and red silty clay with some fine sand, sand increasing with depth	37	177
Sand and gravel	26	203
Clay	4	207
Well 89-04-629		
Owner: City of Brownsville Driller: Rader Water Well Company		
Brown silty clay, with some sand, selenite crystals, and broken glass and other fill in the top 10 to 15 feet	33	33
Broken sand and clay, tan and gray	37	70
Well 89-04-629—Continued		
Fine brown sand with a few streaks of clay	60	130
Brown and gray clay	28	158
Sand and gravel	41	199
Red, gray, brown silty clay	101	300
Well 89-04-630		
Owner: Pedro Rocha (City of Brownsville arranged drilling) Driller: Rader Water Well Company		
Soil	1	1
Clay with sand streaks	9	10
Sand with clay streaks	35	45
Broken clay and sand streaks	10	55
Clay with broken spots	58	113
Sand	2	115
Clay and broken clay	45	160
Very broken clay	10	170
Sand and gravel	26	196
Clay	4	200
Well 89-04-631		
Owner: City of Brownsville Driller: Rader Water Well Company		
Fill	4	4
Brown and gray clay	3	7
Fine brown sand with clay streaks	18	25
Clay with several streaks of sand	40	65
Sand	16	81
Clay	66	147
Sand	43	190
Clay and sand streaks	5	195
Sand with streaks of clay	15	210
Sand	10	220
Clay	5	225

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-04-902		
Owner: City of Brownsville Driller: Rader Water Well Company		
Sandy soil	3	3
Gray-brown silty clay	15	18
Fine brown sand with some silty clay	20	38
Tan, brown, and gray clay and silty clay with thin sand streaks	35	73
Fine brown sand	11	84
Tan plastic clay with some fine sand in last few feet	66	150
Fine brown sand with a few streaks of clay and silt	43	193
Coarse sand and fine to medium gravel	22	215
Clay and silty clay	11	226
Well 89-04-903		
Owner: Robert Mathers (City of Brownsville arranged drilling) Driller: Rader Water Well Company		
Surface clay and soil	5	5
Fine brown sand with clay streaks	15	20
Tan to brown broken clay	40	60
Clay with some sand streaks	25	85
Fine brown sand	10	95
Tan clay	35	130
Sand with hard streaks	50	180
Sand and gravel	10	190
Tan clay	10	200
Well 89-05-102		
Owner: Joe A. Bestiero (City of Brownsville arranged drilling) Driller: Rader Water Well Company		
Soil	2	2
Brown and buff clay and silty clay	28	30
Fine silty sand	5	35

	THICKNESS (FEET)	DEPTH (FEET)
Well 89-05-102—Continued		
Buff clay with a few streaks of sand from 55 to 60 feet	30	65
Fine sand and silty sand with a few streaks of clay at 75 to 80 feet	60	125
Sand and clay streaks	15	140
Gray to blue clay	19	159
Clay with sand streaks	6	165
Sand and gravel	35	200
Clay	5	205
Well 89-05-403		
Owner: —Fleming Driller: Ted Pursley		
Surface soil	3	3
Caliche, shaly	11	14
Shale, sticky	33	47
Sand	34	81
Shale, sticky	36	117
Sand	23	140
Shale, sticky	20	160
Sand	11	171
Sand, hard	16	187
Gravel	11	198
Sand and gravel	13	211
Well 89-05-404		
Owner: City of Brownsville Driller: Rader Water Well Company		
Topsoil	5	5
Clay	15	20
Silty clay	14	34
Very fine, brown silty sand	21	55
Brown and gray clay and silty clay with some streaks of very fine sand	102	157

Table 3.—Drillers' Logs of Wells—Continued

Well 89-05-404—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Very fine dark silty sand with a few thin beds of clay	41	198
Sand and gravel	37	235
Brown and gray clay	5	240

Well 89-05-405

Owner: City of Brownsville
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Soil	1	1
Broken clay	16	17
Sand with clay streaks	28	45
Clay	22	67
Sand with clay streaks	31	98
Clay with sand streaks	27	125
Sand	15	140
Clay	40	180
Sand and gravel	25	205
Clay	5	210

Well 89-05-405—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Sand and gravel	35	245
Clay	10	255

Well 89-05-701

Owner: City of Brownsville
Driller: Rader Water Well Company

	THICKNESS (FEET)	DEPTH (FEET)
Fill	5	5
Broken clay	15	20
Sand	7	27
Clay and broken clay	48	75
Sand	20	95
Clay	20	115
Sand	5	120
Clay	52	172
Sand and gravel	18	190
Clay	2	192
Sand	23	215
Clay	10	225

Table 4.—Water Levels in Observation Wells
Water-level measurements in feet below land surface

Well 88-59-101

Owner: Oscar Thiem

DATE		WATER LEVEL
Sept.	12, 1957	27.6
Mar.	2, 1959	15.8
Aug.	30, 1960	14.1
June	26, 1962	17.3
Aug.	15, 1963	19.1
Aug.	26, 1964	24.5
Aug.	11, 1965	18.7
July	28, 1966	20.9
July	27, 1967	20.5
Aug.	28, 1968	21.3
Aug.	19, 1969	20.7
Aug.	20, 1970	14.6
Aug.	17, 1971	16.4
Aug.	17, 1972	14.7
Sept.	19, 1972	14.7

Well 88-59-102

Owner: Jack Garrett

DATE		WATER LEVEL
July	24, 1952	18.9
Sept.	11, 1957	34.6
Mar.	2, 1959	17.2
Aug.	30, 1960	14.7
June	26, 1962	14.2
Aug.	14, 1963	16.9
Aug.	11, 1965	17.7
July	28, 1966	14.3
July	27, 1967	16.6
Aug.	30, 1968	14.8
Aug.	20, 1970	14.3
Aug.	16, 1971	15.1
Aug.	8, 1972	13.2

Well 88-59-201

Owner: D. H. Palmer

DATE		WATER LEVEL
Aug.	19, 1952	17.7
May	3, 1954	17.5
Sept.	30, 1957	26.2
Feb.	3, 1959	10.5
Aug.	30, 1960	12.2

Well 88-59-202

Owner: T. Kawamara

DATE		WATER LEVEL
Sept.	12, 1957	29.4
Mar.	2, 1959	17.5
Aug.	30, 1960	14.9
June	26, 1962	19.8
Aug.	15, 1963	23.0
Aug.	10, 1965	22.2
July	28, 1966	19.3
Aug.	28, 1968	21.2
Aug.	19, 1969	20.1
Aug.	20, 1970	19.7
Aug.	16, 1971	20.0
Aug.	7, 1972	17.4
Aug.	28, 1973	17.7

Well 88-59-401

Owner: Tom Tanamachi

DATE		WATER LEVEL
Mar.	2, 1959	16.6
June	26, 1962	18.4
Aug.	15, 1963	21.1
Aug.	26, 1964	22.4
Aug.	12, 1965	16.6
July	28, 1966	16.5
Aug.	28, 1968	14.1
Aug.	19, 1969	13.8
Aug.	19, 1970	14.5

Well 88-59-401—Continued

DATE		WATER LEVEL
Aug.	16, 1971	15.1
Aug.	8, 1972	13.0
Aug.	28, 1973	13.4

Well 88-59-502

Owner: O. W. Tucker

DATE		WATER LEVEL
Sept.	4, 1952	18.9
Sept.	12, 1957	24.7
Aug.	30, 1960	17.1
June	26, 1962	15.7
Aug.	15, 1963	17.0
Aug.	26, 1964	20.4
Aug.	12, 1965	15.7
July	28, 1966	13.5
July	27, 1967	23.1
Aug.	28, 1968	16.3
Aug.	19, 1969	15.9
Aug.	19, 1970	11.6
Aug.	16, 1971	11.3
Aug.	7, 1972	7.7
Aug.	28, 1973	7.5

Well 88-60-101

Owner: Louis Stanley

DATE		WATER LEVEL
Sept.	12, 1957	27.4
Mar.	2, 1959	15.1
Aug.	30, 1960	17.3
June	26, 1962	21.0
Aug.	15, 1963	21.4
Aug.	26, 1964	22.5
Aug.	11, 1965	20.1
July	28, 1966	20.1
July	26, 1967	21.0
Aug.	28, 1968	20.0

Table 4.—Water Levels in Observation Wells—Continued

DATE		WATER LEVEL
Well 88-60-101—Continued		
Aug.	19, 1969	19.5
Aug.	19, 1970	15.0
Aug.	16, 1971	16.5
Aug.	7, 1972	13.8
Aug.	29, 1973	13.2
Well 88-60-401		
Owner: J. G. Ballinger		
Mar.	2, 1959	12.3
Aug.	15, 1962	14.4
Aug.	26, 1964	16.1
Aug.	18, 1970	12.1
Aug.	19, 1970	10.0
Aug.	7, 1972	8.4
Well 88-60-701		
Owner: Ben Benson		
Sept.	12, 1957	25.6
Mar.	2, 1959	16.1
Aug.	30, 1960	15.9
June	27, 1962	18.7
Aug.	15, 1963	18.6
Aug.	26, 1964	20.5
Aug.	12, 1965	18.9
July	28, 1966	17.5
July	27, 1967	20.0
Aug.	18, 1969	17.7
Aug.	19, 1960	14.8
Aug.	16, 1971	16.0
Aug.	7, 1972	10.9
Aug.	28, 1973	11.1
Well 88-60-702		
Owner: Carlos Watson		
Aug.	20, 1952	24.5
Sept.	12, 1957	30.6
Mar.	2, 1959	15.1
Well 88-60-708		
Owner: Sams-Porter Corporation		
July	3, 1957	31.0
Oct.	11, 1972	18.8
May	10, 1973	18.9
May	12, 1973	43.8[1]
Well 88-60-719		
Owner: Sams-Porter Corporation		
May	3, 1973	15.8
May	4, 1973	16.0
May	10, 1973	16.6
May	13, 1973	17.0
June	13, 1973	19.7
June	14, 1973	19.4
June	15, 1973	23.3
June	16, 1973	27.8
June	18, 1973	28.5
June	19, 1973	25.7
June	20, 1973	21.3
Oct.	19, 1973	12.7
Well 89-04-101		
Owner: J. T. Canales		
June	27, 1962	30.2
Aug.	15, 1963	22.8
Aug.	26, 1964	32.1
Aug.	11, 1965	23.8
July	28, 1966	27.0
Well 89-04-101—Continued		
July	27, 1967	24.1
Aug.	28, 1968	21.5
Aug.	18, 1969	19.3
Aug.	19, 1970	21.1
Aug.	16, 1971	33.5
Aug.	7, 1972	16.4
Aug.	28, 1973	15.3
Well 89-04-208		
Owner: Water Conservation and Improvement District Number 6		
Apr.	2, 1973	15.4
Apr.	3, 1973	15.5
Apr.	4, 1973	15.6
Apr.	5, 1973	15.7
Apr.	8, 1973	15.8
Apr.	12, 1973	14.7
Apr.	17, 1973	14.6
Apr.	18, 1973	14.5
May	3, 1973	15.8
May	9, 1973	16.2
May	14, 1973	16.5
June	12, 1973	16.8
June	13, 1973	17.8
June	15, 1973	18.5
June	16, 1973	18.8
June	17, 1973	19.2
June	18, 1973	19.5
June	20, 1973	19.6
Oct.	17, 1973	12.2
Oct.	19, 1973	12.1

Table 4.—Water Levels in Observation Wells—Continued

Well 89-04-209

Owner: Water Conservation and Improvement District Number 6

DATE	WATER LEVEL
Apr. 2, 1973	5.9
Apr. 4, 1973	6.0
Apr. 5, 1973	6.1
Apr. 9, 1973	6.2
Apr. 10, 1973	6.1
Apr. 12, 1973	6.0
Apr. 16, 1973	6.1
Apr. 17, 1973	6.0
May 3, 1973	6.8
May 4, 1973	7.0
May 9, 1973	7.3
May 14, 1973	7.6
June 12, 1973	9.5
June 14, 1973	9.7
June 15, 1973	10.1
June 16, 1973	10.4
June 17, 1973	10.6
June 18, 1973	10.9
June 19, 1973	11.3
June 20, 1973	11.6
Oct. 17, 1973	4.8

Well 89-04-308

Owner: Texas Parks and Wildlife Department

DATE	WATER LEVEL
Apr. 2, 1973	8.2
Apr. 3, 1973	7.2
Apr. 4, 1973	8.2
Apr. 5, 1973	8.3
Apr. 9, 1973	8.2
Apr. 10, 1973	8.4
Apr. 11, 1973	8.3
Apr. 15, 1973	8.3
Apr. 20, 1973	8.3
May 3, 1973	8.7
May 4, 1973	8.9
May 9, 1973	9.1
June 12, 1973	10.8
June 13, 1973	11.3
June 15, 1973	11.5
June 16, 1973	11.6
June 17, 1973	11.8
June 18, 1973	11.9
June 19, 1973	12.1
June 20, 1973	12.4
June 21, 1973	12.0

Well 89-04-309

Owner: A. Garcia

DATE	WATER LEVEL
Apr. 2, 1973	9.6
Apr. 5, 1973	9.7
Apr. 8, 1973	9.8
Apr. 11, 1973	9.7
Apr. 15, 1973	9.7
Apr. 20, 1973	9.7
May 3, 1973	10.1
May 4, 1973	10.7
May 14, 1973	10.6
June 12, 1973	12.0
June 13, 1973	12.2
June 15, 1973	11.9
June 16, 1973	12.0
June 17, 1973	12.3
June 18, 1973	16.5
June 19, 1973	16.8
June 20, 1973	17.1
Oct. 15, 1973	9.2
Oct. 16, 1973	9.3

Well 89-04-510

Owner: Jimmy Hollon

DATE	WATER LEVEL
Apr. 2, 1973	13.4
Apr. 3, 1973	13.5
Apr. 4, 1973	13.7
Apr. 5, 1973	13.9
Apr. 8, 1973	13.7
Apr. 9, 1973	13.6
Apr. 10, 1973	13.5
Apr. 12, 1973	13.6
Apr. 15, 1973	13.5
Apr. 16, 1973	13.4
Apr. 17, 1973	13.3
Apr. 18, 1973	13.4
Apr. 20, 1973	13.3
Apr. 22, 1973	13.2
May 2, 1973	14.4
May 3, 1973	14.6
May 4, 1973	14.7
May 9, 1973	14.2
May 14, 1973	14.4
June 12, 1973	14.2
June 13, 1973	14.6
June 14, 1973	15.1
June 15, 1973	15.7
June 16, 1973	16.0
June 17, 1973	16.3
June 18, 1973	16.5
June 19, 1973	16.8
June 20, 1973	17.1
Oct. 21, 1973	11.5

Table 4.—Water Levels in Observation Wells—Continued

Well 89-04-602

Owner: City of Brownsville

DATE	WATER LEVEL
Sept. 30, 1953	22.4
Sept. 30, 1957	16.9
Aug. 30, 1960	10.3
Aug. 15, 1963	14.5
July 28, 1966	19.2
July 27, 1967	21.8
Aug. 28, 1968	15.0
Aug. 19, 1970	14.1
Aug. 16, 1971	18.7
Aug. 7, 1972	11.5
Aug. 28, 1973	10.7

Well 89-04-616

Owner: City of Brownsville

DATE	WATER LEVEL
Apr. 2, 1973	12.2
Apr. 3, 1973	20.5
Apr. 4, 1973	18.2
Apr. 5, 1973	18.4
Apr. 11, 1973	14.9
Apr. 12, 1973	16.7
Apr. 13, 1973	12.8
Apr. 14, 1973	11.9
Apr. 15, 1973	11.6
Apr. 16, 1973	11.4
Apr. 17, 1973	11.3
Apr. 18, 1973	11.0
Apr. 21, 1973	10.9
Apr. 22, 1973	10.8
Apr. 23, 1973	10.6
May 14, 1973	12.2
Oct. 18, 1973	18.6
Oct. 20, 1973	18.3

Well 89-04-627

Owner: City of Brownsville

DATE	WATER LEVEL
Apr. 2, 1973	10.7
Apr. 3, 1973	22.0
Apr. 4, 1973	16.5
Apr. 5, 1973	16.7
Apr. 10, 1973	9.6
Apr. 11, 1973	13.0
Apr. 12, 1973	14.8
Apr. 13, 1973	11.1
Apr. 14, 1973	10.2
Apr. 15, 1973	9.8
Apr. 16, 1973	9.7
Apr. 17, 1973	9.6
Apr. 18, 1973	9.3
Apr. 19, 1973	9.4
Apr. 21, 1973	9.0
May 9, 1973	14.2
June 12, 1973	14.5
June 13, 1973	44.3
June 14, 1973	44.5
June 15, 1973	44.8
June 16, 1973	44.3
June 17, 1973	44.5
June 18, 1973	44.7
June 19, 1973	45.0
June 20, 1973	45.2
June 21, 1973	45.7
Oct. 18, 1973	8.0
Oct. 20, 1973	7.8

Well 89-04-628

Owner: M. J. Tipton, Sr. (City of Brownsville)

DATE	WATER LEVEL
Apr. 2, 1973	11.4
Apr. 3, 1973	13.7

Well 89-04-628—Continued

DATE	WATER LEVEL
Apr. 4, 1973	13.9
Apr. 5, 1973	14.2
Apr. 8, 1973	11.8
Apr. 9, 1973	11.5
Apr. 10, 1973	11.3
Apr. 11, 1973	11.9
Apr. 12, 1973	11.8
Apr. 13, 1973	12.1
Apr. 14, 1973	11.5
Apr. 15, 1973	11.1
Apr. 16, 1973	11.0
Apr. 17, 1973	10.9
Apr. 18, 1973	10.7
Apr. 20, 1973	10.5
Apr. 21, 1973	10.6
Apr. 22, 1973	10.5
Apr. 23, 1973	10.4
Apr. 24, 1973	11.8
May 2, 1973	15.4
May 3, 1973	15.8
May 4, 1973	14.0
May 9, 1973	12.7
Oct. 16, 1973	9.9

Well 89-04-629

Owner: City of Brownsville

DATE	WATER LEVEL
Apr. 2, 1973	11.0
Apr. 3, 1973	21.7
Apr. 4, 1973	16.4
Apr. 5, 1973	16.7
Apr. 10, 1973	10.0
Apr. 11, 1973	13.1
Apr. 12, 1973	14.9
Apr. 13, 1973	11.0

Table 4.—Water Levels in Observation Wells—Continued

DATE		WATER LEVEL
Well 89-04-629—Continued		
Apr.	14, 1973	10.2
Apr.	15, 1973	9.7
Apr.	16, 1973	9.6
Apr.	17, 1973	9.5
Apr.	18, 1973	9.3
Apr.	19, 1973	9.4
Apr.	20, 1973	9.3
Apr.	21, 1973	9.1
Apr.	22, 1973	9.0
Apr.	23, 1973	9.0
Apr.	24, 1973	12.2
May	9, 1973	14.3
June	12, 1973	14.6
June	13, 1973	42.7
June	14, 1973	43.1
June	15, 1973	43.2
June	16, 1973	42.9
June	17, 1973	43.0
June	18, 1973	43.4
June	20, 1973	43.8
June	21, 1973	43.9
Oct.	18, 1973	8.1
Oct.	20, 1973	7.8
Well 89-04-630		
Owner: Pedro Rocha		
Apr.	18, 1973	10.4
Apr.	20, 1973	10.3
Apr.	21, 1973	10.2
Apr.	22, 1973	10.2
Apr.	23, 1973	10.1
Apr.	24, 1973	10.4
May	2, 1973	12.8
May	3, 1973	13.0
Well 89-04-630—Continued		
May	4, 1973	12.6
May	9, 1973	11.4
May	14, 1973	11.8
June	13, 1973	13.3
June	14, 1973	14.5
June	15, 1973	15.4
June	16, 1973	15.5
June	17, 1973	15.6
June	18, 1973	15.7
June	19, 1973	16.0
June	20, 1973	16.2
June	21, 1973	16.3
Oct.	15, 1973	9.8
Well 89-05-102		
Owner: Joe A. Bestiero		
Apr.	2, 1973	0.0
Apr.	5, 1973	0.0
Apr.	8, 1973	0.7
Apr.	12, 1973	0.7
Apr.	16, 1973	0.7
Apr.	18, 1973	0.6
Apr.	21, 1973	0.7
Apr.	23, 1973	0.6
May	3, 1973	0.9
May	9, 1973	1.1
May	14, 1973	1.3
June	12, 1973	13.0
June	13, 1973	1.7
June	14, 1973	1.8
June	15, 1973	4.5
June	16, 1973	1.6
June	17, 1973	13.6
Well 89-05-102—Continued		
June	18, 1973	14.7
June	19, 1973	1.8
Oct.	15, 1973	0.4
Oct.	16, 1973	11.4
Oct.	19, 1973	0.4
Well 89-05-404		
Owner: City of Brownsville		
Apr.	2, 1973	11.1
Apr.	3, 1973	11.2
Apr.	4, 1973	11.1
Apr.	5, 1973	11.3
Apr.	10, 1973	11.4
Apr.	11, 1973	11.3
Apr.	15, 1973	11.3
Apr.	18, 1973	11.4
Apr.	20, 1973	11.2
Apr.	23, 1973	11.2
Apr.	24, 1973	10.9
May	3, 1973	10.7
May	9, 1973	10.8
May	14, 1973	10.7
June	12, 1973	11.7
June	14, 1973	11.8
June	17, 1973	11.9
June	18, 1973	12.1
Oct.	15, 1973	10.4
Oct.	16, 1973	10.3
Oct.	17, 1973	10.1
Well 89-05-405		
Owner: City of Brownsville		
Apr.	16, 1973	9.0
Apr.	17, 1973	8.8

Table 4.—Water Levels in Observation Wells—Continued

DATE		WATER LEVEL	DATE		WATER LEVEL	DATE		WATER LEVEL
Well 89-05-405—Continued			**Well 89-05-405—Continued**			**Well 89-05-405—Continued**		
Apr.	18, 1973	8.7	May	14, 1973	9.6	June	16, 1973	11.3
Apr.	20, 1973	8.6	June	12, 1973	9.7	June	17, 1973	11.5
Apr.	24, 1973	8.2	June	13, 1973	10.1	June	18, 1973	15.7
May	3, 1973	9.7	June	14, 1973	10.7	June	19, 1973	16.0
May	4, 1973	9.8	June	15, 1973	11.1	June	20, 1973	16.2
						June	21, 1973	16.3

[1]Measurement affected by pumping.

Table 5.--Chemical Analyses of Water from Selected Wells and Test Holes

(Analyses given in milligrams per liter except percent sodium, pH, sodium adsorption ratio, and residual sodium carbonate)
Water-bearing unit: All wells pump from the Lower Rio Grande Valley aquifer.
Dissolved solids : The bicarbonate "reported" is converted by computation (multiplying by 0.4917) to an equivalent amount of carbonate, and the carbonate figure is used in the computation of this sum.
Analyses by Texas State Department of Health.

Well	Producing interval (ft)	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 (B)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)
88-59-101	--	168	Sept. 3, 1952	43	--	280	115	537	--	258	387	1,200	0.6	6.0	0.6	2,696	1,170	4,710	7.7	50	6.8	0
103	145-151	151	Sept. 21, 1972	44	--	73	24	167	--	390	143	134	1.0	3.5	.5	781	282	1,180	7.5	56	4.3	.7
105	--	164	Oct. 12, 1972	41	1.6	243	84	419	--	355	490	750	.8	4.5	.9	2,210	950	3,250	7.3	49	5.9	0
204	--	166	Sept. 25, 1972	36	5.2	139	100	463	--	407	580	590	.8	5.5	1.3	2,120	760	3,030	7.4	57	7.3	0
502	--	200	Oct. 30, 1952	46	--	68	28	322	--	437	326	192	--	3.5	.5	--	--	--	--	--	--	--
Do.	--	do	May 28, 1969	22	--	225	80	970	28	289	432	1,680	1.0	10.5	--	--	--	--	--	--	--	--
503	142-147	150	Sept. 26, 1972	50	--	120	42	436	--	465	462	402	1.0	< .4	1.0	1,740	474	2,500	7.4	67	8.7	0
504	--	do	Sept. 25, 1972	41	--	151	55	429	--	454	457	500	1.0	3.5	.9	1,860	610	2,600	7.3	61	7.6	0
603	165-172	172	Oct. 12, 1972	39	--	96	49	298	--	418	471	173	.8	2.5	.9	1,340	444	1,880	7.5	60	6.1	0
605	--	200	Oct. 19, 1972	38	.02	85	32	464	--	495	483	320	1.0	< .4	1.4	1,670	344	2,400	7.5	75	10.8	1.2
701	--	170	Sept. 28, 1972	35	--	26	29	156	--	443	171	83	.8	1.5	.5	770	310	1,145	7.4	52	3.8	1.0
901	--	750	Apr. 17, 1941	--	--	113	22	59	--	340	127	62	--	2.5	--	--	--	--	--	26	1.3	.0
902	--	170	Sept. 19, 1972	32	--	76	31	164	--	426	205	93	.9	< .4	.6	810	319	1,190	7.6	53	4.0	.6
903	163-175	175	do	41	.02	219	34	127	--	433	296	232	.7	2.0	.6	1,170	690	1,680	7.5	29	2.1	0
904	163-169	169	Sept. 20, 1972	37	--	82	25	215	--	447	243	125	1.3	3.5	.8	950	309	1,400	7.7	60	5.3	1.1
905	167-175	175	do	30	--	91	41	297	--	500	451	137	.9	< .4	--	1,290	398	1,800	7.5	62	6.4	.2
906	166-172	172	do	37	--	64	29	212	--	466	181	130	1.2	2.0	.9	890	280	1,330	7.6	62	5.5	2.0
907	170-176	176	do	46	--	64	31	227	--	462	258	107	.9	2.5	.8	960	287	1,400	7.7	63	5.8	1.8
908	181-183	183	do	38	--	89	44	179	--	444	281	111	.9	3.5	.6	970	405	1,400	8.0	49	3.8	0
910	148-156	156	Sept. 29, 1972	46	--	88	38	259	--	487	392	112	1.3	1.5	.8	1,180	377	1,660	7.6	60	5.8	.9
60-101	--	174	May 8, 1952	42	--	172	73	650	--	369	705	770	--	.5	1.5	2,594	729	4,160	7.3	66.0	10.4	0
Do.	--	do	July 8, 1952	31	--	167	78	610	--	420	700	710	1.0	< .4	.7	2,504	740	3,560	7.8	64.3	9.7	0
Do.	--	do	Sept. 19, 1972	31	--	169	75	610	--	399	730	720	1.0	< .4	1.7	2,530	730	3,520	7.4	64.5	9.8	0
102	--	200	Oct. 14, 1972	34	--	66	45	880	--	610	760	700	1.2	< .4	3.0	2,790	348	3,950	7.9	85	20.4	3.0
401	--	204	Jan. 8, 1952	50	--	112	63	626	--	399	812	500	.6	4.0	1.0	--	--	--	--	72	11.7	.6
402	--	200	May 3, 1973	44	--	99	40	430	--	540	540	224	1.2	6.0	--	1,650	412	2,350	7.5	69	9.2	.6
502	--	166	Sept. 20, 1972	46	--	182	75	830	--	520	1,110	720	1.0	< .4	2.5	3,220	760	4,220	7.5	70	13.0	.0
701	--	290	June 23, 1952	34	--	111	60	790	--	501	894	650	1.0	--	2.1	--	--	4,300	7.5	77	15.0	.0
703	156-165	169	Sept. 19, 1972	35	--	80	41	436	--	510	540	258	1.0	2.5	1.4	1,650	367	2,350	7.5	72	9.8	.9
705	188-196	196	Sept. 20, 1972	32	--	100	23	446	--	530	520	259	1.0	1.5	1.8	1,640	343	2,300	7.7	74	10.4	1.8

Table 5.--Chemical Analyses of Water from Selected Water Wells and Test Holes--Continued

Well	Producing interval (ft)	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 (B)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)
88-60-708	240-250	271	Apr. 25, 1973	37	--	87	42	484	--	490	630	280	1.1	7.0	--	1,810	392	2,500	7.5	73	10.6	0.2
Do.	do	do	May 10, 1973	39	--	90	45	500	--	500	650	309	1.2	1.1	--	1,880	409	2,600	7.6	73	10.7	.0
Do.	do	do	do	37	--	87	47	520	--	500	670	309	1.2	1.1	--	1,920	412	2,610	7.6	73	11.1	.0
Do.	do	do	May 11, 1973	37	--	88	47	510	--	499	660	320	1.2	4.5	--	1,910	415	2,610	7.5	73	10.9	.0
Do.	do	do	do	37	--	90	47	520	--	497	680	320	1.2	5.3	--	1,940	418	2,620	7.5	73	11.0	.0
Do.	do	do	do	37	--	94	45	530	--	510	670	320	1.2	.5	--	1,950	420	2,650	7.6	73	11.2	.0
Do.	do	do	do	37	--	91	47	530	--	510	680	314	1.2	< .4	--	1,950	423	2,700	7.6	73	11.2	.0
Do.	do	do	do	34	--	96	45	520	--	500	670	330	1.2	1.7	--	1,940	423	2,700	7.6	73	10.9	.0
Do.	do	do	do	37	--	97	44	530	--	500	690	330	1.2	.9	--	1,980	423	2,700	7.6	73	11.2	.0
Do.	do	do	do	37	--	95	47	530	--	500	720	335	1.1	< .4	--	2,010	432	2,680	7.6	73	11.1	.0
Do.	do	do	do	37	--	97	44	540	--	494	680	325	1.2	3.1	--	1,970	423	2,750	7.4	74	11.4	.0
709	200-270	270	Sept. 21, 1972	35	--	312	143	1,020	--	336	1,500	1,280	1.2	1.5	2.9	4,460	1,370	5,700	7.4	62	12.0	.0
719	67-90	275	Apr. 24, 1973	39	7.15	228	65	418	--	540	680	426	1.1	2.7	1.6	2,130	840	2,950	7.8	52	6.2	.0
Do.	230-253	do	Apr. 26, 1973	35	1.08	70	29	495	--	540	590	250	1.2	.9	1.6	1,740	294	2,400	8.0	79	12.5	2.9
Do.	do	do	June 13, 1973	2	--	20	23	481	--	390	510	250	1.1	2.8	1.0	1,480	143	2,130	7.7	88	17.4	3.5
Do.	do	do	Oct. 19, 1973	1	--	15	17	470	--	388	404	252	1.0	3.1	--	1,360	106	2,080	7.6	90	19.7	4.2
806	16-39	198	Apr. 9, 1973	25	4.2	1,050	1,480	10,800	--	377	6,300	17,900	4.9	7.0	12.6	37,800	8,700	12,000	7.5	73	50.2	.0
Do.	155-178	do	Apr. 10, 1973	35	2.30	151	95	1,040	--	431	950	1,170	1.0	.7	2.2	3,660	770	4,990	7.8	75	16.3	.0
901	--	180	Oct. 16, 1972	34	--	204	104	1,070	--	416	960	1,320	1.0	< .4	2.4	940	940	5,380	7.5	71	15.2	.0
902	68-69	95	Mar. 28, 1973	28	.55	540	293	2,700	--	393	3,590	3,170	1.3	2.3	4.9	10,500	2,560	10,910	7.7	--	--	--
Do.	183-204	204	Mar. 29, 1973	32	6.1	44	449	640	--	540	449	520	1.2	.7	2.1	1,980	218	2,960	8.3	87	18.9	9.5
Do.	do	do	June 12, 1973	1	--	14	17	466	--	298	309	383	.1	2.4	1.0	1,340	107	2,100	7.6	91	19.7	2.7
Do.	do	do	June 21, 1973	1	--	10	16	660	--	333	446	530	1.1	3.0	1.1	1,830	92	2,750	8.1	94	30.1	3.6
Do.	--	do	Oct. 16, 1973	1	--	7	7	451	--	249	280	359	.9	3.3	--	1,230	48	1,990	7.7	95	28.8	3.1
61-701	--	240	Oct. 16, 1972	1	.50	121	83	2,110	--	17	1,020	3,020	.07	< .4	2.5	6,400	650	8,700	8.7	88	36.1	.0
702	--	180	do	35	.74	213	125	1,390	--	433	1,210	1,780	1.0	< .4	3.1	4,970	1,050	6,650	7.5	74	18.7	.0
89-04-101	--	328	Feb. 21, 1950	34	--	122	73	628	--	394	606	700	--	--	--	--	604	3,700	8.1	69	11.1	.0
105	--	202	Sept. 26, 1972	35	--	113	53	342	--	423	540	245	1.2	.6	1.6	--	500	2,140	7.9	60	6.6	.0
106	--	200	Sept. 28, 1972	28	--	47	33	750	--	640	690	486	1.9	< .4	3.6	2,350	253	3,330	7.7	87	20.5	5.4
107	197-212	212	Sept. 21, 1972	28	--	84	42	183	--	393	258	150	.6	< .4	.8	940	384	1,420	7.7	51	4.0	.0
108	--	do	Sept. 19, 1972	35	--	105	42	165	--	422	250	139	.7	< .4	.7	940	435	1,400	7.7	45	3.4	.0
109	195-208	208	do	34	--	78	47	439	--	540	530	264	1.2	< .4	2.0	1,660	388	2,350	7.6	71	9.6	1.0

Table 5.--Chemical Analyses of Water from Selected Water Wells and Test Holes--Continued

Well	Producing interval (ft)	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 (B)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)
89-04-110	183-187	187	Sept. 19, 1972	32	--	69	42	600	--	500	590	466	1.5	1.5	2.3	2,050	346	2,920	8.0	79	14.0	1.2
111	178-188	188	Sept. 21, 1972	29	--	25	15	401	4.0	600	301	160	1.9	< .4	2.6	1,240	127	1,830	7.9	87	15.6	7.3
112	--	212	Sept. 19, 1972	36	--	99	42	165	--	421	249	136	.7	< .4	.7	940	419	1,370	7.4	46	3.5	.0
113	178-190	190	Sept. 28, 1972	30	--	51	39	215	--	423	193	133	1.0	< .4	.9	870	286	1,320	7.8	62	5.5	1.1
114	--	192	do	36	--	104	42	156	--	431	245	131	.7	< .4	.6	930	433	1,350	7.4	44	3.2	.0
208	65-100	200	Mar. 11, 1973	27	--	14	14	520	--	540	231	397	1.9	.5	2.0	1,470	92	2,310	8.3	92	23.5	7.0
Do.	180-200	do	do	29	0.66	25	16	389	--	510	267	199	2.0	< .4	1.5	1,180	126	1,770	8.4	87	14.9	5.7
Do.	do	do	June 14, 1973	2	--	12	5	416	--	359	230	288	1.4	.5	1.3	1,130	51	1,770	7.9	95	25.4	4.8
Do.	do	do	Oct. 19, 1973	1	--	8	4	449	--	381	200	337	1.6	2.7	--	1,100	36	1,940	7.9	96	32.3	5.5
209	112-122	do	Mar. 13, 1973	29	2.25	415	242	2,690	--	473	2,490	3,500	1.1	15.0	2.7	9,620	2,032	11,010	7.3	74	25.9	.0
Do.	180-200	do	do	28	--	48	33	710	--	510	620	540	2.2	.7	.87	2,230	250	3,240	8.1	86	19.6	3.3
Do.	do	do	June 12, 1973	1	--	6	12	740	--	290	540	590	1.5	2.1	1.4	2,060	63	3,000	8.9	96	40.1	3.4
Do.	183-200	do	Oct. 19, 1973	1	--	6	3	331	--	292	202	221	.8	1.5	--	910	30	1,500	8.4	96	27.5	4.2
Do.	do	do	Dec. 11, 1973	12	--	26	20	720	--	443	580	540	2.2	2.3	2.2	2,120	146	3,100	7.8	91	25.8	5.5
Do.	do	do	do	29	--	47	24	720	--	520	570	550	2.3	< .4	2.6	2,200	218	3,190	7.5	88	21.3	4.2
Do.	do	do	do	32	--	45	24	720	--	520	560	540	2.4	.4	--	2,180	214	3,170	7.6	88	21.5	4.3
210	22-45	55	Apr. 2, 1973	24	3.6	457	251	2,330	--	348	2,270	3,160	2.4	1.3	3.9	8,700	2,180	9,970	8.0	70.0	21.7	.0
Do.	110-132	140	do	29	1.08	20	10	434	--	570	274	192	1.7	< .4	1.5	1,260	92	1,890	8.6	91	19.7	7.5
Do.	194-217	220	Apr. 3, 1973	34	--	90	61	600	--	490	890	357	.9	.5	2.5	2,280	476	3,060	8.2	73	11.9	.0
211	46-80	--	Apr. 4, 1973	34	.28	419	259	2,060	--	428	2,550	2,500	2.1	10.1	4.6	8,000	2,110	9,160	7.7	68	19.5	.0
Do.	184-207	235	Apr. 6, 1973	28	1.64	44	25	550	--	475	408	426	2.0	1.3	1.6	1,720	216	2,540	8.1	85	16.4	3.5
301	169-177	177	Sept. 19, 1972	31	--	31	22	570	--	570	380	403	1.9	< .4	--	1,720	167	2,570	7.5	88	19.1	5.9
Do.	do	do	Apr. 10, 1973	35	--	32	21	580	--	570	397	399	2.0	3.1	--	1,750	169	2,600	7.7	88	19.5	6.0
302	29-37	37	Sept. 26, 1972	35	--	29	18	375	--	520	247	209	1.1	< .4	1.3	1,170	148	1,760	8.1	85	13.4	5.5
303	--	180	Sept. 21, 1972	32	--	52	37	790	--	590	640	640	1.7	< .4	2.9	2,490	281	3,550	7.6	86	20.4	4.0
305	--	do	Oct. 19, 1972	34	.92	65	--	880	--	570	710	730	1.2	< .4	2.8	2,740	327	3,870	7.7	85	22.1	2.8
308	179-208	211	Mar. 25, 1973	36	3.80	99	68	1,030	--	530	1,090	890	1.3	< .4	3.2	3,480	530	4,680	8.0	81	19.5	.0
Do.	do	do	June 12, 1973	1	--	50	66	1,110	--	322	1,130	1,000	1.2	2.1	2.3	3,520	398	4,330	8.0	86	24.2	.0
Do.	179-208	do	June 21, 1973	1	--	34	66	1,120	--	288	1,100	1,000	1.2	1.7	1.5	3,470	357	4,650	8.1	87	25.8	.0
Do.	do	do	Oct. 16, 1973	1	--	11	36	1,150	--	173	970	1,020	1.6	8.0	--	3,290	173	4,720	8.0	93	37.7	.0
309	80-100	--	Mar. 27, 1973	23	.08	680	253	2,080	--	288	2,720	3,110	1.3	4.1	3.4	9,000	2,750	9,860	7.6	--	--	--
Do.	179-199	220	Mar. 28, 1973	34	1.8	64	53	910	--	560	820	780	1.2	.9	3.0	2,940	380	4,090	8.1	84	20.3	1.6

Table 5.--Chemical Analyses of Water from Selected Water Wells and Test Holes--Continued

Well	Producing interval (ft)	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Cal-cium (Ca)	Magne-sium (Mg)	Sod-ium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Boron (B)	Dis-solved solids	Total hard-ness as $CaCO_3$	Specific conduct-ance (micromhos at 25°C)	pH	Per-cent sod-ium	Sodium adsorp-tion ratio (SAR)	Residual sodium carbon-ate (RSC)
89-04-309	179-199	220	June 12, 1973	1	--	40	25	960	--	296	820	810	1.3	3.1	2.1	2,810	204	3,900	7.9	91	29.3	0.7
Do.	do	do	June 21, 1973	1	--	13	32	970	--	278	830	830	1.2	2.1	--	2,820	163	4,000	8.5	93	32.9	1.2
Do.	do	do	Oct. 16, 1973	1	--	11	26	970	--	326	740	820	1.6	2.5	--	2,730	134	4,000	7.8	94	36.4	2.6
Do.	do	do	Dec. 13, 1973	8	--	12	27	950	--	360	740	810	1.5	4.9	--	2,750	142	4,000	8.6	94	34.8	3.0
Do.	do	do	do	28	--	70	43	950	--	560	810	800	1.8	1.5	--	2,980	352	4,200	7.4	85	22.0	2.1
Do.	do	do	do	30	--	71	42	920	4.0	550	720	810	1.7	7.0	3.1	2,880	351	4,210	7.5	85	21.3	2.0
503	--	191	Sept. 21, 1972	32	--	42	34	444	--	453	372	331	1.2	< .4	1.6	1,480	245	2,230	7.9	80	12.3	2.5
504	--	185	do	34	--	48	33	306	--	495	264	179	1.1	< .4	1.4	1,110	258	1,650	8.0	72	8.3	3.0
505	--	202	Sept. 20, 1972	32	--	122	22	187	--	261	350	170	1.9	< .4	.6	1,010	398	1,470	7.5	51	9.0	.0
506	--	178	do	30	--	17	14	443	--	610	260	208	1.2	< .4	1.2	1,270	98	1,930	8.2	91	19.2	7.9
507	165-185	185	Sept. 28, 1972	32	--	53	46	250	--	473	222	182	1.0	< .4	1.2	1,020	320	1,530	7.8	63	6.0	1.3
508	--	200	Oct. 18, 1972	34	--	104	73	780	--	449	850	720	.9	< .4	2.3	2,780	560	3,850	7.8	75	14.3	.0
Do.	--	do	Apr. 10, 1973	34	--	100	73	800	--	448	860	720	1.0	1.1	--	2,810	550	3,810	7.5	76	14.8	.0
509	--	do	Oct. 12, 1972	24	--	20	16	487	--	560	347	252	2.7	< .4	2.0	1,430	117	2,110	8.1	90	19.6	6.8
510	80-95	195	Mar. 30, 1973	30	2.6	8	6	464	--	630	210	234	2.0	< .4	2.7	1,270	44	1,960	8.4	96	30.2	9.4
Do.	179-194	do	Mar. 31, 1973	30	.43	21	15	540	--	510	351	373	2.3	< .4	2.0	1,580	113	2,390	8.3	91	21.9	6.0
Do.	do	do	June 12, 1973	1	--	7	4	471	--	395	286	314	2.2	2.5	1.1	1,280	36	1,990	8.4	97	35.1	5.7
Do.	do	do	Oct. 21, 1973	1	--	19	5	102	--	101	25	126	.6	3.3	--	331	70	620	7.9	77	5.3	.2
Do.	do	do	Dec. 11, 1973	2	--	19	9	93	--	95	44	118	.5	4.3	.2	337	84	635	7.2	71	4.4	.0
Do.	do	do	do	21	--	61	25	336	--	333	296	300	1.2	.6	--	1,210	254	1,850	7.5	74	9.1	.3
Do.	do	do	do	21	--	62	22	324	--	349	260	293	1.2	.4	--	1,160	245	1,850	7.6	74	9.0	.8
602	--	200	Jan. 7, 1953	22	--	96	72	283	--	340	69	572	.8	.8	--	1,282	536	2,400	7.9	53	5.3	.0
603	175-190	193	do	32	.02	49	37	590	--	570	550	372	1.2	< .4	2.3	1,910	222	2,700	7.8	82	15.4	3.8
606	--	190	Sept. 26, 1972	36	--	88	49	352	--	409	510	229	1.1	.6	--	1,282	536	2,400	7.9	65	7.4	.0
608	158-228	228	do	32	--	30	25	680	--	530	530	455	1.9	1.5	2.7	2,018	178	2,960	8.4	89	22.1	5.1
Do.	do	do	May 12, 1973	30	--	41	35	700	--	590	570	458	2.0	.6	--	2,130	246	3,050	7.7	86	19.4	4.7
609	--	200	Sept. 20, 1972	31	--	43	29	720	--	550	610	530	2.4	< .4	2.7	2,240	225	3,230	7.8	87	20.8	4.4
610	--	197	do	32	--	53	37	240	4.0	610	650	560	1.2	< .4	3.1	2,380	285	3,420	7.6	85	19.0	4.3
611	--	127	do	29	--	13	9	540	--	660	312	284	1.6	< .4	2.3	1,510	70	2,280	8.2	94	28.1	9.4
612	--	104	do	20	--	216	333	1,370	--	282	2,160	1,760	1.1	< .4	--	6,000	1,910	7,280	6.8	61	13.6	.0
613	--	180	do	29	--	18	32	620	--	620	474	372	2.0	< .4	--	1,850	176	2,750	7.9	88	20.3	6.6
614	134-147	147	Sept. 22, 1972	29	--	22	15	590	--	660	410	326	2.0	< .4	2.7	1,720	116	2,570	7.9	92	83.7	8.4

Table 5.--Chemical Analyses of Water from Selected Water Wells and Test Holes--Continued

Well	Producing interval (ft)	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Cal-cium (Ca)	Magne-sium (Mg)	Sod-ium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Boron (B)	Dis-solved solids	Total hard-ness as $CaCO_3$	Specific conduct-ance (micromhos at 25°C)	pH	Per-cent sod-ium	Sodium adsorp-tion ratio (SAR)	Residual sodium carbon-ate (RSC)
89-04-615	189-197	197	Sept. 28, 1972	30	--	57	36	770	--	610	670	570	1.7	< 0.4	3.2	2,440	290	3,470	7.6	85	19.6	4.1
616	182-197	do	Oct. 12, 1972	34	0.16	51	39	660	--	570	630	427	1.6	< .4	2.4	2,130	288	3,050	8.2	83	16.9	3.5
Do.	do	do	Apr. 1, 1973	32	.17	58	38	680	--	560	670	479	1.8	.5	2.5	2,240	301	3,290	7.7	83	17.0	3.1
Do.	do	do	Apr. 30, 1973	32	--	56	40	710	--	570	680	500	1.8	< .4	--	2,300	307	3,250	7.8	84	17.7	3.2
Do.	do	do	May 1, 1973	32	--	58	41	710	--	560	680	530	1.8	< .4	--	2,330	318	3,330	7.9	83	17.3	2.8
Do.	do	do	do	32	--	60	41	740	--	560	690	510	1.9	< .4	--	2,350	318	3,330	7.8	83	18.0	2.8
Do.	do	do	do	32	--	44	51	750	--	560	700	520	1.9	< .4	--	2,370	321	3,330	7.7	84	18.2	2.7
Do.	do	do	May 2, 1973	32	--	56	43	730	--	560	680	540	1.7	.4	--	2,360	318	3,350	7.8	83	17.8	2.8
Do.	do	do	do	32	--	56	43	730	--	560	690	550	1.8	.4	--	2,380	316	3,350	7.8	83	17.8	2.8
Do.	do	do	May 3, 1973	32	--	59	41	720	--	560	680	540	1.8	.4	--	2,350	318	3,350	7.8	83	17.6	2.8
Do.	do	do	do	34	--	59	42	730	--	550	670	560	1.9	< .4	--	2,370	322	3,350	7.7	83	17.7	2.6
Do.	do	do	June 12, 1973	28	--	54	42	730	--	570	690	479	1.4	< .4	--	2,310	309	3,190	7.8	89	18.1	3.1
Do.	do	do	do	30	--	61	41	760	--	560	670	580	1.4	< .4	--	2,410	321	3,330	7.7	84	18.4	2.7
Do.	do	do	June 13, 1973	28	--	58	46	770	--	550	710	560	1.4	.5	--	2,440	334	3,300	7.7	83	18.3	2.3
Do.	do	do	do	28	--	64	40	780	--	560	640	600	1.4	< .4	--	2,430	326	3,320	7.6	84	18.8	2.6
Do.	do	do	June 14, 1973	30	--	60	40	760	--	550	660	580	1.4	< .4	--	2,400	315	3,370	8.6	94	18.6	2.7
Do.	do	do	do	28	--	60	42	760	--	550	630	610	1.4	.7	--	2,400	324	3,370	7.5	84	18.4	2.5
Do.	do	do	June 15, 1973	29	--	61	39	761	--	550	630	530	1.4	.5	--	2,370	315	3,220	7.7	84	18.7	2.7
Do.	do	do	do	30	--	60	39	760	--	550	670	580	1.4	.5	--	2,410	309	3,370	7.5	84	18.7	2.8
Do.	do	do	June 16, 1973	31	--	62	38	760	--	550	650	590	1.4	< .4	--	2,400	311	3,380	8.0	84	18.7	2.7
Do.	do	do	do	30	--	59	39	760	--	550	650	590	1.4	.5	--	2,400	309	3,370	7.5	84	18.8	2.8
Do.	do	do	June 17, 1973	30	--	60	38	750	--	550	660	590	1.4	1.0	--	2,400	306	3,360	7.5	84	18.6	2.8
Do.	do	do	do	30	--	60	38	760	--	550	680	590	1.4	.5	--	2,430	308	3,380	7.5	84	18.9	2.8
Do.	do	do	June 18, 1973	26	--	59	40	760	--	550	640	560	1.4	< .4	--	2,360	315	3,370	7.7	84	18.7	2.7
Do.	do	do	do	28	--	59	41	780	--	550	630	620	1.4	< .4	--	2,430	316	3,370	7.7	84	19.0	2.6
Do.	do	do	June 19, 1973	28	--	60	40	760	--	550	650	560	1.4	.5	--	2,370	313	3,250	7.6	84	18.6	2.7
Do.	do	do	do	28	--	59	40	760	--	550	660	560	1.4	.5	--	2,380	313	3,350	7.6	84	18.7	2.7
Do.	do	do	June 20, 1973	28	--	59	44	760	--	550	700	560	1.4	< .4	--	2,420	331	3,380	7.6	83	18.2	2.4
Do.	do	do	do	30	--	59	44	760	--	550	700	580	1.4	.4	--	2,440	331	3,320	7.6	83	18.2	2.4
Do.	do	do	June 21, 1973	28	--	59	40	770	--	550	670	600	1.4	.4	--	2,440	312	3,350	7.6	84	18.9	2.2
Do.	do	do	do	28	--	57	45	760	--	550	680	580	1.4	< .4	--	2,420	328	3,300	7.7	83	18.2	2.4
Do.	do	do	June 22, 1973	28	--	59	44	760	--	550	640	580	1.5	< .4	--	2,430	331	3,400	7.6	83	18.2	2.4
623	--	100	Oct. 19, 1972	30	--	27	18	388	--	540	246	187	1.2	< .4	1.8	1,170	142	1,750	8.1	86	14.1	6.0

Table 5.--Chemical Analyses of Water from Selected Wells and Test Holes--Continued

Well	Producing interval (ft)	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Cal-cium (Ca)	Magne-sium (Mg)	Sod-ium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Boron (B)	Dis-solved solids	Total hard-ness as $CaCO_3$	Specific conduct-ance (micromhos at 25°C)	pH	Per-cent sod-ium	Sodium adsorp-tion ratio (SAR)	Residual sodium carbon-ate (RSC)
89-04-624	--	195	Oct. 19, 1972	30	--	20	17	483	--	510	332	280	1.9	1.5	1.8	1,420	120	2,120	7.9	90	19.1	5.9
625	--	190	Oct. 18, 1972	32	--	16	16	482	--	510	313	273	3.5	< .4	1.6	1,390	105	2,110	8.1	91	20.3	6.2
626	--	180	Nov. 20, 1972	29	0.022	62	45	850	--	600	820	640	1.7	< .4	3.1	2,740	340	3,850	7.6	84	20.0	3.0
627	24-46	195	Mar. 21, 1973	23	2.78	630	487	5,800	--	630	6,700	6,400	3.6	7.0	17.0	20,400	3,575	12,000	7.8	--	--	--
Do.	175-195	do	Mar. 23, 1973	34	.60	66	53	690	--	580	700	500	1.3	.5	2.6	2,330	382	3,360	7.8	80	15.3	1.8
Do.	173-195	do	Oct. 18, 1973	1	--	5	32	850	--	405	640	670	1.4	1.7	--	2,420	146	3,550	8.8	93	30.8	3.7
628	93-113	207	Mar. 15, 1973	20	21.0	88	63	1,030	--	560	1,040	850	1.1	1.3	3.2	3,370	476	4,630	7.8	82	20.4	.0
Do.	181-203	do	Mar. 19, 1973	31	.64	53	46	820	--	570	750	630	1.6	.7	2.9	2,610	321	3,670	8.1	85	19.8	2.9
Do.	do	do	June 12, 1973	1	--	7	23	850	--	317	730	670	1.2	1.9	--	2,450	111	3,520	8.7	94	34.9	2.9
Do.	do	do	Oct. 16, 1973	1	--	5	10	860	--	248	690	650	1.6	2.5	--	2,390	55	3,500	9.3	97	51.7	2.9
629	112-134	300	Mar. 19, 1973	29	1.45	42	29	650	--	478	580	453	2.0	2.5	2.4	2,020	222	2,960	8.3	86	18.8	3.3
Do.	176-196	do	Mar. 23, 1973	36	.46	75	56	720	--	560	750	550	1.2	.7	2.8	2,460	418	3,470	7.9	79	15.3	.8
Do.	--	do	Oct. 18, 1973	1	--	5	13	740	--	300	600	530	1.3	7.0	--	2,070	68	3,150	8.9	96	39.1	6.6
Do.	173-195	307	Dec. 13, 1973	21	--	64	46	670	--	550	650	510	1.4	< .4	2.5	2,230	348	3,200	7.6	81	15.6	2.0
Do.	do	do	do	33	--	76	47	680	--	560	610	30	1.5	< .4	2.5	2,250	3,210	3,210	7.6	79	15.1	1.5
Do.	do	do	do	34	--	76	45	680	--	560	610	510	1.6	.8	2.3	2,230	377	3,200	7.6	80	15.2	1.6
630	22-45	204	Apr. 16, 1973	50	.50	109	72	1,610	--	620	1,530	1,310	5.6	14.0	3.4	5,000	568	6,300	7.9	86	29.3	.0
Do.	180-202	do	Apr. 17, 1973	32	.22	35	22	620	--	630	486	357	2.3	.9	2.7	1,860	568	6,300	8.2	89	20.7	6.9
Do.	do	do	June 13, 1973	1	--	9	8	670	--	471	510	405	2.0	2.4	1.6	1,850	53	2,660	8.5	96	39.1	6.6
Do.	do	do	June 21, 1973	1	--	6	8	660	--	433	486	405	2.0	3.0	1.6	1,810	49	2,650	8.8	97	41.5	6.1
Do.	do	do	Oct. 16, 1973	1	--	6	4	650	--	406	470	394	1.8	4.3	--	1,760	29	2,610	8.9	98	50.4	6.0
631	69-82	228	Apr. 21, 1973	32	.76	264	175	2,030	--	325	1,660	2,680	2.2	1.9	4.4	7,000	1,380	8,350	7.8	76	23.7	.0
Do.	152-179	do	do	37	1.52	150	98	1,350	--	443	960	1,730	1.9	1.3	3.4	4,550	780	5,780	7.7	79	21.0	.0
Do.	205-228	do	do	35	4.80	234	159	1,650	11.0	439	1,320	2,300	2.1	2.3	4.0	5,930	1,240	7,450	7.9	--	--	--
632	25	25	Apr. 23, 1973	39	1.2	252	109	1,250	--	740	1,740	990	2.7	2.1	3.8	4,750	1,080	5,450	7.3	72	16.5	.0
902	--	226	Mar. 7, 1973	31	1.45	64	62	990	--	467	760	1,000	1.7	.7	2.8	3,130	372	4,240	7.9	85	33.3	.1
Do.	200-220	do	June 12, 1973	1	--	14	27	1,110	--	273	670	1,000	1.2	.5	2.0	2,860	171	4,170	8.2	94	36.3	1.5
Do.	do	do	Oct. 18, 1973	1	--	5	11	980	--	270	530	810	1.4	9.0	--	2,620	59	3,930	9.7	--	--	--
903	76-89	202	Apr. 1, 1973	30	.2	323	235	3,590	--	590	4,240	2,620	2.7	2.5	12.5	12,300	1,780	12,000	7.9	82	37.0	.0
Do.	166-188	do	Apr. 2, 1973	36	1.6	510	370	3,260	--	400	2,080	5,430	1.2	5.5	6.6	11,900	2,800	12,000	7.8	--	--	--
05-101	--	180	Oct. 19, 1972	35	--	230	153	1,790	--	470	1,660	2,070	1.1	.4	3.9	6,200	1,210	7,850	7.5	76	22.4	.0
102	115-135	--	Mar. 24, 1973	32	2.1	357	227	2,230	--	354	1,600	3,460	1.1	2.9	--	8,100	1,830	9,930	7.5	--	--	--
Do.	183-199	--	do	31	3.0	144	157	1,530	--	466	1,260	1,870	1.1	5.1	--	5,200	1,000	6,880	7.6	77	20.9	.0

Table 5.--Chemical Analyses of Water from Selected Wells and Test Holes--Continued

Well	Producing interval (ft)	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Cal-cium (Ca)	Magne-sium (Mg)	Sod-ium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Boron (B)	Dis-solved solids	Total hard-ness as $CaCO_3$	Specific conduct-ance (micromhos at 25°C)	pH	Per-cent sod-ium	Sodium adsorp-tion ratio (SAR)	Residual sodium carbon-ate (RSC)
89-05-101	184-204	205	June 12, 1973	23	--	176	123	1,560	--	476	1,290	1,820	1.2	1.3	3.5	5,200	950	6,400	7.6	78	22.0	0.0
Do.	--	--	Oct. 16, 1973	1	--	37	100	1,570	--	174	1,000	1,910	1.6	2.5	--	4,710	504	6,540	7.7	87	30.4	.0
201	--	230	Oct. 17, 1973	39	--	266	214	2,150	--	366	1,680	2,980	1.0	< .4	3.9	7,500	1,540	9,350	7.3	75	23.8	.0
89-05-402	--	212	Oct. 12, 1972	44	--	179	69	770	--	540	1,040	640	1.0	< .4	2.1	3,010	730	3,980	7.5	70	12.3	.0
404	165-225	240	Feb. 22, 1973	19	3.74	369	258	2,260	16.0	300	1,610	3,680	1.7	< .4	3.6	8,400	1,990	10,540	7.4	--	--	--
Do.	--	do	Apr. 23, 1973	28	1.78	404	302	2,430	23	364	1,470	4,230	1.2	5.3	3.7	9,070	2,250	8,650	7.7	--	--	--
Do.	165-205	do	June 12, 1973	16	--	193	138	2,100	--	520	2,980	1,460	4.3	1.3	2.4	7,150	7,720	7,720	7.4	81	28.2	.0
Do.	do	do	June 21, 1973	18	--	196	142	2,120	--	520	2,950	1,440	4.3	1.4	5.8	7,130	1,073	7,770	7.3	--	--	--
Do.	do	do	Oct. 17, 1973	11	--	138	69	1,280	--	344	1,930	840	2.6	1.3	--	4,440	630	5,490	7.2	82	22.2	.0
405	22-45	--	Apr. 11, 1973	36	1.49	530	570	5,170	--	640	6,200	6,320	4.4	3.9	9.3	18,100	3,680	12,000	7.7	75	37.1	.0
Do.	67-90	--	do	30	.12	256	173	1,510	--	510	1,370	2,080	1.1	1.5	3.2	5,700	1,350	7,160	7.8	71	17.8	.0
Do.	120-143	--	Apr. 12, 1973	32	.6	89	62	970	--	520	910	850	1.1	1.1	2.4	3,170	477	4,260	8.0	82	19.3	.0
Do.	202-225	225	Apr. 15, 1973	32	.4	143	99	1,220	--	530	1,120	1,250	1.3	1.9	3.4	4,130	760	5,560	7.7	78	19.2	.0
Do.	201-224	do	June 12, 1973	1	--	39	79	1,150	--	332	1,040	1,100	1.1	2.9	2.3	3,580	422	4,750	7.7	86	24.3	.0
Do.	do	do	June 21, 1973	1	--	38	79	1,090	--	294	1,030	1,070	1.0	3.3	2.2	3,460	522	4,800	7.8	85	23.1	.0
Do.	do	do	Oct. 16, 1973	1	--	11	50	950	--	357	790	840	1.3	2.9	--	2,830	234	4,090	8.6	90	27.0	1.1
Do.	do	255	Dec. 12, 1973	4	--	28	68	1,040	--	267	900	1,050	1.2	3.7	--	3,230	342	4,700	7.9	87	24.4	.0
Do.	do	do	do	30	--	138	84	1,190	5.0	540	1,050	1,240	1.8	5.5	--	4,010	690	5,570	7.4	79	19.7	.0
Do.	do	do	do	30	--	138	88	1,220	--	540	1,130	1,260	1.7	1.3	3.4	4,140	710	5,570	7.5	79	19.9	.0
701	75-95	--	Apr. 18, 1973	28	.04	510	392	3,860	--	386	2,730	5,730	2.4	4.1	7.2	13,450	2,880	12,000	7.6	74	31.2	.0
Do.	175-192	--	Apr. 19, 1973	39	.82	372	250	2,340	--	405	1,530	3,760	1.3	1.3	4.9	8,490	1,960	10,030	7.5	--	--	--