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REPORT 100

OCCURRENCE AND QUALITY OF GROUND WATER IN SHACKELFORD COUNTY, TEXAS

By

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ABSTRACT

Shackelford County is in the drainage basin of the Brazos River in north-central Texas. Permian rocks of the Wichita and Clear Fork Groups, dipping gently to the northwest, are found at the surface within the county. Alluvial deposits of Quaternary age are found along the major streams in the county.

Small amounts of ground water, used mostly for household needs and watering livestock, are produced in Shackelford County from the Moran, Putnam, Admiral, Belle Plains, and Lueders Formations of Permian age and from Quaternary alluvial deposits. This water occurs erratically in zones of generally low permeability on or near the outcrop. Sixty-seven percent of the wells (excluding salt water supply wells) are completed in the Lueders Formation and Quaternary alluvial deposits.

Water quality in Shackelford County varies widely. Although a general range in the native quality of water is apparent, water from some wells contains high concentrations of sodium, calcium, and chloride which does not fall within this general range. This water is from apparently or possibly contaminated wells. Several wells produce water high in nitrate content, indicating the possibility of contamination by sewage or animal wastes.

Methods of disposal of oil-field brines are the probable cause of some of the poorer water quality in Shackelford County. Disposal of brine is also responsible for extensive soil damage and vegetative kill in some areas of the county. In 1961, 10,668,641 barrels of salt water was reported produced with oil and gas in the county. Of this amount, over 96 percent was reported returned to the subsurface through injection and disposal wells, nearly 4 percent was reported placed into surface pits, and less than 1 percent was reported disposed of by other methods. In 1967, 9,649,746 barrels of salt water was produced with oil and gas in the county. Of this amount, 97.2 percent was injected into the subsurface, less than 0.1 percent was disposed in unlined surface pits, and 2.7 percent was disposed by other methods.

OCCURRENCE AND QUALITY OF GROUND WATER IN SHACKELFORD COUNTY, TEXAS

INTRODUCTION

Purpose and Scope

This investigation is one of several ground-water studies that are currently being conducted by the staff of the Texas Water Development Board in a block of 18 counties in north-central Texas to meet a growing need for more detailed and accurate ground-water information in this area. The Board recognizes the significance of ground water in this region and is aware of the vital need for obtaining detailed and accurate information on the depth of occurrence of usable-quality water as the basis for providing adequate and equitable protection for those water supplies. Several towns with municipal water supplies in north-central Texas are served by ground water or have water wells as a standby supply. In addition to meeting municipal needs for water in the area, ground water is often the sole source supplying domestic, farm, and ranch needs. Reports from the results of the investigations in Archer, Brown, Coleman, Montague, Stephens, and Young Counties have been published by the Board (See references at end of text), and reports on each of the 12 remaining counties will be prepared and published as field studies are completed.

This report provides information on the location and extent of fresh water-bearing strata and the chemical quality of all ground water used; the surface and shallow subsurface geology as it relates to the depth and occurrence of ground water; the methods and amounts of oil-field brine disposal and the chemical character of brines; and the effects on water quality that may be caused by surface or subsurface disposal of oil-field brines, inadequate surface casing, or improperly plugged wells in the county.

This study was made under the general direction of John J. Vandertulip, former Chief Engineer; Richard C. Peckham, director, Ground Water Division; Bernard B. Baker, assistant director in charge of Availability Programs; and under the direct supervision of Loyd E. Walker, coordinator, West Texas Investigations.

Methods of Investigation

During this investigation, an attempt was made to locate all water wells and springs in Shackelford County, and for these information was compiled on well depth, depth to water in the wells, geologic formations in which the wells are completed, and methods of well construction.

Surface elevations of wells and springs were established with the aid of U.S. Geological Survey topographic maps. These elevations were used in comparing the depths to water and in determining the geologic formation in which the wells are completed.

Water samples were collected for chemical analysis from 99 of the wells and springs, and these analyses were studied to determine the chemical characteristics of the ground water and, where possible, to locate possible areas of pollution. The analyses were compared with analyses of water samples taken from some of the same wells in 1964 to see what change, if any, had taken place in the quality of the water.

Various published geologic maps and numerous electric logs of oil and gas tests were studied and used to interpret the geologic conditions relating to the occurrence of ground water.

Oil-field brine disposal practices were observed in the field, and available information on areas and amounts of brine production, and methods of brine disposal was studied to identify possible connections with present or potential contamination of ground water.

Data from the water well inventory, chemical analyses of ground water and oil-field brines, and the inventory of salt-water production and disposal for the years 1961 and 1967 conducted by the Railroad Commission of Texas were tabulated. Climatological data that are significant to the occurrence and use of water in the county were compiled, including precipitation, lake-surface evaporation, and temperature range.

Previous Investigations

Several reports contain information on the geology of north-central Texas, but no detailed study of ground water has been made in Shackelford County. Rocks in the county have been described and mapped by numerous investigators, although generally without consistent agreement as to formation names and stratigraphic relationships. The surface geology of the county has been mapped by Sellards, Adkins, and Plummer (1932); Hedrick, Owens, and Meyers (1937); and Stafford (1960); and remapping is underway by the University of Texas Bureau of Economics Geology as part of the Abilene Sheet of the Geologic Atlas of Texas.

The U.S. Geological Survey and the West Central Texas Municipal Water District (the principal owner of Hubbard Creek Reservoir) are conducting investigations, begun in 1958, of the surface-water hydrology of Hubbard Creek watershed, and have prepared manuscript reports on salt-water problems caused by brines in the alluvial gravels near Albany and Moran.

A recent reconnaissance investigation of ground-water resources of the entire Brazos River basin was made by Cronin and others (1963), but the coverage within Shackelford County was limited, as would be expected in this type of study. Numerous reports relating to the geology of the area are listed in the selected references.

Well-Numbering System

The numbers assigned to wells and springs in this report conform to the statewide well-numbering system used by the Texas Water Development Board. Each well and spring is assigned a number to facilitate record keeping and locating wells within the State. This system is based on division of the State into quadrangles formed by degrees of latitude and longitude, and repeated division of these quadrangles into smaller ones as illustrated on Figure 1.

The largest quadrangle, a 1-degree quadrangle, is divided into sixty-four 7½-minute quadrangles, each of which is further divided into nine 2½-minute quadrangles. Each 1-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 1-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 1-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. In addition to the 7-digit well number, a 2-letter prefix is used to identify the county. The prefix for Shackelford County is XA, and the county lies wholly within the 1-degree quadrangle number 30.

Acknowledgements

The writer expresses his appreciation to the many ranchers, farmers, oil operators, and other persons who generously gave information and cooperated in the collection of data. Appreciation is also expressed to the Agricultural Stabilization and Conservation County Committee, the U.S. Soil Conservation Service, the Railroad Commission of Texas, the Texas State Department of Health, the Texas Highway Department, the U.S. Geological Survey, the West Central Texas Municipal Water District, and other local and county agencies who furnished information.

GEOGRAPHY

Location

Shackelford County comprises an area of about 887 square miles and lies generally between 99°05' and 99°36' west longitude and 32°31' and 32°56' north latitude in north-central Texas (Figure 2). Albany, the county seat, is near the center of the county about 127 miles west of Fort Worth and 36 miles northeast of Abilene.

Climate

The climate of Shackelford County is subhumid. The average annual rainfall at Albany was 25.55 inches during the period 1907-66, with a maximum of 47.01 inches in 1941 and a minimum of 11.07 inches in 1956. The rainfall for each year from 1907 through 1966 is shown on Figure 3.

The mean temperature for the month of July is 97°F, and that of January is 31°F. The average annual-mean temperature is 64.7°F. The first frost in the fall usually occurs about November 9, and the last in the spring about March 30, leaving an annual growing season of about 223 days.

The average annual gross lake surface evaporation is 79 inches based on records for the 26-year period 1940-65. The average annual net lake surface evaporation (average annual gross lake surface evaporation less the average annual effective rainfall) is about 56 inches (Figure 4).

The average monthly distribution of precipitation and the average monthly distribution of gross and net lake surface evaporation are shown on Figure 4.

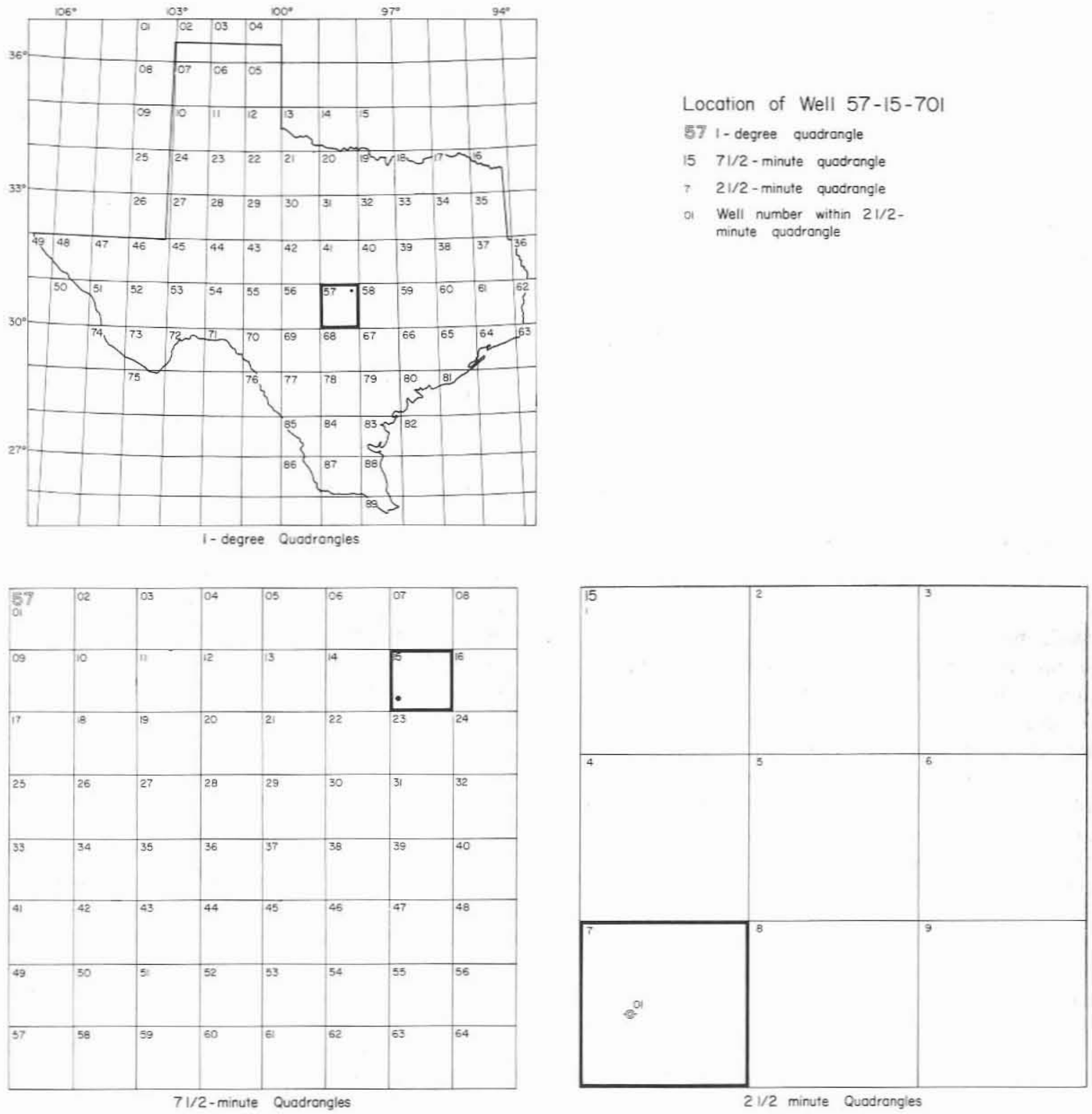


Figure 1.—Well Numbering System

Topography and Drainage

Shackelford County is in the Osage Plains section of the Central Lowland physiographic province of Texas. The topography is characterized by gently rolling terrain broken by north-south trending escarpments. The land-surface elevation ranges from less than 1,150 feet above mean sea level in the Clear Fork Brazos River valley in the northeastern part of the county to about 2,050 feet in the southwestern part of the county.

Shackelford County is in the Brazos River drainage basin. A topographic divide trends north-south across the county. This divide enters Shackelford County in the center of the north county line, passes about eight miles west of Albany, and enters Callahan County about nine miles east of the southwest corner of Shackelford County. This divide determines the route by which water will flow into Clear Fork Brazos River.

Creeks that drain the county west of the divide flow northwest, and the creeks east of the divide flow east or northeast, all drainage in the county being tributary to Clear Fork Brazos River. The southwestern part of the county is drained by Spring and Long Creeks; the west-central part of the county is drained by Chimney, Hog, and Bluff Creeks; and the northwestern part by Swager, Pinto, Fish, and Antelope Creeks.

The northeastern part of Shackelford County is drained by Collins, Mill, Foyle, Taylor, and Murphy Creeks, and the central and southeast parts are drained by Hubbard Creek and its tributaries.

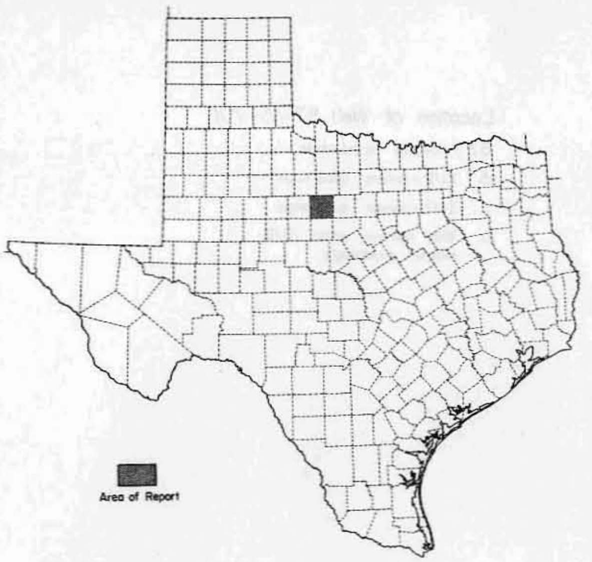


Figure 2.—Location of Shackelford County

McCarty Lake, located 5 miles southwest of Albany on Salt Prong Hubbard Creek, has been the municipal water supply for Albany since 1941. A water-supply line tying the Albany water system to Hubbard Creek Reservoir in Stephens County is now under construction. This reservoir was constructed in 1961-62 by the West Central Texas Municipal Water District to supply water for Abilene, Albany, Anson, and Breckenridge. The lake has a capacity of 317,800 acre-feet.

Moran is served by Lake Moran, a small reservoir on an unnamed tributary of Deep Creek, located about 2 miles southwest of Moran.

History, Population, and Economy

Shackelford County was established in 1858 from a part of Bosque County. The county was settled by only a few ranchers prior to the Civil War.

In 1867, Fort Griffin was established near a ford on the Clear Fork Brazos River to protect the settlers and passengers along the Butterfield stage route. A cowtown grew up around the fort as a supply point on the western cattle trail.

The county was organized in 1874 with Fort Griffin as the county seat. In 1875 the town of Albany was established and the county seat was moved there.

The Texas Central Railroad extended its line to Albany in 1881, opening the county to further settlement. Moran was established in 1882 as a station on the railroad.

In 1883 the newspaper "Albany News" was founded. Besides keeping its own early files, the News has preserved the early records of the "Jacksboro Frontier Echo", "Fort Griffin Echo", "Albany Sun", and "Albany Star" which constitute a valuable source of frontier history.

The discovery of oil near Moran in 1910 and near Albany in 1926 opened up the county for more population growth.

The population of Shackelford County grew from 44 in 1860 to 2,037 in 1880. The oil booms brought an increase in population to 4,961 in 1920 and a high of 6,695 in 1930. There has been a steady decline in population since 1940. According to the 1960 Federal census, the county had a population of 3,990 and Albany, the largest town in the county, had a population of 2,174.

The highway system in Shackelford County includes U.S. Highways 180, 283, and 380, State Highway 351, and a few paved farm-to-market roads. Railroad service to Albany was discontinued by the Missouri-Kansas-Texas Railroad Company in 1967. Albany has a class two airport, but the nearest scheduled airline service is at Abilene.

The economy of Shackelford County depends primarily on agriculture and the production of oil and gas. The county is famous for its advanced ranching methods and Hereford cattle. Over 90 percent of the agricultural income is from beef cattle production. There is some farming throughout the county, especially in the northwest and southeast parts. Small grains, cotton, and hay were harvested from 19,184 acres in 1959 according to records of the U.S. Department of Agriculture.

The production of oil and gas is the major industry in Shackelford County. Since the first oil discovery in 1910, about 106 million barrels of oil has been produced in the county. In 1966, about 3 million barrels of oil was produced according to the Railroad Commission of Texas.

GENERAL GEOLOGY

Formations that contain usable ground water in Shackelford County are near-surface rocks of Permian and Quaternary age (Table 1). The Pueblo Formation of the Wichita Group of Permian age, cropping out in the extreme southeastern part of the county, is the oldest rock unit that occurs at the ground surface. Progressively younger Permian rocks crop out to the west in a series of north-south trending bands across the county as shown on the geologic map (Figure 10), while Quaternary alluvium is generally confined to stream valleys.

The Moran Formation, which crops out near the eastern edge of the county, is the oldest stratigraphic

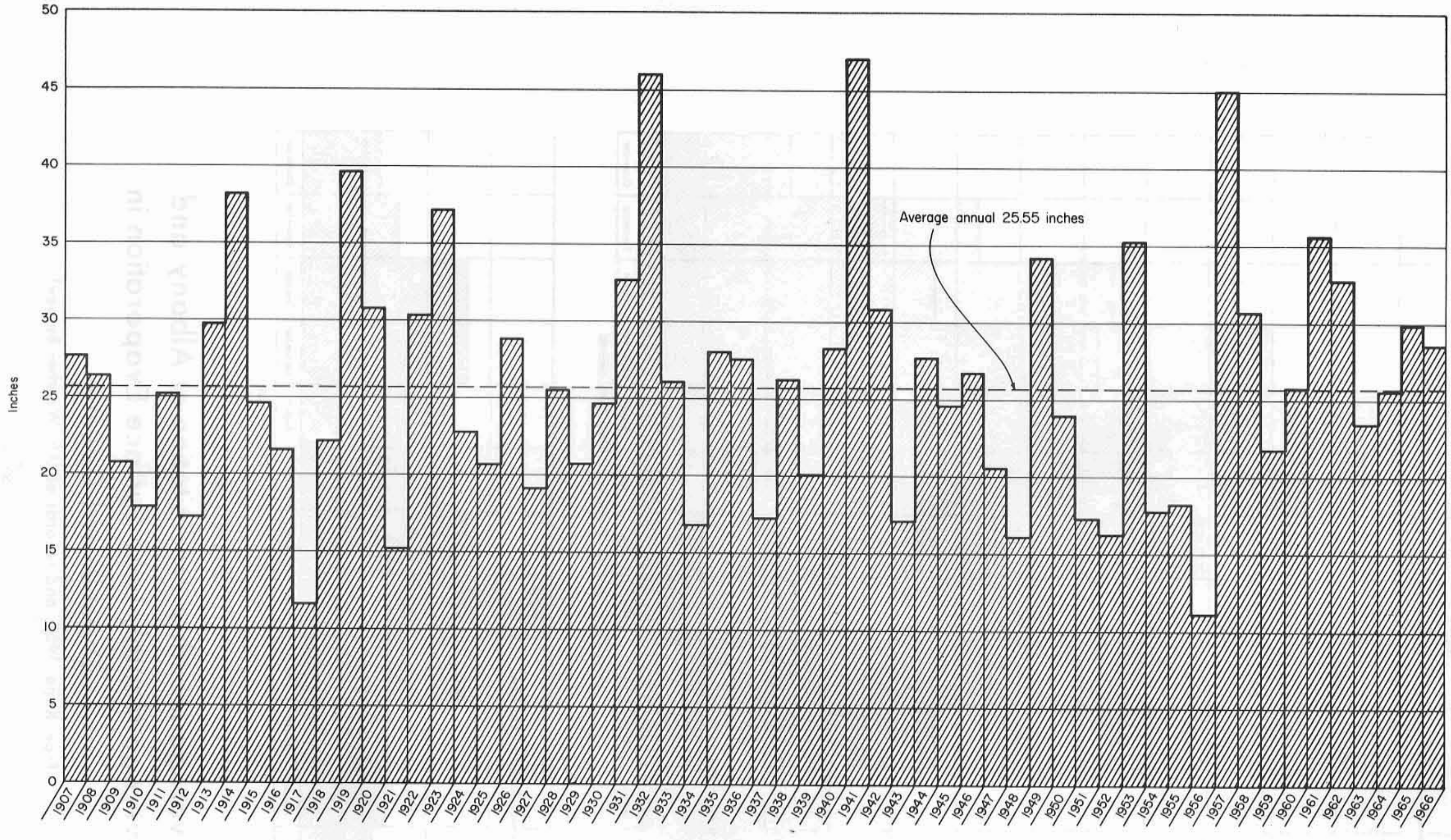


Figure 3

Annual Precipitation at Albany, 1907-66

(From Records of U.S. Weather Bureau)

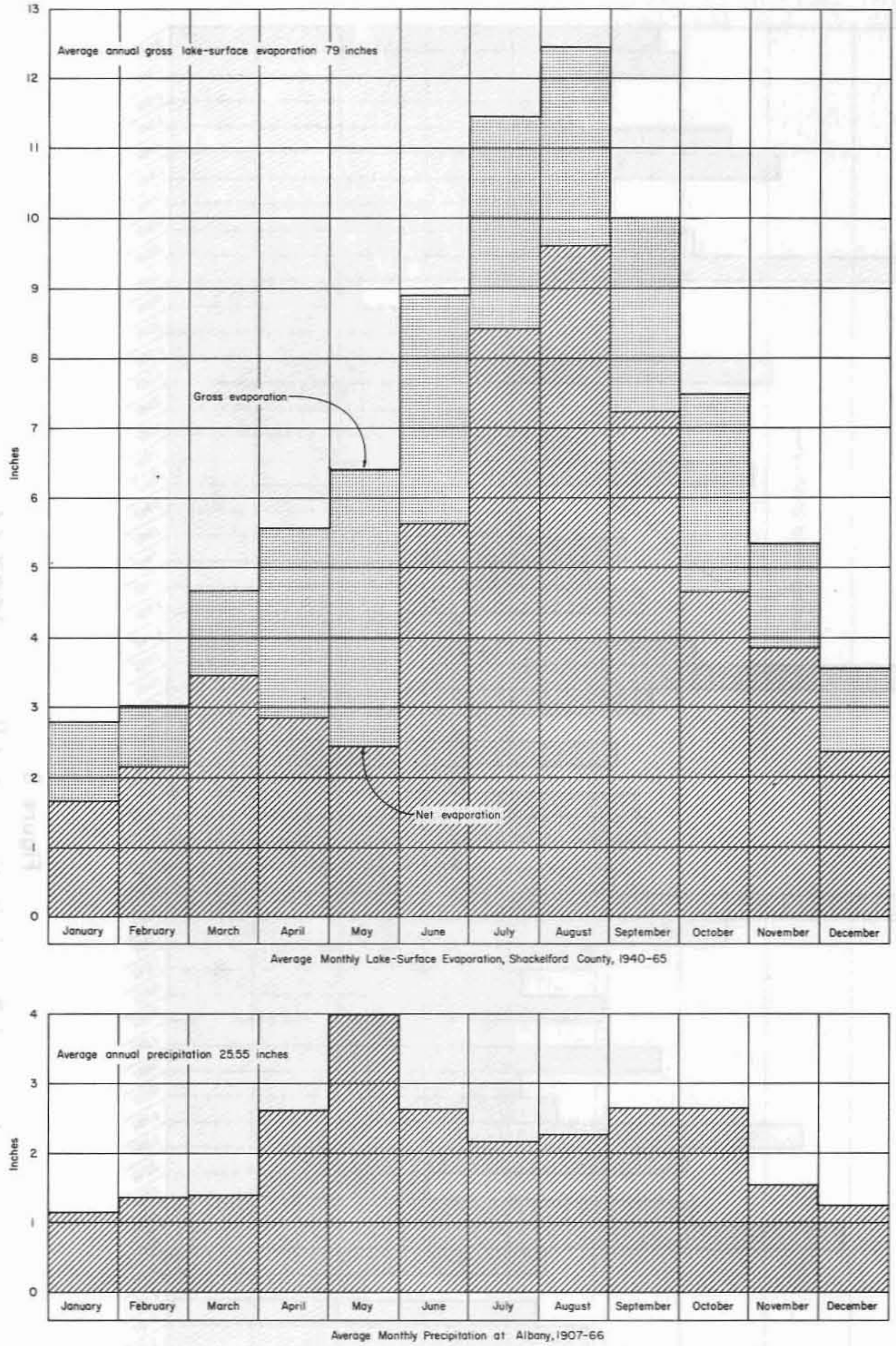


Figure 4

Average Monthly Precipitation at Albany and Average Monthly Lake-Surface Evaporation in Shackelford County

(From Kane, 1967, and records of U.S. Weather Bureau)

Table 1.—Stratigraphic Units and Their Water-Bearing Properties in Shackelford County

SYSTEM	GROUP	FORMATION	MEMBER	APPROXIMATE THICKNESS (FEET)	PREDOMINANT CHARACTER OF ROCKS	WATER-BEARING CHARACTERISTICS
Quaternary		Alluvium		0 to 20	Gravel, sand, silt, sandy silt, and clay; usually deposited along rivers and major tributaries, although some gravels are found on higher plateaus.	Yields fresh to slightly saline water in small quantities to wells.
Permian	Clear Fork	Arroyo		—	Thin limestone beds and thick shales.	Not known to yield usable-quality water in Shackelford County.
	Wichita	Lueders		90	Massive to thin limestone beds with thin shale breaks.	Yields fresh to slightly saline water in small quantities to wells in the outcrop.
		Clyde	Talpa Limestone Grape Creek Limestone	220	Thin to massive limestone beds alternating with shale and marl.	Not known to yield usable-quality water in Shackelford County.
		Belle Plains	Bead Mountain Limestone Valera Shale Jagger Bend Limestone Voss Shale Elm Creek Limestone Jim Ned Shale	325	Limestones and thick to thin shales.	Yields fresh to slightly saline water in small quantities to wells in the outcrop.
		Admiral	Overall Limestone Wildcat Creek Shale Hords Creek Limestone Lost Creek Shale	165	Thin-bedded limestones and thick shales.	Do.
		Putnam	Coleman Junction Limestone Santa Anna Branch Shale	85	Thin limestone beds and thick shales with some thin lenticular sandstones.	Do.
		Moran	Sedwick Limestone Gouldbusk Limestone Ibex Limestone Watts Creek Shale	275	Thin limestone beds, massive shales, and channel-fill sandstones.	Do.
		Pueblo	Camp Colorado Limestone Salt Creek Bend Shale Stockwether Limestone Camp Creek Shale	220	Thin limestone beds, massive shales, and channel-fill sandstones.	Not known to yield usable-quality water in Shackelford County.
—?——?—						
Pennsylvanian	Cisco			1,050	Thin limestone beds, massive shales, and channel-fill sandstones.	Do.
	Canyon			800	Massive to thin limestone beds interbedded with massive shales and thin lenticular sandstones.	Do.
	Strawn			1,600	Thick units of shale, limestone, and sandstone.	Do.
	Bend			175	Thick shale units with some sand and conglomerate.	Do.
Mississippian				200	Limestone and shale beds.	Do.
Ordovician	Ellenburger			—	Massive limestone.	Do.

unit known to contain water of usable quality in the county. Other units that contain usable-quality ground water are the Putnam, Admiral, Belle Plains, and Lueders Formations, and the alluvial deposits that occur along major streams (Figure 10). Older rocks which occur in the subsurface are listed in Table 1, and their stratigraphic relationships are shown on Figures 13 and 14.

The principal, large, buried structural features affecting the attitude of strata in north-central Texas are illustrated on Figure 5. These structures include the Bend flexure, Red River uplift, Muenster arch, Fort Worth basin, eastern Midland shelf, Concho arch, and Concho shelf.

Shackelford County is on the Concho shelf where rocks of Pennsylvanian and Permian age form a westward-dipping homocline. Geological formations underlying the county dip west-northwest about 40 feet per mile, excluding the channel-fill sandstones that occur in the Permian rocks and the surficial deposits of Quaternary alluvium.

On the geologic map, delineation of Permian formations is based largely on the previous mapping of numerous traceable limestone beds in the county by Hedrick, Owens, and Myers (1937). These mapped beds were assigned to the various formations according to the nomenclature used by Stafford (1960) and based on the formation definitions of Moore (1949) and Eargle (1960). Mapping of the Quaternary alluvium on Figure 10 is from Stafford (1960) with some modification based on field observation.

Not all of the limestone beds that were used by Moore and Eargle in defining these Permian formations have been found traceable on the ground across Shackelford County, so that the position of formation boundaries in some areas is questionable as indicated by dashed boundary lines on Figure 10. More defined mapping of the surface geology in Shackelford County is presently (1969) underway by the Bureau of Economic Geology, The University of Texas at Austin, as a part of the Abilene Sheet of the Geologic Atlas of Texas.

GENERAL GROUND-WATER HYDROLOGY

In north-central Texas, the occurrence of ground water is erratic, and there are no large, continuous, prolific ground-water aquifers such as those found in the High Plains and Gulf Coast regions of Texas. However, ground water in north-central Texas conforms to the same fundamental principles of occurrence as that in other areas of the State.

Hydrologic Cycle

The hydrologic cycle is the sum total of processes and movements of the earth's moisture from the sea, through the atmosphere to the land, and eventually, with numerous delays en route, back to the sea. All water occurring in Shackelford County is from precipitation. The water available for use—whether as direct precipitation, streamflow, water from wells, or spring discharge—is captured in transit, and after its use and reuse is returned to the hydrologic cycle. This cycle is graphically illustrated in Figure 6 which shows the continuing movement of water from the oceans through evaporation to precipitation and its return either directly or ultimately to the ocean.

Source, Occurrence, and Movement of Water

The geologic history of sedimentary deposition and erosion is a primary factor controlling the occurrence and movement of ground water in the north-central Texas area. The rocks found in the shallow subsurface range from sporadic, uncemented, clastic beds to the more widespread and more continuous beds of cemented or compacted shale, sandstone, and limestone. In uncemented rocks, such as sand, gravel, and clay, water occurs in the spaces between individual particles; whereas, in cemented or compacted sedimentary rocks, it occurs chiefly in cracks and fissures produced by earth movement or contraction and in openings formed by solution where the rocks are soluble. If these openings are isolated, the movement of ground water is hindered. However, most openings are interconnected and permit ground water to move through them. The essential factor is that ground water of usable quality is continually moving from the point at which it entered the ground-water body, called the recharge area, to points of discharge, generally at lower elevations, either in stream drainage or through wells.

Recharge is the process by which water is added to an underground water-bearing formation, whether by precipitation on the outcrop of the formation or by seepage from surface streams or lakes on the outcrop. Factors that limit the amount of recharge received by a formation are the amount and frequency of precipitation, the area and extent of the outcrop, the topography, the type and amount of vegetation, the condition of the soil in the outcrop area, and the capacity of the formation to accept recharge. Discharge is the process by which water is removed from the formation, either through surface drainage or through wells.

The direction and rate of movement of water through a porous medium, such as an underground geologic formation, is influenced by a variety of factors, which include the nature of the formation itself, the external pressures applied on it, and the fundamental physical laws of gravity and momentum. These factors

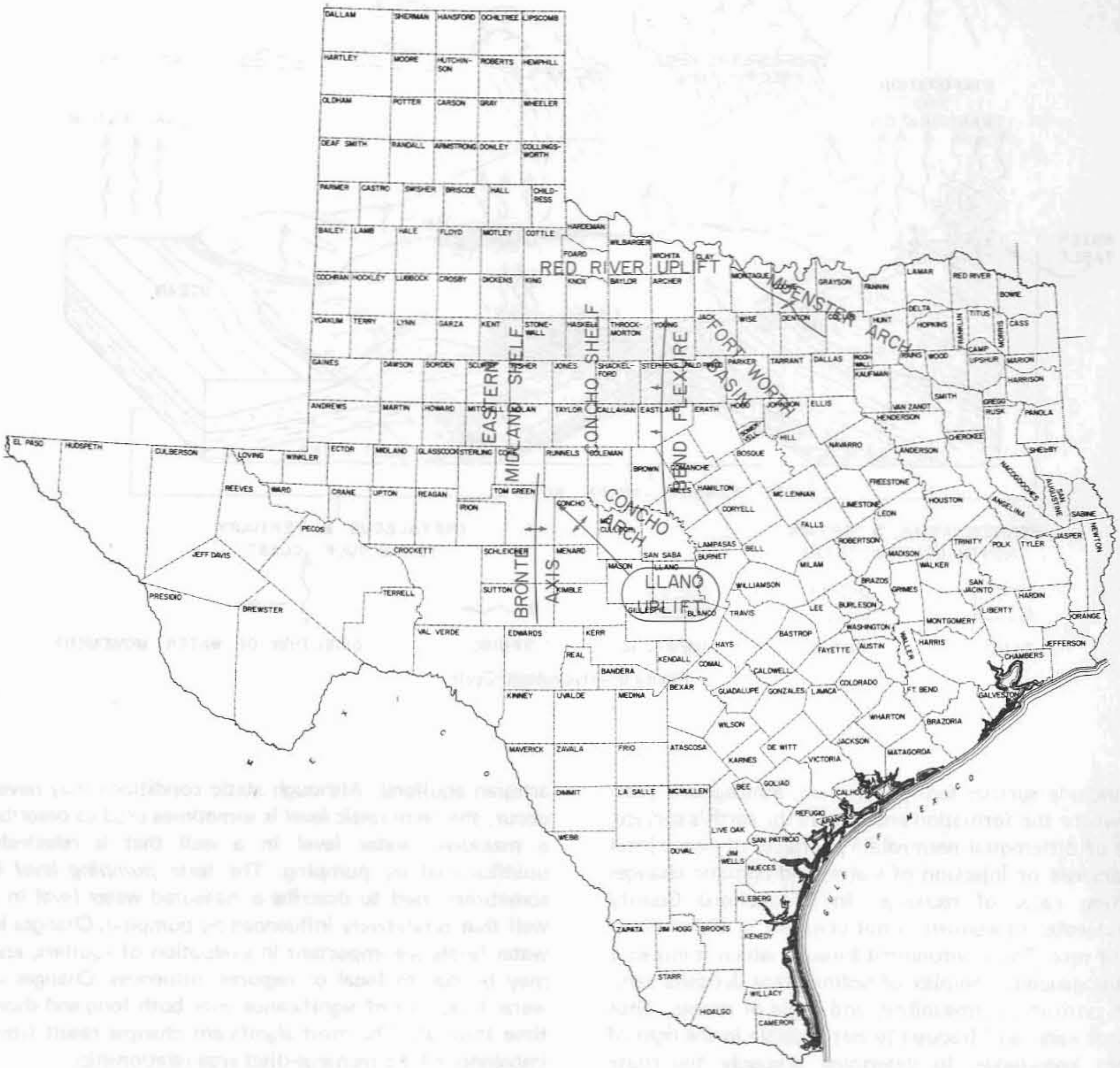


Figure 5

Major Structural Features in North-Central Texas

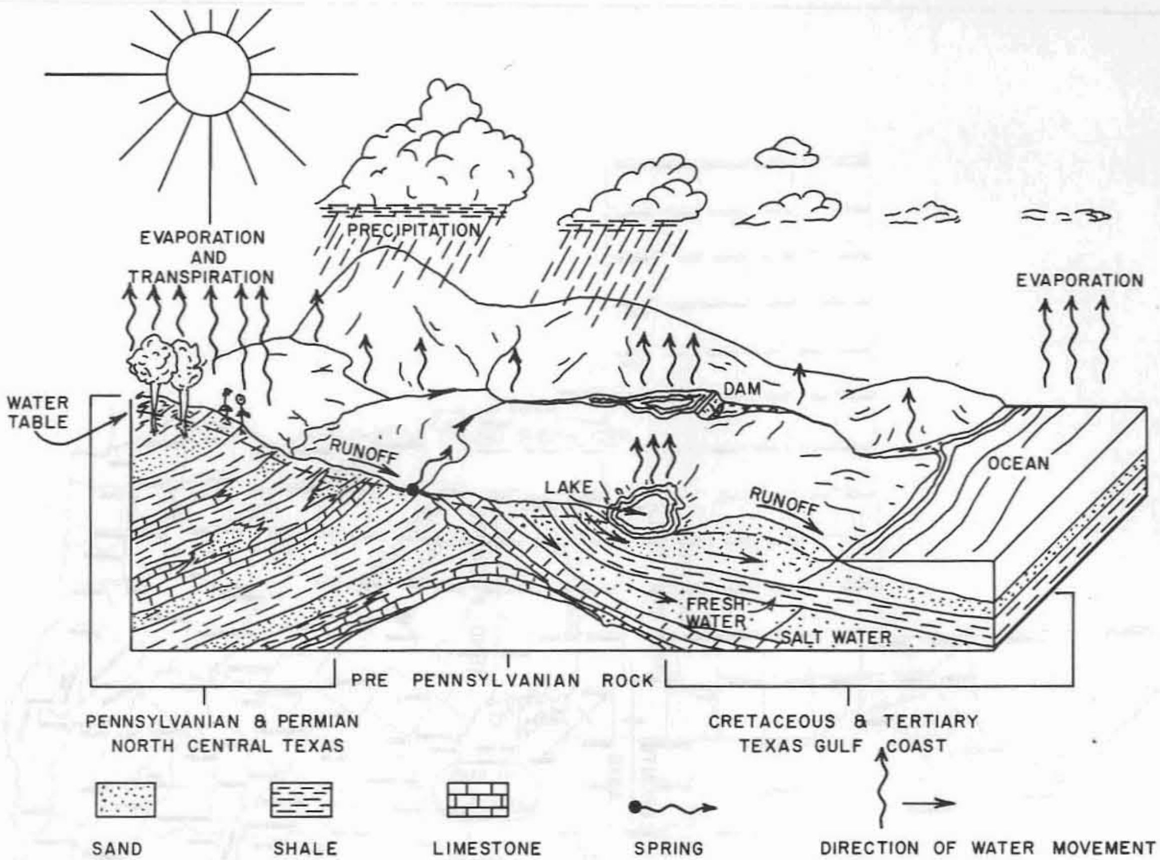


Figure 6.—Hydrologic Cycle

also include surface tension, friction, atmospheric pressure where the formation encounters the earth's surface, paths of differential permeability, effects of heavy local withdrawals or injection of water, and climatic changes affecting rates of recharge. In Shackelford County ground-water movement is not constant in either direction or rate. The environment through which it moves is a heterogeneous complex of sedimentary deposits varying in porosity, permeability, and angle of repose. Thus it is not easy, and frequently not possible in the light of present knowledge, to determine precisely the route water will take from the point of recharge to the points of discharge at the ground surface. In the area of this study, however, this route is probably circuitous and of relatively short geographic extent. As a consequence, a landowner, whether private or public, has a particular need for understanding the hydrologic factors affecting the occurrence of ground water. Only by a careful discriminating study of the geologic environment of his immediate locality can he determine the availability of ground water for beneficial use, or the means required to protect available ground water from pollution.

Water-Level Fluctuations

Measurements of water levels in wells show locally the depths to the water table (the piezometric surface in artesian aquifers). Although static conditions may never occur, the term *static level* is sometimes used to describe a measured water level in a well that is relatively uninfluenced by pumping. The term *pumping level* is sometimes used to describe a measured water level in a well that is relatively influenced by pumping. Changes in water levels are important in evaluation of aquifers, and may be due to local or regional influences. Changes in water levels are of significance over both long and short time intervals. The most significant changes result from imbalance of the recharge-discharge relationship.

Concentrated pumpage also can produce significant changes in water levels. The water table near a pumped well is drawn down into the shape of an inverted cone with its apex at the pumped well. Development of this cone is dependent upon the hydraulic properties of the aquifer and the pumping rate. The cone of depression expands until it intercepts recharge which is equal to the demand, or it continues to expand as water is withdrawn from storage. In heavily developed irrigation areas, the cone of each well is superimposed upon the cones of adjacent wells, thus creating a regional cone of depression in the water table or piezometric surface.

Changes in atmospheric pressure, tidal forces, and earthquakes can affect changes in water levels, but the fluctuations are usually very small.

GENERAL CHEMICAL QUALITY OF GROUND WATER

Chemical-Quality Standards and Criteria

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 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.

In addition to the natural mineralization of water that occurs in its environment, the quality of ground water can also be affected by man. Municipal and domestic sewage systems (including septic tanks), industrial waste, and oil-field brine that is improperly disposed of can enter into ground water and render it unfit for most uses.

Included amoung 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 chemical constituents can be difficult and expensive. The source and significance of the principal dissolved-mineral constituents occurring in ground water are summarized in Table 2.

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 mg/l (milligrams per liter) is as follows:

DESCRIPTION	DISSOLVED-SOLIDS CONTENT (MG/L)
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

The U.S. Public Health Service has established standards for drinking water to be used on common carriers engaged in interstate commerce. The standards are designed primarily to protect the traveling public and are often used to evaluate public water supplies. According to these standards, chemical constituents should not be present in the water supply in excess of the listed concentrations except where more suitable supplies are not available. Some of the standards adopted by the U.S. Public Health Service (1962, p. 7-8) are as follows:

SUBSTANCE	CONCENTRATION (MG/L)
Chloride (Cl)	250
Fluoride (F)	(*)
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3)	45

SUBSTANCE	CONCENTRATION (MG/L)
Sulfate (SO_4)	250
Total dissolved solids	500

* When fluoride is present naturally in drinking water, the concentration should not average more than the appropriate upper limit shown in the following table:

ANNUAL AVERAGE OF MAXIMUM DAILY AIR TEMPERATURES (°F)	RECOMMENDED CONTROL LIMITS OF FLUORIDE CONCENTRATIONS (MG/L)		
	LOWER	OPTIMUM	UPPER
50.0 to 53.7	0.9	1.2	1.7
53.8 to 58.3	.8	1.1	1.5
58.4 to 63.8	.8	1.0	1.3
63.9 to 70.6	.7	.9	1.2
70.7 to 79.2	.7	.8	1.0
79.3 to 90.5	.6	.7	.8

Water having concentrations of chemical constituents in excess of the recommended limits may be objectionable for many reasons. 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 mg/l may produce a laxative effect, and water containing chloride exceeding 250 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).

Hardness in water is caused principally by calcium and magnesium. Excessive hardness causes increased consumption of soap and induces the formation of scale in hot water heaters and water pipes. The following table shows the commonly accepted standards and classifications of water hardness:

HARDNESS RANGE (MG/L)	CLASSIFICATION
60 or less	Soft
61 to 120	Moderately hard
121 to 180	Hard
More than 180	Very hard

Water that is suitable for industrial use may not be acceptable for human consumption, and different standards may apply. 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

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

(From Doll and Others, 1963, Table 7)

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. More than 1 or 2 mg/l of iron in surface waters generally indicates acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 mg/l stains laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. U.S. Public Health Service (1962) 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 ancient 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 mine waters and 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. Some calcium sulfate is considered beneficial in the brewing process. U.S. Public Health Service (1962) drinking-water standards recommend that the sulfate content should not exceed 250 mg/l.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient 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. U.S. Public Health Service (1962) drinking-water standards recommend that the chloride content should not exceed 250 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 susceptbility of the individual. (Maier, 1950)
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. U.S. Public Health Service (1962) drinking-water standards suggest a limit of 45 mg/l. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes some water of crystallization.	U.S. Public Health Service (1962) drinking-water standards recommend that waters containing more than 500 mg/l dissolved solids not be used if other less mineralized supplies are available. Waters containing more than 1000 mg/l dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All 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 as much as 60 ppm are considered soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; more than 180 mg/l, very hard.
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, and 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.

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 (Fe^{+++}), will cause plugging of the reservoir. Organisms such as iron bacteria, algae, and fungi have an effect of plugging the reservoir 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 with 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.

Both the concentration and the composition of the dissolved constituents should be considered in appraising quality of water for irrigation. The chemical characteristics that seem to be most important in evaluating the quality of water for irrigation are: (1) relative proportion of sodium to the other cations, (2) total concentration of soluble salts, (3) amount of residual sodium carbonate, and (4) concentration of boron.

The U.S. Salinity Laboratory staff (1954, p. 69-82) proposed a system of classification commonly used for judging the suitability of water for irrigation. The classification is based on the salinity hazard as measured by the electrical conductivity (specific conductance) of the water and the sodium hazard as measured by the sodium adsorption ratio (SAR). Figure 7 illustrates this classification system.

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 those which have a high salinty tolerance and only then under certain ideal soil and drainage conditions. Although very little water is used for irrigation in Shackelford County, the specific conductance and SAR values of water from wells in the

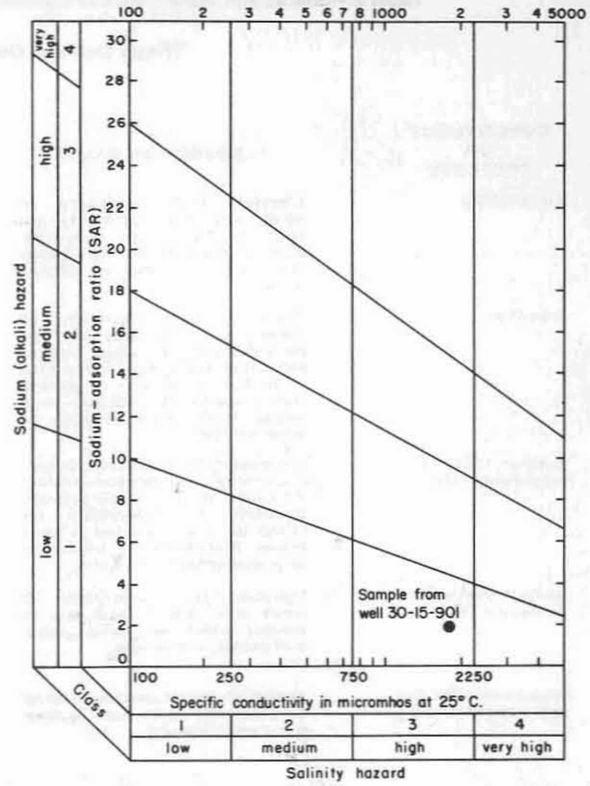


Figure 7.—Diagram for the Classification of Irrigation Waters (After U.S. Salinity Laboratory Staff, 1954, p. 80)

county are shown in the table of chemical analyses of this report (Table 4). The reader interested in comparing the suitability of water from wells in the county for irrigation may plot the specific conductance and SAR values on the classification diagram (Figure 7).

Excessive boron will also make water unsuitable for irrigation. Scofield (1936, p. 286) has indicated that a boron concentration of as much as 1 mg/l is permissible for irrigating sensitive crops, and as much as 3 mg/l is permissible for tolerant crops.

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. The limiting factor in treatment is cost. Each water may require a different treatment method which should be designed for that particular water and its intended use. However, once a treatment is established it probably will not have to be changed as the chemical characteristics of uncontaminated ground water remain fairly constant.

OCCURRENCE AND QUALITY OF GROUND WATER

Shackelford County lies within the surface outcrop of the Wichita and Clear Fork Groups of Permian age. These rocks, consisting of interbedded limestones and shales with some lenticular sandstones, contain fresh to slightly saline ground water erratically in shallow, discontinuous zones of generally low permeability. Unconsolidated alluvial deposits of Quaternary age overlie the Permian rocks along the major streams of the county, and also yield small amounts of fresh to slightly saline water to wells. The occurrence of fresh to slightly saline water in formations of Permian age is limited mainly to the areas of outcrop or a very short distance downdip from the outcrop. However, fresh to slightly saline water is not known to occur below the Moran Formation of the Wichita Group in the county. The geologic units as used in this report are shown in Table 1, and their stratigraphic and structural relationships are shown on the cross sections on Figures 13 and 14.

Most of the water wells in Shackelford County are used for domestic and livestock supplies. Many of the wells, especially the older ones, are hand dug and lined with fieldstone. There are a few drilled wells that are cased with oil-field casing or with galvanized well casing of small diameter. Most wells that are presently in use are equipped with windmills or small electric jet pumps which produce less than 10 gpm (gallons per minute). Among those wells being used at the time of this investigation were 42 domestic and livestock wells, 28 industrial (waterflood-supply) wells, one irrigation well, and one public-supply well. The 28 industrial wells (generally converted oil and gas tests) supply brines from formations below the Moran Formation for use in waterflood operations in the county. Chemical analyses of some of these brines are included in Table 5. The locations of all wells and springs visited during this investigation are shown on Figure 10.

Water samples were collected for chemical analysis from 98 wells and springs in Shackelford County. Of these, 11 were brines collected from waterflood-supply wells. The characteristics of these brines are discussed in a later section of this report.

Analyses of 87 water samples collected during this investigation (excluding 11 brine samples from waterflood-supply wells) show that the chemical quality of water from wells in the county varies widely. The content of total dissolved solids ranged from 91 to 55,400 mg/l (milligrams per liter). Most (76) of the samples contained less than 3,000 mg/l and were fresh or slightly saline. Thirty-six samples contained less than 1,000 mg/l total dissolved solids. The wide variation in the chemical quality is also reflected in the concentrations of some of the principal chemical constituents in the samples. Bicarbonate concentrations ranged from 78 to 680 mg/l. Sulfate ranged from less than 4 to 3,070 mg/l, and the chloride concentration ranged from 3 to 35,100 mg/l. Some of the wells with an unusually high total dissolved solids and chloride content are probably contaminated and are discussed in greater detail in later sections of this report. Analyses of water samples from wells in Shackelford County are shown in Table 4. (Analyses of brines are shown in Tables 5 and 6.) The location of wells sampled, well depth, and the chloride, sulfate, and total dissolved-solids content are shown on Figure 12.

Permian System

Wichita Group

Rocks of the Wichita Group consist of the Pueblo, Moran, Putnam, Admiral, Belle Plains, Clyde, and Lueders Formations.

Pueblo Formation

The Pueblo Formation occurs in the subsurface throughout most of Shackelford County but crops out in a limited area in the extreme southeastern and eastern part of the county and in adjoining areas of western Stephens County (Figure 10). The Pueblo is made up of alternating beds of thin limestone and thick shale cut by lenticular sandstone and siltstone channels (Table 1). No potable water is known to be produced from these rocks in Shackelford County. However, 13 wells completed in the Pueblo produce brine for oil field secondary recovery operations in the county. These wells are listed in the records of wells and springs (Table 3) and their locations are shown on Figure 10. Chemical analyses of brines produced from six of these wells are shown in Table 5.

Moran Formation

The Moran Formation overlies the Pueblo Formation and crops out in the eastern part of Shackelford County (Figure 10). This formation consists of thick shales, thin limestones, and lenticular sandstones that occur from the top of the Camp Colorado Limestone Member of the Pueblo Formation to the top of the Sedwick Limestone Member of the Moran (Table 1). Small amounts of fresh to slightly saline water are contained in permeable sandstones on or near their outcrop.

Thirteen wells in the county are completed in this formation. Eight wells, 30-31-901 through 30-31-908, located just southeast of Moran (Figure 10) are completed in a local channel sand which underlies the Ibex Limestone Member (called the Dothan Sandstone by oil and gas operators). All wells are used for livestock and domestic purposes except two which are currently unused. Analyses of water samples from 12 wells show a wide variation in chemical quality (Table 4). Total dissolved solids ranged from 181 to 6,800 mg/l. However, most (10) of the samples contained less than 3,000 mg/l. Bicarbonate content ranged from 179 to 423 mg/l, chloride content from 10 to 1,730 mg/l, sulfate content from 6 to 3,070 mg/l, fluoride content from 0.3 to 3.8 mg/l, and nitrate content from less than 0.4 to 210 mg/l.

Most of the water produced by wells completed in the Moran contains chemical concentrations which exceed those recommended by the U.S. Public Health Service (1962) for drinking water on common carriers. Water from these wells, however, is being used for domestic supplies.

Putnam Formation

The Putnam Formation consists of the Santa Anna Branch Shale and the Coleman Junction Limestone Members (Table 1). These members are cut by thin lenticular sandstone and siltstone channels. Some of the channel sands contain small amounts of fresh to slightly saline water in or near the outcrop. The outcrop area of the Putnam is shown on Figure 10.

Only four wells and one spring are known to produce water from the Putnam Formation in Shackelford County. The wells are all relatively shallow, and are drilled or dug in the outcrop west and northwest of Moran and northeast of Albany (Figure 10). Only well 30-15-101 and spring 30-31-701 are presently being used—for watering livestock. Chemical analyses of water samples collected from the spring and wells show wide variance in chemical quality. The concentrations of dissolved solids and chloride ranged from 630 to 13,200 mg/l and 52 to 8,000 mg/l, respectively. Chemical analyses of water from wells 30-15-101 and 30-31-201 show relatively high concentrations of sodium and chloride which indicate possible contamination by oil-field brines. Water from well 30-31-201 (13,200 mg/l dissolved solids) was reported by the owner to have been used in the past for domestic and livestock supply, which would indicate that the quality of water produced by this well has deteriorated (Table 4).

Admiral Formation

The Admiral Formation is made up of alternating thin limestones and thick shales with some small sandstone lenses. The formation includes those rocks that occur from the top of the Coleman Junction Limestone Member of the Putnam Formation to the top of the Overall Limestone Member of the Admiral (Table 1). The outcrop area of the Admiral is shown on Figure 10. Only five wells are known to be completed in zones of local permeability on or near the outcrop of the Admiral. One of the wells, 30-15-401, is currently being used. Water samples collected from these wells for chemical analyses during this study were all fresh to slightly saline (Table 4). In 1964, water samples were collected from wells 30-15-401 and 30-15-404. Little change in quality was noted from a comparison of the analyses of these early samples and those collected in 1966 or 1967. Total dissolved-solids content of all the samples range from 560 to 1,670 mg/l. The ranges in concentration of other principal constituents are as follows: silica, 4 to 18 mg/l; calcium, 40 to 184 mg/l; magnesium, 20 to 118 mg/l; sodium, 51 to 486 mg/l; bicarbonate, 305 to 438 mg/l; sulfate, less than 2 to 176 mg/l; chloride, 29 to 820 mg/l; fluoride, 0.6 to 2.6 mg/l; and nitrate, less than 0.4 to 370 mg/l. Water from well 30-15-404 contains a considerably higher amount of sodium and chloride than the water samples collected from other wells producing from the Admiral in the same vicinity, which may indicate contamination by oil-field brines.

The high nitrate concentration of three wells (30-15-401, 48 mg/l; 30-15-402, 78 mg/l; and 30-15-403, 370 mg/l) is an indication of biological contamination, possibly from nearby sewage sources.

Water from wells completed in the Admiral Formation has a higher concentration of total dissolved solids than is recommended for human consumption by the U.S. Public Health Service (1962), but the water is fresh or slightly saline and has been used for domestic supplies for many years.

Belle Plains Formation

The Belle Plains Formation crops out in a north-south trending band, about 4 to 7 miles wide, across the central part of Shackelford County (Figure 10).

The formation includes the rocks that occur from the top of the Overall Limestone Member of the Admiral Formation to the top of the Bead Mountain Limestone Member of the Belle Plains (Table 1), and consists of limestones interbedded with thick to thin shales, a few sandstone lenses, and anhydrite deposits near the top of the formation. At the surface, however, the anhydrite has been leached out.

Five wells yield fresh to slightly saline water from zones of local permeability in the outcrop of the Belle Plains. The wells are all relatively shallow (15 to 29 feet), all but one are hand dug, and only three are currently in use.

Chemical analyses show that water from four of the five wells has relatively low mineral concentration (Table 4). However, water from well 30-22-204 has markedly higher concentrations of chemical constituents (total dissolved solids, 2,380 mg/l; chloride, 820 mg/l;

and sodium, 443 mg/l) which may be due to contamination by brine.

Several septic tanks are located near well 30-22-204 which may account for the unusually high nitrate content (280 mg/l) of the water.

Three of the wells, 30-14-201, 30-22-201, and 30-22-202, produce water that meets the quality standards set by the U.S. Public Health Service (1962) for use on common carriers, and are being used as domestic supplies.

Clyde Formation

In Shackelford County, the Clyde Formation consists of thin to massive limestone beds alternating with marls and shales. Rocks of this formation include the Grape Creek and Talpa Limestone Members (Table 1). The outcrop area of these rocks is shown on Figure 10. No fresh or slightly saline water is known to be produced from the Clyde Formation in the county.

Lueders Formation

The Lueders Formation crops out in a rather irregular pattern in the western part of Shackelford County. Streams draining the western part of the county have removed the overlying Arroyo Formation exposing the Lueders in long, narrow, sinuous outcrops along the stream valleys (Figure 10).

The Lueders consists of massive to thin limestone beds with thin shale breaks.

Thirty-nine wells and three springs are known to produce or have produced water of usable quality from fractures and solution cavities in the limestones of the Lueders. Most of these wells are concentrated in two areas. One area is just northeast of Lueders in the northwest corner of the county, and the other area is in the southwest corner (Figure 10). Actually, most of the wells are on the outcrop of the Arroyo Formation but are completed in the underlying Lueders. Most of the wells are shallow and hand dug. Only 15 of the 41 wells and springs were in use at the time of this investigation, and these were used as domestic or livestock supplies.

Water samples were collected from all wells and springs known to yield water from the Lueders. The quality of water is highly variable. The range in dissolved-solids content of these samples is shown below:

RANGE IN DISSOLVED SOLIDS (MG/L)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES	CUMULATIVE PERCENT
500 or less	9	20.9	20.9
501 to 1,000	11	25.6	46.5
1,001 to 1,500	2	4.7	51.2
1,501 to 2,000	10	23.3	74.5
2,001 to 3,000	5	11.6	86.1
over 3,000	6	13.9	100.0

Ranges in concentration of the principal chemical constituents are as follows:

calcium	23 to 4,340 mg/l	sulfate	<4 to 1,550 mg/l
magnesium	2 to 2,240 mg/l	chloride	3 to 35,100 mg/l
sodium	2 to 13,400 mg/l	fluoride	0.1 to 4.0 mg/l
bicarbonate	78 to 680 mg/l	nitrate	<0.4 to 245 mg/l

Although the quality of water from the Lueders ranges widely, it is generally of better quality than that from other Permian rocks in the county.

Alteration of native-quality water has occurred in some areas of the Lueders Formation, but historical data necessary for comparison to indicate where or how much alteration has occurred are not available. Total dissolved solids and chloride content of water from three wells and one spring, which are believed to be contaminated, are shown on the following page.

WELL	TOTAL DISSOLVED SOLIDS (MG/L)	CHLORIDE (MG/L)
30-04-501	9,800	5,900
30-04-502	12,900	7,900
30-04-506	55,400	35,100
30-12-406 (Spring)	5,200	3,000

It was reported that the three wells have been used for domestic supplies in the past, and the spring 30-12-406 was reported to have produced potable water until about 1955.

Samples of water from wells 30-04-701 and 30-12-102, 103, and 104 have an unusually high nitrate content, possibly due to the effects of sewage from nearby septic tanks and animal wastes from barnyards.

All of the water wells inventoried which were completed in the Lueders were reported to have produced usable-quality water in the past, but many of them have been abandoned because of urbanization, use of surface-water supplies, and apparent contamination.

Although many of these wells produce water containing a higher concentration of minerals than is recommended by the U.S. Public Health Service (1962), they have been used for years as domestic and livestock supplies.

Clear Fork Group

The Clear Fork Group consists of the Arroyo Formation in Shackelford County.

Arroyo Formation

The Arroyo Formation consists of thin, dolomitic limestone beds alternating with thick shales, with some anhydrite and sandstone lenses. In Shackelford County the formation is relatively thin and occurs mainly on the topographic divides in the western part of the county (Figure 10). The Arroyo Formation is not known to yield water to wells or springs in the county.

Quaternary System

Alluvium

Alluvium of Quaternary age, consisting of unconsolidated sand, gravel, silt, and clay, occurs in the terraces and floodplains of the present streams (Figure 10). Small amounts of alluvium are found along almost all streams in the county, but these deposits are significant to the occurrence of ground water only along the Clear Fork Brazos River and its major tributaries.

Some of the sands and gravels of these sediments yield small amounts of fresh to slightly saline water to wells in the county. In two localities, where wells have relatively high yields, the sand and gravel are thick and the permeability is apparently high. Well 30-07-403, which supplies Fort Griffin State Park, was reportedly pumped at the rate of 200 gallons per minute for 24 hours, and well 30-15-901, the only irrigation well in use in the county at the time of this study, was reported by the owner to yield 100 gallons per minute.

Twenty-five wells and one spring were located which produce or have produced water of usable quality from the Quaternary alluvium in Shackelford County. Water samples were collected for chemical analysis from 18 of these wells and the spring during this study. The results of the analyses are tabulated in Table 4. Analyses of water samples collected from six of the wells in 1964 are also tabulated for comparison.

The quality of water from the wells and spring completed in the alluvium is fairly constant and generally better than that from other rocks in the county. The range in dissolved-solids content of water collected during this study was from 458 to 3,250 mg/l. Twelve of the samples, or over half of those collected, contained less than 1,500 mg/l and only one sample (well 30-22-501) contained more than 3,000 mg/l. The numbers of samples falling within various ranges are shown at the top of the next page.

RANGE IN DISSOLVED SOLIDS (MG/L)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES	CUMULATIVE PERCENT
500 or less	1	5.0	5.0
501 to 1,000	4	21.0	26.0
1,001 to 1,500	7	37.0	63.0
1,501 to 2,000	2	11.0	74.0
2,001 to 3,000	4	21.0	95.0
over 3,000	1	5.0	100.00

The ranges in concentration of the major chemical constituents are shown below:

calcium	69 to 356 mg/l	sulfate	9 to 910 mg/l
magnesium	15 to 143 mg/l	chloride	45 to 1,820 mg/l
sodium	45 to 790 mg/l	fluoride	0.2 to 2.6 mg/l
bicarbonate	146 to 670 mg/l	nitrate	<0.4 to 69 mg/l

Most of the water samples contained less than 1,000 mg/l of chloride. Wells yielding water with higher chloride concentrations are shown below:

WELL	TOTAL DISSOLVED SOLIDS (MG/L)	CHLORIDE (MG/L)
30-16-701	2,670	1,250
30-22-501	3,250	1,820
30-22-602	2,180	1,040
30-22-603	2,120	1,180

Wells 30-16-701, 30-22-501, and 30-22-602 are presently being used for domestic supply. Well 30-22-603 was developed for a livestock supply.

Alteration of the chemical quality of native ground water in the alluvium may have occurred, but historical data necessary for comparison to indicate where and how much alteration has occurred are not available.

A comparison of analyses of water samples taken from three wells in 1964 and again in 1966-67 reveal a change in water quality over this period. Total dissolved solids and chloride content of the water decreased in two wells and increased in another as shown below:

WELL	CHLORIDE (MG/L)		TOTAL DISSOLVED SOLIDS (MG/L)	
	1964	1966-67	1964	1966-67
30-07-504	322	185	1,125	720
30-15-901	890	274	2,920	960
30-16-701	910	1,250	2,020	2,670

The water produced from the alluvial sediments in Shackelford County generally contains a higher concentration of total dissolved solids than is recommended by the U.S. Public Health Service (1962) for drinking water to be used on common carriers. Twelve of the samples taken during this study contain more than the recommended upper limit of 250 mg/l chloride. One well contains more than 125 mg/l magnesium, four wells more than 250 mg/l sulfate, and one well more than 45 mg/l nitrate, each of these being a recommended upper limit. However, this water has been used for livestock and domestic purposes without apparent harmful effects.

Water from well 30-07-403, which supplies Fort Griffin State Park, has a higher chloride and total dissolved-solids content than is recommended by the U.S. Public Health Service, but it is the best supply available. In fact, the water is of better quality than that used by many communities in the State.

In addition to alluvial deposits along the major streams in Shackelford County, remnants of older alluvial deposits, probably of Pliocene to Pleistocene age, are found at higher elevations. These sediments were deposited by ancient stream networks as unconsolidated terrace and floodplain gravels, sands, silts, and clays, and then eroded by the present drainage system. No usable-quality water is known to be produced from these sediments.

According to long-time residents of the area, most of these sands and gravels contained little or no water in the past. Now, however, many of these deposits either contain water high in chloride content or contain residual salts left after the evaporation of water. During periods of rainfall, these salts are leached out and contribute to contamination of surface drainageways and ground water.

The presence of salts is probably due to the disposal of oil-field brines in unlined surface pits. Pressure due to secondary recovery injection has possibly forced brines to the surface or into the shallow subsurface through bore holes of unplugged or improperly plugged oil and gas tests and added to this problem.

WATER-QUALITY PROTECTION PROGRAMS

Surface Casing

The function of the Surface Casing Program of the Ground Water Division of the Texas Water Development Board is to recommend to oil and gas operators and the Railroad Commission of Texas the depth to which usable quality ground water should be protected in drilling for oil and gas. The authority for participation by the Board in the Surface Casing Program is derived from rules promulgated by the Railroad Commission under authority given that agency by statutes dealing with the regulation of drilling and production activities of the petroleum industry.

Statewide Rule 13 of the Railroad Commission requires that operators obtain a letter from the Texas Water Development Board regarding the occurrence of fresh-water strata in a field or area in question and that the fresh-water strata be protected to the depth recommended by the Board if the lease or area is not covered by field rules or lease recommendations. Railroad Commission Rule 8 requires that all fresh water be protected in drilling, plugging, or production activities, or disposing of salt water already produced.

In carrying out its duties under Rule 13, the Texas Water Development Board created the Surface Casing Program in the Ground Water Division. The staff of the Surface Casing Program is responsible for maintaining technical data files upon which to base fresh water protection recommendations in all areas of the State, and for preparing these recommendations for operators contemplating drilling oil or gas tests. The recommended depth to which ground water of usable quality should be protected in a given area is based on all pertinent information available to the Surface Casing Program staff at the time the recommendation is given. Recommended depths in any one area may therefore be revised from time to time as additional subsurface information becomes available.

Known depths of wells that produce or have produced water of usable quality, such as domestic, municipal, industrial, livestock, or irrigation wells, are of primary value in determining the depth of usable water. Electric or gamma-ray neutron logs on oil and gas tests are used in many areas to determine the depth to the base of usable quality ground water. Surface elevation is given special consideration when a recommendation is given in an area that has moderate to high surface relief, as is common to portions of Shackelford County. This consideration is imperative when the slope of the land surface does not conform to the dip of the underlying rocks, because of the danger that poor quality water will cause contamination of surface and ground water by moving along the dip of the beds to fresh-water zones or to points of discharge in stream channels. This information is interpreted in the light of the available knowledge of the geology and ground-water hydrology on the area involved.

During the 5-year period 1963-67, the Surface Casing Program staff prepared 1,438 recommendations for protection of usable quality ground water for oil and gas tests drilled in Shackelford County. Two hundred and fifty of these recommendations were prepared during 1967. The depths of these recommendations range from 60 to 100 feet.

Subsurface Disposal

The Regular Session of the 61st Texas Legislature in 1969 passed Senate Bill 138 (Article 7621b, Vernon's Texas Civil Statutes) which prescribed the permit system for subsurface disposal of municipal and industrial wastes in Texas. This act in effect designated the Texas Water Quality Board as the permit-issuing agency for all injection wells to dispose of "...industrial and municipal waste, other than waste arising out of or incidental to the drilling for or the producing of oil or gas...", and the Texas Railroad Commission as the permit-issuing agency for all injection wells "...for the purpose of disposing of waste arising out of or incidental to the drilling for or the producing of oil or gas..." Section 4(b) of this statute also directed that any person applying to the Railroad Commission for a permit to inject... "Waste arising out of or incidental to the drilling for or producing of oil or gas..." shall obtain a letter from the Texas Water Quality Board "...stating that the drilling of the injection well and the injection of such waste into the subsurface stratum will not endanger the fresh water strata in that area and that the formation or strata to be used for such waste disposal are not fresh water sands."

Opinions by the Attorney General of Texas pertinent to the implementation of Article 7621b are to the effect: (1) that "injection well," when correctly interpreted, includes only those wells which are drilled or used for the purpose of disposal and does not include an injection well where the purpose of the well is to increase production from an oil or gas-bearing stratum, and (2) that a determination by Texas Water Quality Board is not binding on the Railroad Commission but is merely advisory.

The staff of the Texas Water Quality Board reviews applications to dispose of salt water into subsurface zones and advises the operators and the Texas Railroad Commission of the acceptability of such applications. Waterflood, pilot projects for secondary recovery, and other secondary recovery operations where salt water is injected into subsurface zones which are productive of oil or gas are granted permits by the Railroad Commission without consultation with the Texas Water Quality Board. Also, the inspection of construction and completion of all brine injection systems is a regulatory function of the Railroad Commission.

The above functions designated to the Texas Water Quality Board were formerly responsibilities of the Texas Water Development Board. In the period August 1961 to February 1968, 59 applications to the Railroad Commission for salt-water disposal wells in Shackelford County were reviewed by the staff of the Subsurface Disposal Program of the Water Development Board. Each of these applications was reviewed on an individual basis with consideration given to geologic and hydrologic data of the area, method of completion of the proposed injection well, volume of salt water to be injected, and injection pressure to be used.

In addition to the salt-water disposal wells, the Railroad Commission, from August 1961 to December 1965, granted permits for 39 projects involving the use of injection wells in waterflood, pressure maintenance, and other secondary recovery operations in Shackelford County. The number of injection wells utilized in these projects ranges from one well in pilot projects for secondary recovery programs to as many as 13 or more injection wells in the larger waterflood projects. Generally, these projects are granted permits which contain provisions for expansion of the water-injection facilities by the use of additional injection wells as the operations expand.

OIL-FIELD BRINE PRODUCTION AND DISPOSAL

Quantity and Distribution of Produced Brine

During 1962, the Railroad Commission of Texas, the Texas Water Pollution Control Board, and the Texas Water Commission cooperated in collection and tabulation of information submitted by oil and gas operators concerning the 1961 oil-field brine production and disposal in Texas. The Railroad Commission of Texas and the Texas Water Development Board have cooperated in a similar collection and tabulation of the 1967 oil-field brine production and disposal in Texas which is now being compiled. Table 7 is a summary of the brine production in 1961 and 1967 by oil fields and by arbitrarily defined producing areas in Shackelford County. The location and extent of the brine-producing areas in the county and the amount of brine production and method of disposal in each area for 1967 are shown on Figure 11.

The total production of oil-field brines reported for 1967 (9,649,746 barrels) was only about 90 percent of the total reported 1961 production (10,668,641 barrels). In 1961, 403,491 barrels or 3.8 percent of the total production was reported disposed into open, unlined surface-disposal pits. However, only 5,885 barrels or less than 0.1 percent was reported placed into pits for disposal in 1967. This drop is probably due to the no-pit order issued by the Railroad Commission in 1964. In 1961, 10,264,650 barrels or 96.2 percent of the total production of salt water was reported injected into wells for disposal. This includes both pressure maintenance wells and salt-water disposal wells. In 1967, 9,382,182 barrels or 97.2 percent of the total production was reported disposed by injection. In 1961, 500 barrels or less than 0.1 percent of the total reported brine production was disposed by other methods, such as dumping into surface drainageways or on road and lease surfaces. In 1967, however, the method of disposal was not reported for 261,679 barrels or 2.7 percent of the total brine production. This brine is included under miscellaneous disposal in Table 7.

There have been some significant changes in the distribution of brine production and in the methods of disposal in the county since 1961. Seven of the areas (areas 1, 4, 12, 17, 18, 25, and 30) ceased producing brine after 1961. Only one area (area 6) was producing in 1967 which was not producing in 1961. In 1961, some brine was disposed in open-surface pits in each of the 30 areas shown on Figure 11 except areas 6, 23, and 30. In 1967, however, disposal of brine in surface pits was reportedly confined to areas 2, 5, 15, 22, 26, and 27 (Figure 11). All other areas were disposing by injection into the subsurface or by other methods.

The greatest use of surface pits apparently occurs in area 15 where a reported 2,555 barrels of brine was disposed by this method in 1967.

Chemical Quality of Produced Brine

Chemical analyses of some oil-field brines from various producing zones in Shackelford County are tabulated in Table 6. These analyses show the same ions present in the brines that are present in samples from water wells used for domestic and livestock supplies (Table 4). However, sodium, magnesium, calcium, and chloride ions are present in much greater concentrations in the brines.

Tables 4 and 5 present chemical analyses in milligrams per liter, which is the preferred metric system unit. Table 6 presents similar data (from Laxson and others, 1960), but in ppm (parts per million) by weight. Parts per million may be considered equal to milligrams per liter at concentrations less than about 7,000 ppm. At higher concentrations the units are not directly interchangeable, as conversion must take into account the greater differences in density of saline waters.

In the oil-field brine samples (Table 6), the sodium concentration ranges from 25,850 to 60,900 ppm. The chloride concentration ranges from 44,000 to 143,000 ppm. The concentration of magnesium ranges from 535 to 4,240 ppm. The total dissolved-solids range is from 76,000 to 249,500 ppm.

In addition to the brine produced with oil in the county, 28 waterflood-supply wells produce brine for use in oil field secondary recovery operations. These wells are listed in the records of wells (Table 3), and their locations are shown on Figure 10. Chemical analyses of brines from 11 of these wells are shown in Table 5. These are typical sodium chloride brines containing 95,000 to 135,000 mg/l total dissolved solids.

ALTERATION OF NATIVE QUALITY OF GROUND WATER

Alteration of the chemical quality of ground and surface water, as evidenced by the chemical analyses of water, has occurred locally in Shackelford County. Although a study of the contamination of surface water was not included in the scope of this report, it is impossible to ignore the interrelationship of ground and surface water. Alteration of the chemical quality of surface water may affect the quality of ground water by downward percolation of the altered water, and alteration of ground-water quality may affect surface water by outflow from springs and by contribution to the base flow of streams (See Figure 6).

The alteration of the chemical quality of ground water may be due to both natural and artificial means. Natural alteration occurs when water dissolves minerals from the rocks over which it flows or through which it percolates. In Shackelford County natural alteration is evidenced by high sulfate concentration (from anhydrite) and high bicarbonate concentration (from limestone and dolomite).

Artificial alteration of the quality of ground water may be either biological or chemical. Biological contamination is usually due to poor well construction and to location of water wells near septic tanks, livestock feedlots, and barnyards. It is usually evidenced by a high nitrate concentration in the water. Several wells in the county seem to be contaminated by one or more of these causes (Table 4).

Alteration of the chemical quality of ground water may also be associated with the operations of the oil and gas industry. Brines produced with oil and gas may commingle with usable-quality water in several ways. Brines placed in shallow surface pits for disposal may contaminate ground water by downward seepage or percolation. Overflow of brines from surface pits may contaminate surface water. Saline water may move up the bore holes of improperly plugged or cased wells into shallow fresh-water zones, due to natural pressure and the pressure of secondary-recovery injection. Ground-water quality may also be altered by lateral and vertical movement of injection fluids from improperly constructed municipal and industrial waste-disposal wells.

The location of 13 wells, apparently contaminated by oil-field brines, and several areas of vegetative kill, apparently the result of discharge of oil-field brine onto the surface or overflow of brine from disposal pits, are shown on Figure 11. Figure 8 shows diagrams of the chemical analyses of water from some of these apparently contaminated wells, native quality or apparently unaltered ground water, and typical oil-field brines. The diagrams illustrate the chemical similarity between typical oil-field brines and water from wells which have been contaminated by brine. Only a small amount of brine entering a water supply is necessary to change significantly the chemical character of the water. Although there are many indications of apparent contamination in Shackelford County, efforts have been and are being made by many petroleum operators to avoid contamination of the soil, surface water, and ground water, especially by curtailing the use of open, unlined surface pits as a means of brine disposal.

Figure 9 consists of photographs of several vegetative-kill areas observed in this study. The areas are found in several locations and range in size from less than one acre to several acres. Photographs A and B show an area in the Ivy field (area 1, Figure 11) in the northwest corner of the county. An area of surface kill extends for about a mile along a small tributary of California Creek. More than 20 surface disposal pits are in the drainage area of this tributary. Several waterflood systems are in operation in the Ivy field. Photographs C and D show a salt water injection well in the Ivy field. In the background of photograph D is an old abandoned salt water disposal pit. Photograph E shows a large area bare of vegetation surrounded by surface disposal pits. Photograph F shows a producing oil well with tank battery, which sometimes overflows into an oil sump, and a series of salt water overflow pits. Photographs G

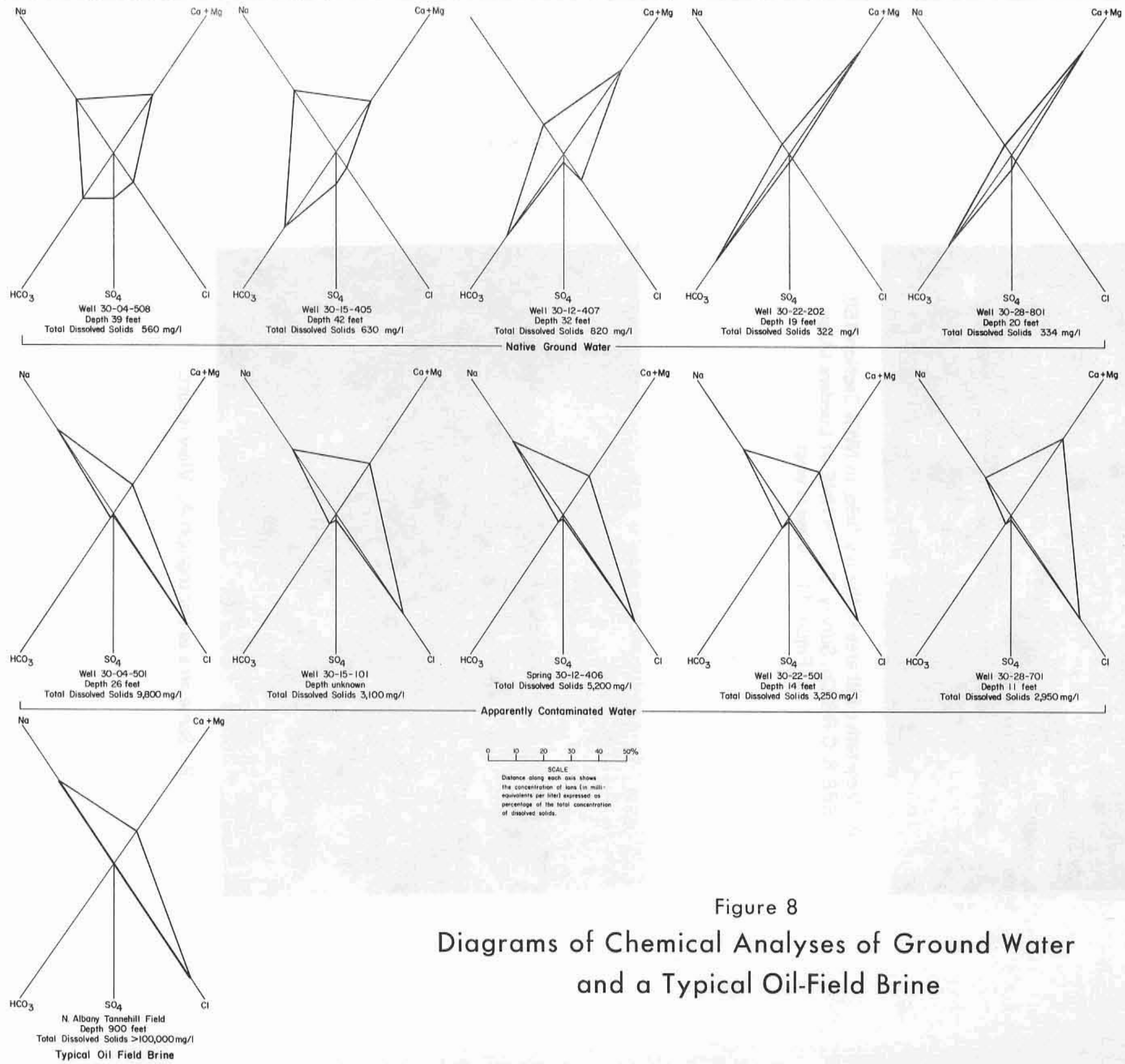
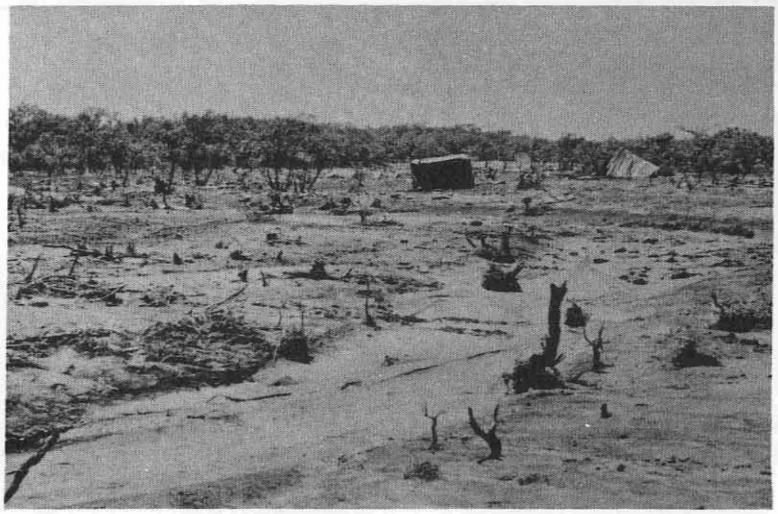
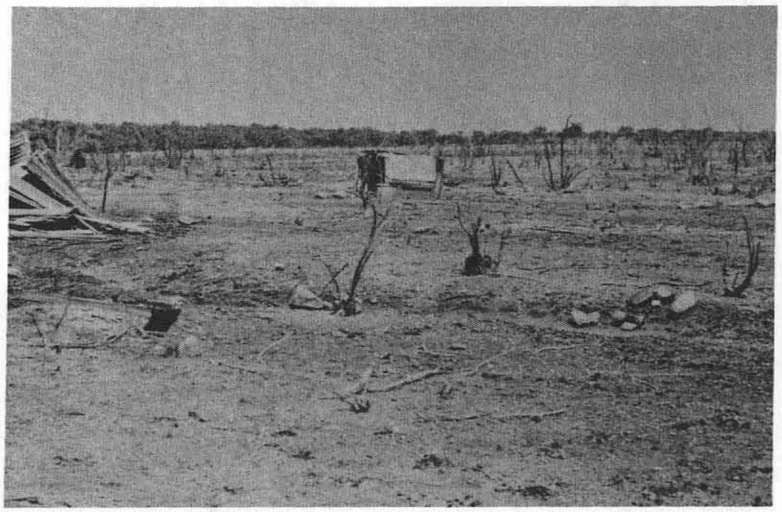


Figure 8
Diagrams of Chemical Analyses of Ground Water and a Typical Oil-Field Brine



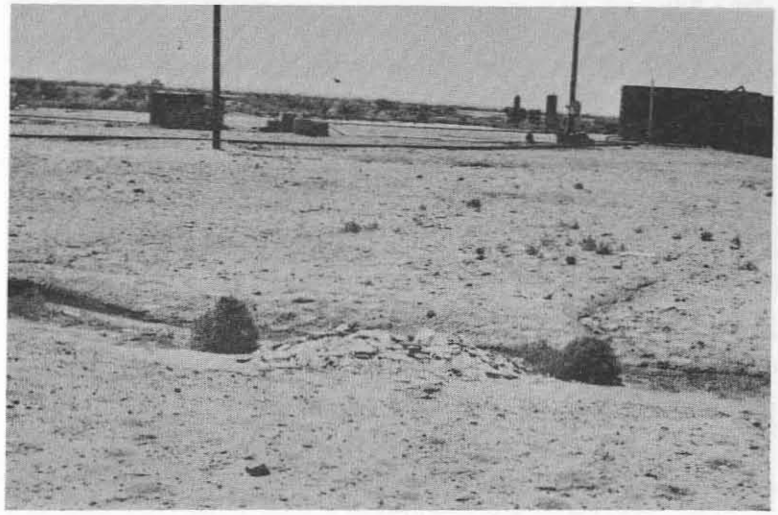
A. Vegetative-kill area in the Ivy field, in NW¼ Section 158, BBB & C RR Co. Survey, 9 miles NNE of Lueders (Area 1, Figure 11). View is west.



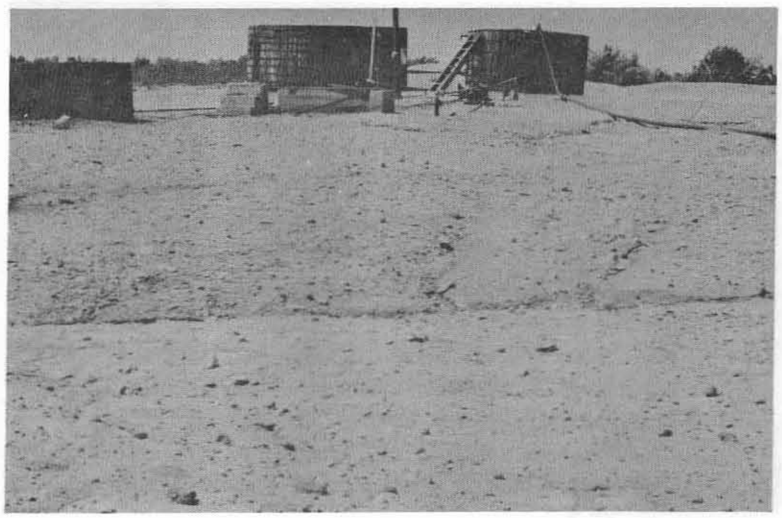
B. Same area as photograph A. View is east.

Figure 9

Photographs of Surface Disposal Pits and Vegetative-Kill Areas



C. Salt water injection well in the Ivy field, NE¼ Section 158, BBB & C RR Survey (Area 1, Figure 11). View is west.

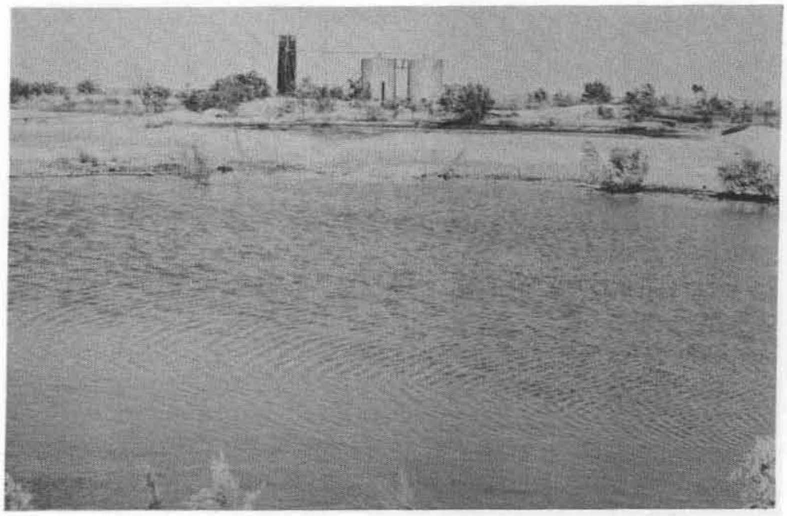


D. Same area as photograph C. Earth mound in right background is abandoned brine pit. View is north.

Figure 9—Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas

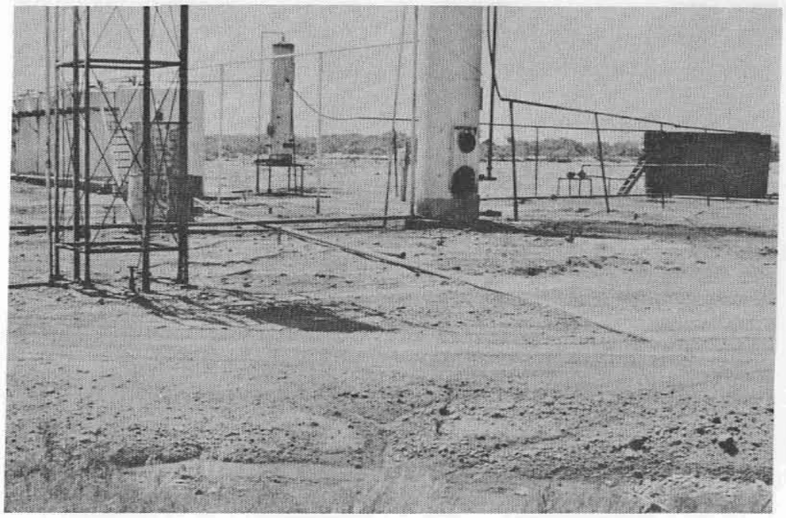
E. Vegetative-kill area in the Ivy field, SE¼, Section 158, BBB & C RR Co. Survey (Area 1, Figure 11). View is west.



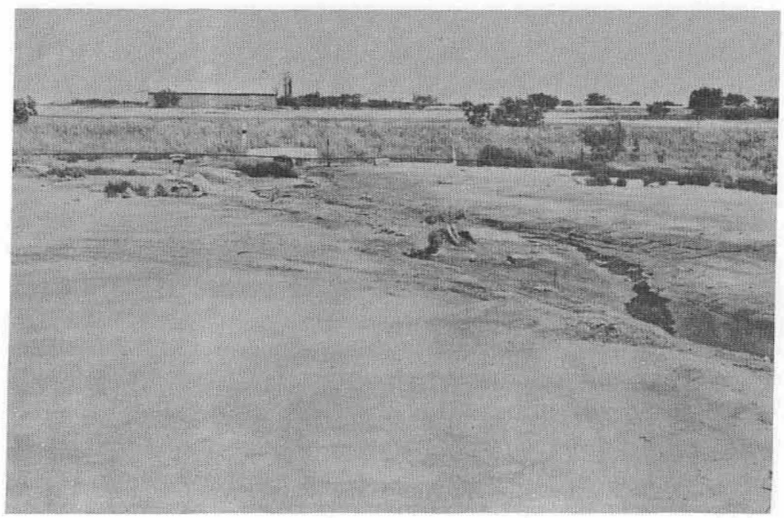
F. Tank battery, surface-disposal pit, and overflow pit in the Ivy field, SW¼ Section 159, BBB & C RR Co. Survey (Area 1, Figure 11). View is east.

Figure 9—Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas



G. Tank battery with oil-salt water treaters and salt water storage tank, NE¼ Section 163, BBB & C RR Co. Survey (Area 1, Figure 11). View is west.

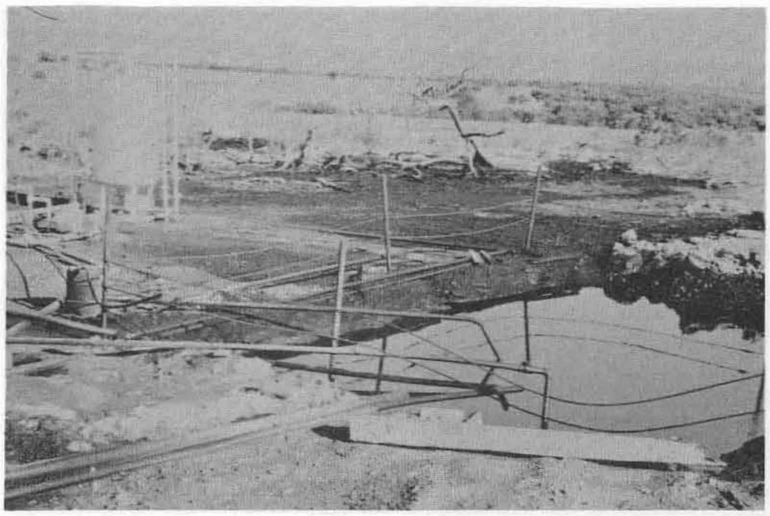


H. Same area as photograph G. Note barren soil in foreground. View is east.

Figure 9—Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas

I. Salt water injection system in the Newell field, SW¼ Section 13, Blk. 11, T & P RR Co. Survey (Area 9, Figure 11). Dark stain in background is oil spillage (Area 9, Figure 11). View is south.

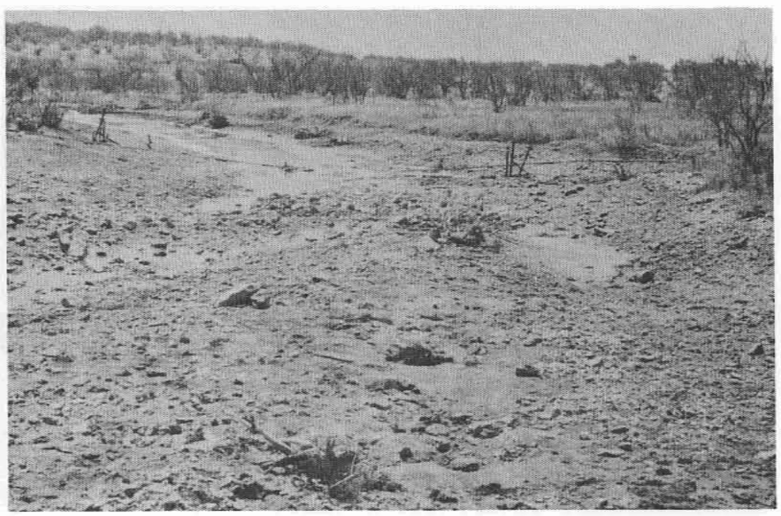


J. Surface disposal pit filled with oil, Shackelford County Regular field, Section 22, Blk. 11, T & P RR Co. Survey (Area 9, Figure 11). View is north.

Figure 9–Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas

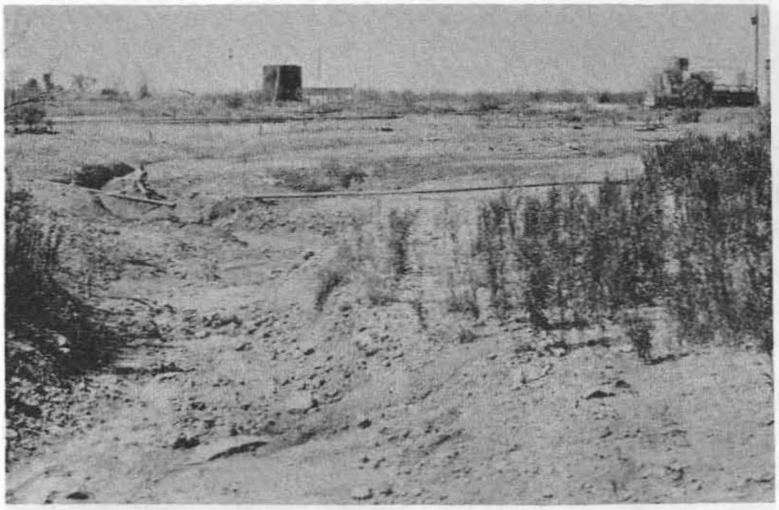
K. Tank battery in the Cook field, SE¼ Section 84, ET RR Co. Survey (Area 9, Figure 11). View is west.



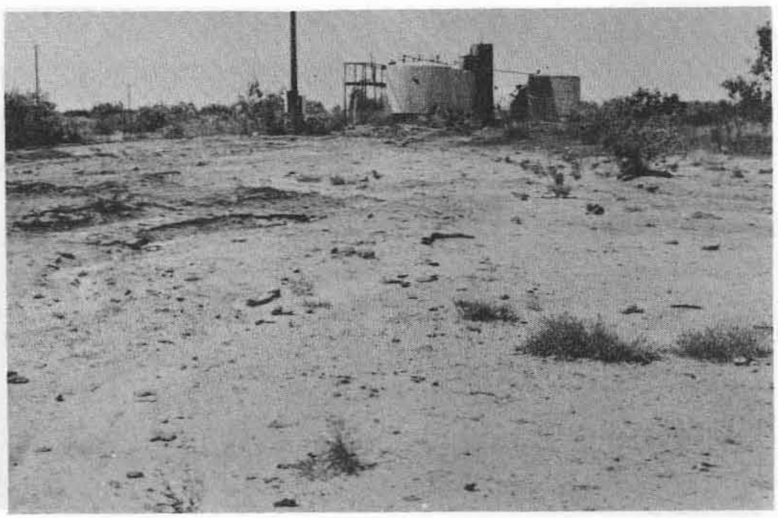
L. Surface drainageway barren of vegetation, Three Sisters field, Section 529, TE & L Co. Survey (Area 5, Figure 11). View is east.

Figure 9—Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas



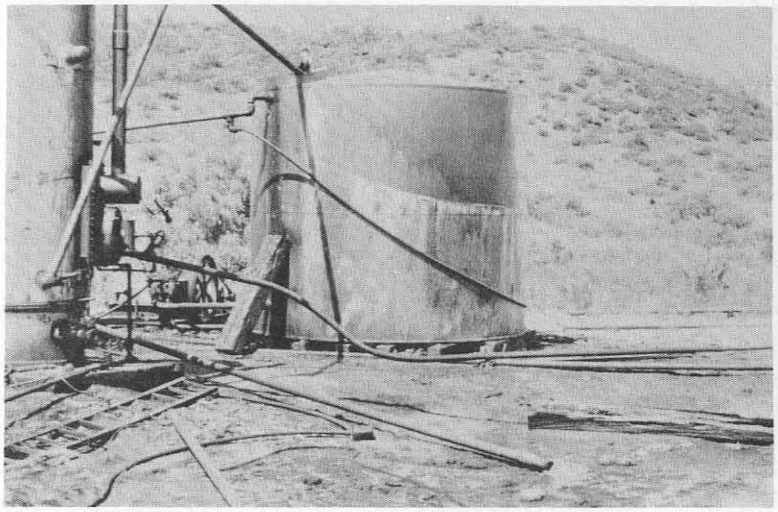
M. Same area as photograph L. View is south.



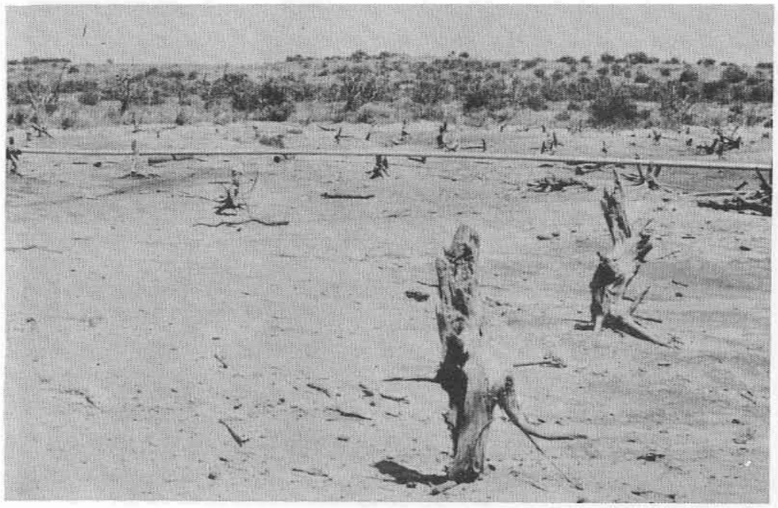
N. Barren soil in the Sedwick area, SE¼ Section 15, LAL Survey (Area 27, Figure 11). View is south.

Figure 9—Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas



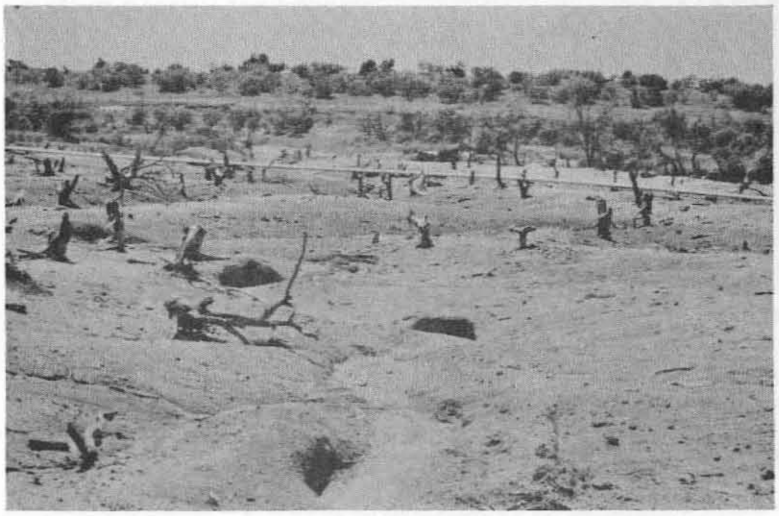
O. Leaking salt-water tank in the same area as photograph N. View is southwest.



P. Part of an extensive vegetative-kill area, Section 68, University Lands (Area 27, Figure 11). View is north.

Figure 9—Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas



Q. Same area as photograph P. View is south.

R. Same area as photographs P and Q. View is northwest.

Figure 9—Continued

Photographs of Surface Disposal Pits and Vegetative-Kill Areas

and H show an oil well, tank battery, and a brine tank with a large surrounding area of vegetative-kill. About half of the land area in this field shows extensive soil and plant damage.

West of Albany in the Cook and Newell fields (area 9, Figure 11) are several small areas of vegetative kill. Photograph I shows a tank battery and injection well about 4 miles west of Albany. The hillside below the well is completely barren of vegetation. In a small tributary of North Fork Hubbard Creek are indications of both salt water and oil flow. Photograph J shows a tank battery about 2 miles southwest of Albany. An oil sump and salt water disposal pit are still in use near the well. A small area of vegetative kill is downhill from the pit.

Photograph K shows a tank battery on a small tributary of Cook Creek. There is an extensive area of vegetative kill along the creek. A leaking salt-water line contributing brine to the creek is south of the tanks.

Six miles northeast of Albany, east of U.S. Highway 283, are several extensive areas of vegetative kill (area 5, Figure 11). Photograph L shows one of these areas along a small tributary of Taylor Creek. Photograph M shows the view across the kill area from the creek toward a waterflood system with a supply well, storage tanks, and injection well in the background.

Photograph N shows one of several small areas of vegetative kill in the Sedwick area (area 27, Figure 11) about 5 miles north of Moran. A tank battery with one tank leaking salt water onto the surface is shown in photograph O.

Photographs P, Q, and R show an extensive area of vegetative kill about 2 miles west of Moran (area 27, Figure 11). Several acres of land are completely barren of vegetation along a small tributary of Deep Creek, and the tributary shows signs of salt water over a mile from the oil field.

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Table 3.--Records of Water Wells and Springs, Shackelford County

Water-bearing unit : Qal, alluvium; Pwl, Lueders Formation; Pwbp, Belle Plains Formation; Pwa, Admiral Formation; Pwp, Putnam Formation; Pwm, Moran Formation; Pwpu, Pueblo Formation; PPcs, Cisco Group; PPcn, Canyon Group; PPs, Strawn Group; Oe, Ellenburger Group.

Water levels : Reported water levels given in feet; measured water levels given in feet and tenths.

Method of lift and type of power: B, bucket or bailer; C, cylinder; Cf, centrifugal; E, electric; G, natural gas, butane, or gasoline; H, hand; J, jet; N, none; S, submersible; T, turbine; W, windmill.

Use of water : D, domestic; Ind, industrial; Irr, irrigation; N, none; P, public supply; S, livestock.

WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (FT)	CASING: DIAMETER (IN)	CASING: DEPTH OF WELL (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
*30-04-501	Ellis A. Bean	--	--	26	42	--	Pwl	1,579	7.0	Jan. 12, 1967	N	N	Dug well.
* 502	do	--	--	--	42	--	Pwl	1,570	5.9	do	N	N	Do.
* 503	Ted Willoughby	Ted Willoughby	1925	15	42	--	Pwl	1,560	9.3	Jan. 16, 1967	N	N	Do.
* 504	do	do	1935	17	5	--	Pwl	1,577	11.1	do	N	N	
* 505	J. J. Simpson	--	Old	16	--	--	Pwl	1,564	13.9	do	N	N	Dug well.
* 506	do	--	Old	17	--	--	Pwl	1,567	8.0	do	N	N	Do.
* 507	do	--	1952	26	5	--	Pwl	1,569	24.8	do	N	N	Originally drilled as a seismograph shot hole.
* 508	Tull Newcomb	--	Old	39	48	--	Pwl	1,575	6.1	Jan. 20, 1967	N	N	Dug well.
* 701	Kenneth Hansen	--	1917	24	--	--	Pwl	1,566	14.5	Jan. 12, 1967	C,W	D,S	Dug for silo. Hole filled with water and was converted for water supply.
* 702	John McCowan	--	Old	16	42	--	Pwl	1,519	9.9	do	C,W	S	Dug well.
* 703	Mrs. George Reves	--	Old	4	54	--	Pwl	1,519	--	--	N	N	Water level in well same as level in creek. Well partially filled with mud.
* 705	W. C. McCowan		--	Spring	--	--	Pwl	1,515	(+)	Jan. 11, 1967	Flows	S	
† 05-401	Howsley and Jacobs	West Central Texas Drilling Co.	1955	1,420	--	--	Pwpu	1,488	--	--	C,E	Ind	Water-supply well for oil field secondary recovery operations.
402	do	Howsley and Jacobs	1957	1,884	--	--	PPcs	1,516	--	--	C,E	Ind	Do.

See footnotes at end of table.

Table 3.--Records of Water Wells and Springs, Shackelford County--Continued

WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (FT)	CASING: DIAMETER (IN)	CASING: DEPTH OF WELL (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
30-05-403	Howsley and Jacobs	--	--	--	--	--	Pwpu	1,517	--	--	C,E	Ind	Water-supply well for oil field secondary recovery operations.
† 501	do	do	1956	1,374	--	--	Pwpu	1,454	--	--	C,E	Ind	Do.
502	H. R. Stasney trust	--	--	--	--	--	Pwpu	1,529	--	--	C,E	Ind	Do.
503	do	--	--	--	--	--	Pwpu	1,504	--	--	C,E	Ind	Do.
† 504	do	--	--	1,275	--	--	Pwpu	1,506	--	--	C,E	Ind	Do.
† 505	do	M. E. Morrell Drilling Co.	--	1,640	--	--	Pwpu	1,482	--	--	C,G	Ind	Do.
701	Howsley and Jacobs	R. G. Makwell	1958	1,564	--	--	Pwpu	1,624	--	--	C,E	Ind	Do.
702	do	do	1958	1,653	--	--	Pwpu	1,589	--	--	C,E	Ind	Do.
* 07-401	State of Texas	--	--	46	10	46	Qal	1,190	--	--	J,E	N	Reported used as public supply well until February, 1966.
* 402	do	--	--	46	10	46	Qal	1,190	--	--	N	N	
* 403	do	Jack Leonard	1966	45	--	--	Qal	1,204	--	--	S,E	P	Reported yield 200 gallons per minute for 24 hours.
501	Morris Ledbetter	Morris Ledbetter	1964	43	4	43	Qal	1,202	--	--	N	N	Hole bridged at 25 feet.
502	do	do	1936	33	36	--	Qal	1,203	29.4	Sept. 21, 1966	N	N	Dug well. Hole caved near bottom.
* 503	Mrs. Letha Ledbetter	--	1952	41	24	--	Qal	1,202	35.0	Oct. 3, 1966	T,E	S	
* 504	Guy Caldwell	--	--	31	36	--	Qal	1,200	25.0	Sept. 26, 1966	C,W	D,S	
* 801	do	--	--	56	10	--	Qal	1,180	34.0	do	C,W	N	
* 12-102	Walter Heller	--	1966	100	5	--	Pwl	1,565	13.9	Jan. 10, 1967	N	N	Test hole.
* 103	do	--	1966	40	5	--	Pwl	1,563	12.7	do	N	N	Do.

See footnotes at end of table.

Table 3.--Records of Water Wells and Springs, Shackelford County--Continued

WELL	OWNER	DRILLER	DATE COM-PLET-ED	DEPTH OF WELL (FT)	CASING: DIAM-ETER (IN)	CASING: DEPTH OF WELL (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
* 104	W. C. Reynolds	--	Old	40	42	--	Pwl	1,536	16.6	Jan. 12, 1967	B,H	D,S	Dug well.
* 402	V. R. Latimer	V. R. Latimer	1965	32	5	32	Pwl	1,598	20.5	Nov. 11, 1966	J,E	S	
* 403	Oscar Armstrong	--	Old	6	42	--	Pwl	1,522	2.7	Jan. 12, 1967	T,E	D,S	Dug well.
* 404	John Swenson	--	Old	16	60	--	Pwl	1,520	12.6	Jan. 11, 1967	T,E	D,S	Do.
* 405	M. A. Ivy	--	1936	13	42	--	Pwl	1,524	7.2	Jan. 19, 1967	N	N	
* 406	Olga Lieb Taylor	--	--	Spring	--	--	Pwl	1,560	(+)	do	Flows	N	
*30-12-407	V. R. Latimer	V. R. Latimer	1965	32	5	32	Pwl	1,587	9.7	Nov. 11, 1966	N	N	
* 412	W. G. Swenson	--	1947	56	6	--	Qal	1,508	35.2	Mar. 16, 1967	C,W	D,S	
† 413	Humble Oil and Refining Co.	R-H-K Drilling Co.	1960	2,638	7	2,638	PPcs	1,575	1,169	June 2, 1960	C,E	Ind	Water-supply well for oil field secondary recovery operations.
* 501	John Swenson	--	Old	30	72	--	Pwl	1,518	25.8	Jan. 11, 1967	T,E	D,S	Dug well.
* 502	do	--	1954	24	60	--	Pwl	1,511	18.4	do	C,W	N	Do.
* 601	A. V. Jones and Sons	--	1959	1,450	--	--	Pwpu	1,594	--	--	C,E	Ind	Water-supply well for oil field secondary recovery operations.
* 701	Mack Gray, et al	--	Old	15	48	--	Pwl	1,634	7.0	Jan. 6, 1967	N	N	Dug well.
801	Marshall R. Young	Roeser and Pendleton, Inc.	1952	5,315	10 7	64 3,412	Oe	1,691	--	--	C,G	Ind	Water-supply well for oil field secondary recovery operations.
802	do	Marshall R. Young	1953	4,775	10 7	78 ?	Pwpu	1,683	24.1	May 16, 1967	C,G	N	Formerly used as water-supply well for oil field secondary recovery operations.
† 803	do	Roeser and Pendleton, Inc.	1936	1,615	8 6	31 1,494	Pwpu	1,687	--	--	C,G	Ind	Water-supply well for oil field secondary recovery operations.
* 901	Morris Miller	--	1925	20	84	--	Pwl	1,652	5.4	Oct. 16, 1966	Cf,E C,W	Ind D,S	Sometimes supplies water for drilling rigs. Dug well.

See footnotes at end of table.

Table 3.--Records of Water Wells and Springs, Shackelford County--Continued

	WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (FT)	CASING DIAMETER (IN)	CASING DEPTH OF WELL (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
*	902	Morris Miller	--	1930	54	8	--	Pwl	1,677	20.9	Oct. 16, 1966	N	N	Former oil test. Plugged back to present depth.
*	903	do	--	--	--	--	--	Pwl?	1,690	33.7	Oct. 16, 1968	N	N	Do.
	13-201	Roark and Hooker	--	1943	1,445	--	--	Pwpu	1,713	--	--	C,E	Ind	Water-supply well for oil field secondary recovery operations.
†	401	A. V. Jones and Sons	--	--	1,707	--	--	PPcs	1,756	--	--	C,E	Ind	Do.
	601	Marshall R. Young	Roeser and Pendleton, Inc.	1948	1,862	10 7	32 1,836	PPcs	1,850	--	--	C,G	Ind	Do.
	901	do	do	1949	5,180	10 7	120 1,753	Oe	1,827	--	--	C,G	Ind	Do.
	902	Morrell Drilling Co.	Morrell Drilling Co.	1965	2,168	--	--	PPcs	1,805	--	--	C,E	Ind	Do.
*	14-201	J. H. Nail	--	Old	15	36	--	Pwbp	1,415	--	--	C,E	D	Dug well.
†	701	Marshall R. Young	Marshall R. Young	1953	3,095	10 7	73 3,093	PPs	1,581	--	--	C,G	Ind	Water-supply well for oil field secondary recovery operations.
	702	do	do	1953	3,179	10 5	73 1,617	PPs	1,671	--	--	C,G	Ind	Do.
†	703	do	Roeser and Pendleton, Inc.	1947	1,468	--	--	PPcs	1,561	--	--	C,G	Ind	Do.
	704	do	Marshall R. Young	1954	3,180	10 7	75 3,166	PPs	1,651	--	--	C,G	Ind	Do.
	901	Three S Oil Co.	J. Edward Martin	1957	872	8 5	63 400	PPcs	1,408	--	--	C,E	Ind	Do.
*	15-101	Guy Caldwell	--	Old	--	12	--	Pwp	1,288	15.2	Apr. 12, 1967	C,W	S	
*	401	C. A. Schkade	--	--	13	48	--	Pwa	1,415	4.6	Nov. 14, 1966	J,E	D,S	Dug well.
*	402	E. O. Bernstein	--	--	36	7 7/8	--	Pwa	1,413	5.3	Feb. 17, 1967	N	N	

See footnotes at end of table.

Table 3.--Records of Water Wells and Springs, Shackelford County--Continued

WELL	OWNER	DRILLER	DATE COM-PLET-ED	DEPTH OF WELL (FT)	CASING DIAM-ETER (IN)	CASING DEPTH OF WELL (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
* 15-403	E. O. Bernstein	--	Old	15	48	--	Pwa	--	8.4	Feb. 17, 1967	N	N	Cistern--ground water enters through fractures in bottom.
* 404	Mrs. Oswald Bernstein	--	--	95	10	--	Pwa	1,407	4.6	Feb. 21, 1967	C,H	N	Depleted gas well. Casing bridged at 95 feet.
* 405	Alvin Bernstein	--	--	42	8	--	Pwp	1,387	(+)0.3	Feb. 16, 1967	Flows	N	
† 406	Three S Oil Co.	Roeser and Pendleton, Inc.	1952	1,655	7	1,571	PPcn	1,326	--	--	C,E	Ind	Water-supply well for oil field secondary recovery operations.
407	do	Marshall R. Young	--	1,200	--	--	PPcs	1,391	--	--	C,E	Ind	Do.
601	Earl Pickard	Otto Schade	1953	33.0	7	--	Pwm	1,327	14.4	Oct. 3, 1966	N	N	
* 901	Grady Petree	Ed L. Chapman	1964	29	12	29	Qal	--	22.7	Nov. 14. 1967	N	Irr	
* 902	do	do	1964	25	12	25	Qal	--	--	--	N	N	Hole caved.
* 16-401	Bob Green	--	Old	18	36	--	Pwm?	1,306	10.3	Mar. 17, 1967	N	N	Dug well.
* 701	D. L. Jones	--	--	60	6	60	Qal	1,180	27.4	Jan. 25, 1967	J,E	D	
* 20-101	W. F. Baker	--	--	Spring	--	--	Pwl	1,592	(+)	Apr. 5, 1962	Flows	N	
*30-21-201	Mrs. Dell Newell	--	--	22	36	--	Pwl	1,900	13.5	Apr. 13, 1967	B,H	D,S	Dug well.
301	A. V. Jones and Sons	--	1958	1,364	8 5	64 1,364	Pwpu	1,721	--	--	C,E	Ind	Water-supply well for oil field secondary recovery operations.
* 302	Mrs. Dell Newell	--	Old	7	--	--	Qal	1,708	6.1	May 4, 1967	N	N	
* 22-201	Floyd McComas	--	Old	29	48	--	Pwbp	1,450	6.1	Nov. 4, 1966	C,W	S	Dug well.
* 202	Meadley Watts	--	Old	19	36	--	Pwbp	1,448	3.1	do	C,W	D,S	Do.
203	Duncan Leach	--	1955	--	--	--	Qal	1,383	12.0	Jan. 4, 1967	N	N	
* 204	Clifford Teinert	--	--	21	6	--	Pwbp	1,407	9.6	do	N	N	
* 401	Duncan Leach	--	Old	16	48	--	Pwbp	1,480	6.8	do	N	N	Dug well.
* 501	Glen Leach	--	Old	14	36	--	Qal	1,389	10.9	do	C,W	S	Do.

See footnotes at end of table.

Table 3.--Records of Water Wells and Springs, Shackelford County--Continued

WELL	OWNER	DRILLER	DATE COM-PLET-ED	DEPTH OF WELL (FT)	CASING: DIAM-ETER (IN)	CASING: DEPTH OF WELL (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
* 22-502	Carter J. King, Jr.	--	Old	21	36	--	Qal	1,393	19.2	Apr. 7, 1967	N	N	Dug well.
* 601	J. B. Matthews	--	1952	10	60	--	Qal	1,341	4.6	Oct. 10, 1966	N	N	Do.
* 602	Bruce Bray	--	1956	8	36	--	Qal	1,356	3.6	do	J,E	D,S	Do.
* 603	W. C. Godwin	--	1964	15	24	--	Qal	1,365	8.0	Apr. 7, 1967	N	S	Do.
* 23-101	A. L. Black	J. L. Douglas	1948	18	8	--	Pwa	1,411	13.0	Mar. 10, 1967	J,E	N	Do.
* 401	J. H. Todd	J. H. Todd	1935	21	48	--	Qal	1,394	17.7	Oct. 3, 1966	C,W	D,S	Dug well.
* 402	Walter Humber	--	Old	12	42	--	Qal	1,304	6.7	Feb. 15, 1967	N	N	Do.
403	do	--	Old	13	42	--	Qal	1,309	10.3	do	N	N	Do.
* 701	A. E. Koenig	--	--	Spring	--	--	Qal	1,298	(+)	Mar. 3, 1967	C,W	D,S	
* 702	Bob Cockral	Bob Cockral	1962	12	24	--	Qal	1,299	6.3	Mar. 16, 1967	C,W	D,S	Dug well.
* 901	Ronald Harris	--	1948	70	5	--	Pwm	1,282	14.7	Mar. 23, 1967	J,E	D,S	
* 902	C. W. Bouldin	--	Old	24	36	--	Pwm	1,275	15.9	Mar. 29, 1967	T,E	D,S	Dug well.
* 28-401	Alton Whitaker	--	1961	21	5	--	Pwl	1,738	7.5	May 4, 1967	N	N	
* 402	City of Abilene	--	Old	17	48	--	Pwl	1,715	9.5	May 10, 1967	C,W	N	Dug well.
* 403	do	--	Old	14	36	--	Pwl	1,740	8.1	do	N	N	Do.
* 404	Mrs. Nannie Box	--	Old	15	42	--	Pwl	1,762	7.7	May 8, 1967	C,W	N	Do.
* 405	Mrs. C. G. Stinchcomb	--	Old	8	42	--	Pwl	1,738	4.7	do	N	N	Do.
* 406	H. O. West	--	Old	21	36	--	Pwl	1,757	7.2	May 24, 1967	C,W	S	Do.
* 28-501	C. T. Brady	--	Old	8	42	--	Pwl	1,775	6.2	Apr. 9, 1967	Cf,G	S	Do.
* 502	do	--	Old	22	48	--	Pwl	1,802	20.1	do	C,W	D,S	Do.
* 503	Dee Gooch	--	Old	8	48	--	Pwl	1,770	4.6	May 18, 1967	N	N	Do.

See footnotes at end of table.

Table 3.--Records of Water Wells and Springs, Shackelford County--Continued

WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (FT)	CASING: DIAMETER (IN)	CASING: DEPTH OF WELL (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
* 28-504	C. H. Box	--	Old	11	60	--	Pwl	1,768	10.1	May 24, 1967	N	N	Dug well.
* 701	R. L. Philips	--	Old	11	36	--	Pwl	1,776	8.8	May 4, 1967	J,E	D,S	Do.
* 702	K. K. Morrisett	--	Old	10	42	--	Pwl	1,772	10.0	May 9, 1967	N	N	Do.
* 801	J. J. Arendall	--	1932	20	60	--	Pwl	1,797	18.6	May 6, 1967	B,H	D	Do.
* 30-401	James Dyer and Glen Elliott	--	Old	29	48	--	Qal	1,495	17.1	Feb. 21, 1967	C,W	S	Do.
701	Petroleum Corporation of Texas	Petroleum Corporation of Texas	1960	1,730	10 7	66 1,730	PPcs	1,535	--	--	C,E	Ind	
* 31-201	Miles Benda	--	Old	58	42	--	Pwp	1,392	15.6	Feb. 28, 1967	N	N	Dug well.
* 501	Roy C. McCoy	--	--	70	7	--	Pwp?	1,401	9.8	do	N	N	Former oil test. Plugged back to present depth.
* 502	W. C. Allen	Luke Ledbetter	1965	60	7	60	Pwm?	1,328	--	--	C,W	D,S	
* 701	A. Burton	--	1967	Spring	--	--	Pwp	1,375	--	--	--	S	Dug for tank. Encountered shallow water table.
* 901	Lucion Brooks	--	1954	40	--	--	Pwm	1,397	--		J,E	D,S	Former oil test. Plugged back to present depth.
* 902	do	--	1905	30	--	--	Pwm	1,395	17.3	Feb. 21, 1967	C,W	S	
* 903	Mrs. Lucy Robinson	--	Old	20	10	--	Pwm	1,387	11.9	Feb. 23, 1967	N	N	
* 904	L. C. Kays	--	1962	65	6	65	Pwm	1,390	--	--	J,E	D,S	
* 905	C. A. and C. B. Edwards	--	1908	41	42	--	Pwm	1,401	25.4	Feb. 24, 1967	B,H	D,S	Dug well.
* 906	Dr. R. W. Pruett	Ed. L. Chapman	1964	40	5	40	Pwm	1,351	--	--	T,E	S	
* 907	C. H. Bynum	--	--	65	--	--	Pwm	1,401	--	--	C,W	D,S	Former oil test. Plugged back to present depth.
* 908	Mrs. E. Raymond	--	Old	22	36	--	Pwm	1,392	11.9	Feb. 28, 1967	T,G	S	Dug well.

See footnotes at end of table.

Table 3.--Records of Water Wells and Springs, Shackelford County--Continued

WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (FT)	CASING		WATER-BEARING UNIT	ALTITUDE OF LAND SURFACE (FT)	WATER LEVEL		METHOD OF LIFT	USE OF WATER	REMARKS
					DIAMETER (IN)	DEPTH OF WELL (FT)			BELOW LAND-SURFACE DATUM (FT)	DATE OF MEASUREMENT			
* 30-32-401	J. B. Branham	--	1957	30	6	--	Qal	1,309	13.2	Feb. 17, 1967	J,E	D,S	

* See Table 4 for chemical analysis.

† See Table 5 for chemical analysis.

Table 4.--Chemical Analyses of Water From Wells and Springs, Shackelford County

WELL	OWNER	DEPTH OF WELL (FT)	DATE OF COLLECTION	SILICA (SiO_2)	CAL-CIUM (Ca)	MAGNE-SIUM (Mg)	SODIUM (Na)	BICAR-BONATE (HCO_3)	SUL-FATE (SO_4)	CHLO-RIDE (Cl)	FLUO-RIDE (F)	NI-TRATE (NO_3)	DIS-SOLVED SOLIDS	TOTAL HARDNESS AS $CaCO_3$	PERCENT SODIUM	SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C.)	pH	SAR
								Moran Formation										
30-16-401	Bob Green	18	Mar. 17, 1967	13	49	6	9	179	6	10	0.3	<0.4	181	145	12.1	344	7.0	0.3
23-901	Ronald Harris	70	Mar. 23, 1967	16	114	32	199	292	213	234	.7	103	1,060	418	50.8	1,700	7.6	2.0
902	C. W. Bouldin	24	Mar. 29, 1967	19	191	57	261	272	99	690	.8	22	1,470	710	44.4	2,650	7.3	4.3
31-502	W. C. Allen	60	Mar. 23, 1967	12	100	45	281	392	240	341	.7	<.4	1,210	436	58.3	2,040	8.1	5.9
901	Lucion Brooks	40	Feb. 21, 1967	12	236	68	194	326	496	334	.6	23	1,520	870	32.7	2,320	7.5	2.9
902	do	30	do	18	344	77	217	303	770	422	.7	64	2,060	1,180	28.6	2,830	7.2	2.7
903	Mrs. Lucy Robinson	20	Feb. 23, 1967	8	148	41	560	287	164	990	.8	<.4	2,050	540	69.3	3,550	7.5	10.5
904	L. C. Kays	65	Feb. 24, 1967	5	97	70	1,060	340	192	1,730	1.1	<.4	3,320	530	81.2	5,710	7.5	20.1
905	C.A. and C. B. Edwards	41	do	9	237	40	225	232	228	458	.5	210	1,520	760	39.3	2,500	7.4	3.6
906	Dr. R. W. Pruett	40	Feb. 28, 1967	10	226	246	1,730	423	3,070	1,280	3.8	<.4	6,800	1,580	70.1	8,700	7.7	18.9
907	C. H. Bynum	65	do	10	82	36	70	301	158	75	.8	7	590	356	30.1	935	7.9	1.6
908	Mrs. E. Raymond	22	do	11	58	16	36	206	55	46	.5	6	330	211	27.3	560	7.5	1.1
								Putnam Formation										
30-15-101	Guy Caldwell	--	Apr. 12, 1967	17	303	112	710	282	130	1,690	0.8	<0.4	3,100	1,220	56.2	5,220	7.4	8.9
405	Alvin Bernstein	42	Feb. 16, 1967	6	54	28	141	454	127	52	.6	<.4	630	251	55.0	1,027	7.4	1.8
31-201	Miles Benda	58	Feb. 28, 1967	5	560	280	4,090	301	149	8,000	.9	<.4	13,200	2,550	77.7	>12,000	7.2	35.3
501	Roy C. McCoy	70	do	2	49	57	194	143	15	476	.3	<.4	860	358	54.1	1,800	6.7	4.5
701	A. Burton	Spring	Mar. 20, 1967	9	177	57	98	221	263	244	1.1	110	1,070	680	23.9	1,700	7.5	1.6
								Admiral Formation										
30-15-401	C. A. Schkade	13	Sept. 29, 1964	18	69	20	51	305	29	29	1.4	42	560	257	30.0	682	7.4	1.4
401	do	13	Nov. 14, 1966	16	85	23	77	372	71	54	1.3	48	570	308	35.1	904	7.8	1.9
402	E. O. Bernstein	36	Feb. 17, 1967	13	71	47	92	438	52	72	2.6	78	640	371	34.9	1,056	7.7	2.1
403	do	15	do	16	184	118	195	431	176	394	1.9	370	1,670	950	30.9	2,740	7.7	2.7
404	Mrs. Oswald Bernstein	95	Sept. 29, 1964	12	40	28	442	417	<2	580	2.1	<.4	1,520	216	81.7	2,340	7.6	13.0
404	do	95	Feb. 21, 1967	10	46	55	486	322	<4	820	.6	<.4	1,580	342	75.6	2,840	7.5	11.5
23-101	A. L. Black	18	Mar. 10, 1967	4	64	42	220	386	<4	373	.7	<.4	890	336	58.8	1,250	7.4	5.2

Table 4.--Chemical Analyses of Water From Wells and Springs, Shackelford County--Continued

WELL	OWNER	DEPTH OF WELL (FT)	DATE OF COLLECTION	SILICA (SiO_2)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	BICARBONATE (HCO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	FLUORIDE (F)	NITRATE (NO_3)	DISSOLVED SOLIDS	TOTAL HARDNESS AS $CaCO_3$	PERCENT SODIUM	SPECIFIC CONDUCTANCE (MICROMHOS AT 25° C.)	pH	SAR
							Belle Plains Formation											
30-14-201	J. H. Nail	15	Sept. 30, 1966	16	95	18	21	350	27	29	0.5	<0.4	329	314	12.9	648	7.8	0.5
22-201	Floyd McComas	29	Nov. 4, 1966	15	94	16	46	416	31	11	.7	<.4	419	299	24.9	692	7.4	1.2
202	Meadley Watts	19	do	12	96	9	14	348	13	6	.3	1.0	322	280	9.7	558	7.7	.4
204	Clifford Teinert	21	Jan. 4, 1967	9	192	122	443	203	409	820	.8	280	2,380	980	49.5	3,620	7.6	6.2
401	Duncan Leach	16	do	16	129	29	80	412	28	183	.5	<.4	670	442	28.2	1,150	7.4	5.2
							Lueders Formation											
30-04-501	Ellis Bean	26	Jan. 12, 1967	15	550	198	2,900	404	66	5,900	0.8	5	9,800	2,180	74.3	>12,000	7.2	27.1
502	do	--	do	17	750	327	3,660	450	50	7,900	.6	<.4	12,900	3,210	71.3	>12,000	6.9	28.1
503	Ted Willoughby	15	Jan. 16, 1967	18	290	73	380	386	314	740	.8	16	1,950	1,020	39.6	3,150	7.2	4.2
504	do	17	do	20	147	78	333	570	475	327	3.2	<.4	1,660	690	51.2	2,950	7.4	2.6
505	J. J. Simpson	16	do	10	97	68	135	296	113	335	1.0	1.0	910	520	35.9	1,620	7.8	2.6
506	do	17	do	22	4,340	2,240	13,400	173	222	35,100	1.1	<.4	55,400	20,000	59.2	>12,000	6.7	41.2
507	do	26	do	18	219	107	173	338	233	610	.8	2.5	1,520	990	27.6	2,510	7.4	2.4
508	Tull Newcomb	39	Jan. 19, 1967	12	45	33	104	233	153	95	1.5	<.4	560	250	47.4	920	7.9	2.8
701	Kenneth Hansen	24	Jan. 12, 1967	12	93	123	374	425	405	474	3.6	125	1,820	740	52.5	2,730	7.8	6.0
702	John McCowan	16	Jan. 11, 1967	17	180	106	170	378	387	341	1.1	39	1,430	890	29.5	2,230	7.3	2.5
703	Mrs. George Reves	4	Jan. 13, 1967	15	204	107	244	372	580	408	1.1	<.4	1,740	950	35.8	2,500	7.2	3.4
705	W. C. McCowan	Spring	Jan. 11, 1967	18	590	125	288	401	1,550	437	1.1	3	3,210	1,980	--	3,720	7.3	--
12-102	Walter Heller	100	Jan. 10, 1967	19	205	232	540	407	770	1,020	1.0	113	3,100	1,470	44.6	4,530	7.2	6.2
103	do	40	do	17	151	192	530	325	510	940	2.5	245	2,750	1,170	49.7	4,210	7.6	6.7
104	W. C. Reynolds	40	Jan. 12, 1967	19	192	149	303	310	459	710	.9	59	2,040	1,090	37.6	3,200	7.8	4.0
402	W. R. Latimer	32	Nov. 11, 1966	18	125	47	72	590	44	94	.4	4.5	700	510	23.5	1,156	7.4	1.4
403	Oscar Armstrong	6	Jan. 12, 1967	16	223	125	117	447	620	206	.7	<.4	1,530	1,070	19.2	2,130	7.2	1.6
404	John Swenson	16	Jan. 11, 1967	21	85	29	13	348	19	17	.5	<.4	347	296	8.5	570	7.6	.3
405	M. A. Ivy	13	Jan. 19, 1967	19	231	157	131	475	870	146	.9	4.5	1,790	1,220	18.9	2,300	7.1	1.6
406	Olga Lieb Taylor	Spring	do	17	306	197	1,360	325	118	3,000	1.1	2.5	5,200	1,570	65.6	8,000	7.8	14.9

Table 4.--Chemical Analyses of Water From Wells and Springs, Shackelford County--Continued

WELL	OWNER	DEPTH OF WELL (FT)	DATE OF COLLECTION	SILICA (SiO_2)	CALCIUM (Ca)	MAGNESIUM (Mg)	Sodium SODIUM (Na)	BICARBONATE (HCO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	FLUORIDE (F)	NITRATE (NO_3)	DISSOLVED SOLIDS	TOTAL HARDNESS AS $CaCO_3$	PERCENT SODIUM	SPECIFIC CONDUCTANCE (MICROMHOS AT 25° C.)	pH	SAR
30-12-407	V. R. Latimer	32	Nov. 11, 1966	24	140	54	91	680	44	129	.5	<.4	820	570	--	1,360	7.3	--
501	John Swenson	30	Jan. 11, 1967	20	93	43	47	407	103	44	.9	4.5	560	409	20.0	895	7.5	1.0
502	do	24	do	21	71	40	44	397	58	27	.9	22	479	341	21.9	766	7.8	1.0
701	Mack Gray, et al.	15	Jan. 6, 1967	15	160	110	285	439	271	550	0.9	105	1,710	850	42.0	2,700	7.7	4.3
901	Morris Miller	20	Dec. 10, 1964	17	122	21	46	318	36	135	.8	3.5	534	390	20.4	955	7.1	1.0
901	do	20	Oct. 16, 1966	13	121	23	43	318	32	131	.6	1.5	520	398	18.9	935	7.5	.9
902	do	54	do	1	55	13	58	78	<4	179	.1	1.5	346	189	40.1	719	7.1	1.8
903	do	--	do	6	23	2	2	85	6	3	.1	3.0	91	68	6.9	162	7.0	.1
20-101	W. F. Baker	Spring	Apr. 5, 1967	16	47	40	17	344	14	11	1.3	4.5	320	284	11.5	559	7.3	.4
21-201	Mrs. Dell Newell	22	Apr. 13, 1967	15	69	24	131	260	111	132	1.1	37	650	272	51.2	1,049	7.8	2.5
28-401	Alton Whitaker	21	May 4, 1967	16	79	35	81	387	63	93	1.9	7.0	570	340	34.2	961	7.5	1.9
402	City of Abilene	17	May 10, 1967	18	57	114	172	426	138	315	1.5	41	1,070	610	38.0	1,990	7.5	3.0
403	City of Abilene	14	do	12	81	52	81	368	76	155	1.5	4.0	640	417	29.8	1,135	7.5	1.7
404	Mrs. Nannie Box	15	May 8, 1967	18	146	106	340	320	299	610	2.1	80	1,760	800	48.1	3,040	7.6	5.2
405	Mrs. C. G. Stinchcomb	8	do	8	79	15	38	336	13	28	.5	4.0	351	259	17.1	609	7.4	.7
406	H. O. West	21	May 24, 1967	15	78	21	43	268	67	67	.5	3.0	427	281	24.9	736	7.4	1.1
501	C. T. Brady	8	Apr. 9, 1967	13	95	22	35	332	40	47	1.2	25	441	329	18.6	737	7.5	.8
502	do	22	do	15	54	48	92	392	92	56	4.0	17	570	331	37.5	930	7.7	2.2
503	Dee Gooch	8	May 18, 1967	12	200	60	375	278	23	960	1.0	<.4	1,770	750	52.2	3,400	7.3	6.0
504	C. H. Box	11	May 24, 1967	31	389	99	435	475	6	1,410	.4	<.4	2,600	1,380	40.7	4,550	7.5	5.1
701	R. L. Phillips	11	May 4, 1967	15	196	329	426	253	85	1,760	1.1	14.5	2,950	1,840	33.7	5,250	7.2	4.3
702	K. K. Morrisett	10	May 9, 1967	16	263	164	298	336	53	1,190	1.4	<.4	2,150	1,330	32.7	4,110	7.2	3.6
801	J. J. Arendall	20	May 6, 1967	13	59	33	13	299	32	11	.7	25	334	282	9.2	567	7.7	.3
								Alluvium										
30-07-401	State of Texas	46	Oct. 1, 1964	15	229	75	191	444	179	510	1.0	0.4	1,640	880	32.0	2,410	7.3	2.8
402	do	46	do	10	124	56	164	381	173	277	1.0	.4	1,190	540	39.8	1,690	7.5	3.1
403	do	45	Oct. 7, 1966	15	213	56	166	384	55	530	.3	.4	1,220	760	32.1	2,160	7.3	2.6

Table 4.--Chemical Analyses of Water From Wells and Springs, Shackelford County--Continued

WELL	OWNER	DEPTH OF WELL (FT)	DATE OF COLLECTION	SILICA (SiO_2)	CAL-CIUM (Ca)	MAGNE-SIUM (Mg)	SODIUM (Na)	BICAR-BONATE (HCO_3)	SUL-FATE (SO_4)	CHLO-RIDE (Cl)	FLUO-RIDE (F)	NI-TRATE (NO_3)	DIS-SOLVED SOLIDS	TOTAL HARDNESS AS $CaCO_3$	PERCENT SODIUM	SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C.)	pH	SAR
30-07-503	Mrs. Letha Ledbetter	41	Oct. 3, 1966	18	222	109	155	580	550	184	0.6	3.0	1,530	1,000	25.1	2,150	7.9	2.1
504	Guy Caldwell	31	Sept. 30, 1964	20	117	29	259	342	209	322	2.1	3.5	1,125	410	57.9	1,870	7.3	5.6
504	do	31	Sept. 26, 1966	18	117	20	128	406	54	185	.4	.4	720	375	42.6	1,245	7.1	2.9
801	do	56	do	15	178	72	243	288	640	199	1.7	65	1,700	740	41.7	2,190	7.5	3.9
12-412	W. G. Swenson	56	Mar. 16, 1967	17	163	76	208	333	436	291	.9	28	1,380	720	38.7	2,140	7.7	3.4
15-901	Grady Petree	29	Sept. 30, 1964	17	414	88	435	283	720	890	1.6	68	2,920	1,400	40.4	4,090	7.0	5.1
901	do	29	Nov. 14, 1966	10	176	35	107	342	171	274	.2	11	960	590	28.5	1,610	7.3	1.9
902	do	25	Sept. 30, 1964	13	520	79	451	246	407	1,380	1.3	28	3,130	1,630	37.5	4,800	7.0	4.9
16-701	D. L. Jones	60	Sept. 30, 1964	18	308	64	285	359	75	910	1.0	<.4	2,020	1,030	37.5	3,220	7.0	3.9
701	do	60	Jan. 25, 1967	18	356	105	483	475	221	1,250	.5	<.4	2,670	1,320	44.3	4,390	7.2	5.7
21-302	Mrs. Dell Newell	7	May 4, 1967	18	192	36	185	610	9	410	.8	<.4	1,160	630	39.0	2,060	7.4	3.2
22-501	Glen Leach	14	Jan. 4, 1967	18	299	97	790	317	65	1,820	.5	5	3,250	1,150	60.2	5,500	7.4	10.1
502	Carter J. King, Jr.	21	Apr. 7, 1967	17	114	31	258	353	51	441	.7	4.0	1,090	414	57.5	1,940	7.5	5.5
601	J. B. Matthews	10	Oct. 10, 1966	11	146	40	224	306	114	453	.4	<.4	1,140	530	47.8	1,985	7.9	4.2
602	Bruce Bray	8	do	19	196	87	510	377	135	1,040	.6	1.5	2,180	850	56.8	3,680	8.2	7.6
603	W. C. Godwin	15	Apr. 7, 1967	2	69	70	650	146	72	1,180	.7	1.5	2,120	461	75.3	3,740	6.8	13.1
23-401	J. H. Todd	21	Oct. 3, 1966	12	94	15	45	275	43	45	.4	69	458	298	24.7	757	7.7	1.1
402	Walter Humber	12	Feb. 15, 1967	13	149	61	170	299	90	480	.4	<.4	1,110	620	37.3	1,950	7.7	3.0
701	A. E. Koenig	Spring	Mar. 13, 1967	3	79	36	103	331	184	79	.6	9	660	347	39.2	1,041	7.8	2.4
702	Bob Cockral	12	Mar. 16, 1967	16	118	47	160	317	379	121	.7	27	1,030	489	41.5	1,520	7.5	3.1
30-401	James Dyer and Glen Elliot	29	Feb. 21, 1967	12	114	22	49	337	36	122	.4	2.0	520	375	22.0	926	7.4	1.1
32-401	J. B. Branham	30	Feb. 17, 1967	22	155	143	580	670	910	550	2.6	22	2,710	970	55.6	3,730	7.4	8.2

Table 5.--Chemical Analyses of Brines From Waterflood-Supply Wells, Shackelford County

(Analyses given are in milligrams per liter except percent sodium, specific conductance, pH, and SAR.)

Analyses performed by Texas Department of Health.

WELL	OWNER	DEPTH OF WELL (FT)	DATE OF COLLECTION	SILICA (SiO_2)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	BICARBONATE (HCO_3)	SULFATE (SO_4)	CHLORIDE (CL)	FLUORIDE (F)	NITRATE (NO_3)	DISSOLVED SOLIDS	TOTAL HARDNESS AS $CaCO_3$	PERCENT SODIUM	SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C.)	pH	SAR
							PENNSYLVANIAN SYSTEM											
							Strawn Group											
30-14-701	Marshall R. Young	3,095	Apr. 12, 1967	6	7,520	1,750	40,500	32	69	81,000	1.7	<0.4	130,900	26,000	77.2	>12,000	5.8	109.2
							Canyon Group											
30-15-406	Three S Oil Co.	1,655	Apr. 5, 1967	--	5,800	1,470	32,400	--	20	66,000	1.1	<0.4	106,000	20,600	77.4	>12,000	3.7	98.3
							Cisco Group											
30-12-413	Humble Oil & Refining Co.	2,638	May. 10, 1960	--	7,228	1,422	34,768	62	11	70,600	--	--	114,001	--	--	--	5.5	--
			Mar. 16, 1967	--	8,300	1,030	36,900	--	5	75,000	0.8	<0.4	120,600	25,000	75.7	>12,000	4.0	98.7
13-401	A. V. Jones & Sons	1,707	Mar. 10, 1967	3	5,500	1,210	33,600	77	13	66,700	--	< .4	107,000	18,800	79.3	>12,000	6.7	106.5
14-703	Marshall R. Young	1,468	Apr. 12, 1967	6	7,720	1,990	41,900	15	178	83,000	1.7	< .4	135,000	27,500	76.8	>12,000	5.7	109.8
							PERMIAN SYSTEM											
							Wichita Group (Pueblo Formation)											
30-05-401	Howsley & Jacobs	1,420	Mar. 9, 1967	2	6,300	1,860	38,600	79	53	78,000	1.1	<0.4	125,000	23,500	78.1	>12,000	6.2	109.7
501	do	1,374	do	--	6,700	1,900	37,000	38	<4	76,700	1.0	< .4	122,000	24,500	76.7	>12,000	6.0	102.9
504	H. R. Stasney, Trust	1,275	do	--	6,500	1,480	36,800	48	<4	72,800	.7	< .4	118,000	22,300	78.0	>12,000	6.1	107.2
505	do	1,640	do	3	6,200	1,600	40,900	60	<4	75,300	1.2	< .4	123,900	22,200	80.2	>12,000	6.0	119.5
12-601	A. V. Jones & Sons	1,450	Mar. 16, 1967	2	4,800	1,060	29,700	82	57	58,900	--	< .4	95,000	16,400	79.6	>12,000	6.5	100.8
803	Marshall R. Young	1,615	May 16, 1967	7	8,000	1,800	30,600	98	26	65,000	.9	< .4	105,500	27,500	70.7	>12,000	6.6	80.2

Table 6.—Chemical Analyses of Oil-Field Brines, Shackelford County

(Analyses Are in Parts Per Million Except pH.)

Data From Laxson and Others, 1960.

PRODUCING ZONE	FIELD	AVERAGE DEPTH OF WELL	AREA SHOWN ON FIGURE 11	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	BICARBONATE (HCO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	DIS-SOLVED SOLIDS	pH
				Permian System							
Frye sand	Regular	800	----	8,960	4,032	59,110	9	150	78,500	150,605	5.3
Tannehill sand	N. Albany	---------	13	6,480	2,208	29,527	54	150	63,500	101,855	6.7
Bluff Creek Sand	Matilda Perkins	1,600	13	6,430	1,360	32,600	95	160	65,400	124,800	6.5
Flippen lime	Newell	---------	9	6,070	1,620	39,500	80	0	76,300	132,700	6.6
Cook sand	Nail	---------	2	6,700	1,295	35,000	110	0	69,400	129,500	7.2
Cook lime	Hendrick ranch	---------	2	4,100	1,030	30,200	110	1,050	56,000	99,400	7.2
				Pennsylvanian System							
Hope sand	Nail TR3	---------	2	6,180	1,310	35,700	90	360	70,500	126,300	6.5
King sand	1 mi. N of Ivy	1,899	1	5,750	2,038	31,280	77	163	64,200	------------	5.8
Swastika sand	Regular	---------	----	7,280	2,544	37,630	73	63	78,500	126,000	6.5
Moran	Wildcat	---------	----	11,750	1,860	48,250	150	375	100,000	170,900	6.4
Palo Pinto	8 mi. E of Hamby	---------	23	10,900	4,240	48,900	165	0	107,000	185,400	6.4
Fry sand	Wildcat			3,350	960	33,160	160	538	44,000	76,000	7.3
Gardner	8 mi. E of Hamby	---------	24	22,800	2,840	60,900	65	20	143,000	249,0	5.5
Strawn	Kadane-Beaumont	2,467	17	17,820	1,829	47,500	126	119	111,300	------------	6.3
Lake sand	Sedwick	3,900	27	14,250	1,635	60,500	45	107	123,000	220,600	5.2
				Mississippian System							
Mississippian	Sanders	---------	10	7,020	1,570	35,200	157	548	70,730	------------	6.6
				Ordovician System							
Ellenburger	Pittman & Reynolds	4,536	11	2,865	691	25,850	505	1,174	45,800	76,885	7.3
				Cambrian System							
Cambrian	9 mi. E of Nugent	---------	15	3,150	535	26,500	300	1,340	46,800	88,100	6.7

Table 7.—Reported Oil-Field Brine Production and Disposal in 1961 and 1967, Shackelford County

(Quantities Reported in Barrels)

AREA 1/	FIELD 2/	BRINE PRODUCTION 1961	BRINE PRODUCTION 1967	DISPOSAL INTO PITS 1961	DISPOSAL INTO PITS 1967	INJECTION WELLS 1961	INJECTION WELLS 1967	MISCEL-LANEOUS 1961	MISCEL-LANEOUS 1967
1	Ivy	25,915	0	0	0	25,915	0	0	0
	Shell (King)	28,000	0	0	0	28,000	0	0	0
	County regular	878,380	0	2,380	0	876,000	0	0	0
	Area Total	932,295	0	2,380	0	929,915	0	0	0
2	M.P.C. (Flippen)	57,305	28,623	0	0	57,305	28,623	0	0
	Nail	61,320	57,305	0	0	61,320	57,305	0	0
	Nail (Cook, upper)	581,310	1,727,202	0	0	581,310	1,727,202	0	0
	Nail, North (Cook)	91,250	9,000	0	0	91,250	9,000	0	0
	Nail, Tract 2 (Fly, upper)	16,790	26,258	0	0	16,790	26,258	0	0
	Roark-Nail	912	220,161	912	0	0	220,161	0	0
	Whistler-Bend (Gardner)	5,425	0	0	0	5,425	0	0	0
	Whistler-Bend (Moran)	3,650	0	0	0	3,650	0	0	0
	Whistler (Hope)	180	0	180	0	0	0	0	0
	County regular	312,532	237,089	4,097	1,800	308,435	235,289	0	0
	Area Total	1,130,674	2,305,638	5,189	1,800	1,125,485	2,303,838	0	0
3	Nail, Tract 20 (Cook)	1,460	4,567	0	0	1,460	4,567	0	0
	County regular	4,840	0	460	0	4,380	0	0	0
	Area Total	6,300	4,567	460	0	5,840	4,567	0	0
4	County regular	7,425	0	7,060	0	365	0	0	0
	Area Total	7,425	0	7,060	0	365	0	0	0
5	Aliceanne (Mississippian 4470)	0	46	0	0	0	46	0	0
	Dorothy Sue, East (Mississippian)	0	18,250	0	0	0	18,250	0	0
	Dorothy Sue, Northeast (Mississippian 4475)	0	586	0	0	0	586	0	0
	Gem (Caddo)	2,555	0	0	0	2,555	0	0	0
	Gem (Mississippian)	30	50	30	0	0	50	0	0
	Gem, Northeast (Caddo)	9,205	0	9,205	0	0	0	0	0
	Gem, Northeast (Mississippian)	1,180	0	1,180	0	0	0	0	0
	Lea Anne, Southeast (Mississippian 4480)	0	134	0	0	0	134	0	0
	Ranch View (Caddo)	0	43,133	0	0	0	43,133	0	0
	Ranch View, Southeast (Mississippian)	0	12,025	0	0	0	12,025	0	0
	Schade (Mississippian)	0	1,080	0	0	0	1,080	0	0
	County regular	737,291	851,219	31,308	365	705,983	850,854	0	0
	Area Total	750,261	926,523	41,723	365	708,538	926,158	0	0
6	Fort Griffin, East (Caddo)	0	3,790	0	0	0	3,790	0	0
	Fort Griffin, East (Mississippian)	0	70,196	0	0	0	70,196	0	0
	Oxford (Mississippian 4590)	0	99,750	0	0	0	99,750	0	0
	Sharon Lynn (Mississippian)	0	30,000	0	0	0	30,000	0	0
	Sloan (Mississippian)	0	30,000	0	0	0	30,000	0	0
	County regular	0	3,650	0	0	0	3,650	0	0
	Area Total	0	237,386	0	0	0	237,386	0	0
7	Sloan, South (Caddo)	800	0	800	0	0	0	0	0
	Sloan, South (Caddo, Upper)	20,560	0	10,560	0	10,000	0	0	0
	Sloan, South (Mississippian)	2,500	67,525	2,300	0	200	67,525	0	0
	Area Total	23,860	67,525	13,660	0	10,200	67,525	0	0

Table 7.—Reported Oil-Field Brine Production and Disposal in 1961 and 1967, Shackelford County—Continued

AREA 1/	FIELD 2/	BRINE PRODUCTION 1961	BRINE PRODUCTION 1967	DISPOSAL INTO PITS 1961	DISPOSAL INTO PITS 1967	INJECTION WELLS 1961	INJECTION WELLS 1967	MISCEL-LANEOUS 1961	MISCEL-LANEOUS 1967
8	Blaco (Bluff Creek)	10,950	0	0	0	10,950	0	0	0
	Conway (Bluff Creek)	730	0	730	0	0	0	0	0
	Lueder, East (Cook)	6,144	22,630	0	0	6,144	22,630	0	0
	County regular	1,239,659	451,491	30,918	0	1,208,741	451,491	0	0
	Area Total	1,257,483	474,121	31,648	0	1,225,835	474,121	0	0
9	Albany (Mississippian)	2,555	9,228	0	0	2,555	9,228	0	0
	Cook Ranch	1,023,838	803,690	1,365	0	1,022,473	803,690	0	0
	Cook Ranch (Mississippian)	0	9,125	0	0	0	9,125	0	0
	Cook Ranch (Strawn)	204,772	29,150	0	0	204,772	29,150	0	0
	Harry Hines (1600)	43,780	668,653	8,650	0	40,130	668,653	0	0
	Low-Davis (Cook)	16,500	0	0	0	16,500	0	0	0
	Newell (Cook)	84,900	23,950	0	0	84,900	23,950	0	0
	New Kirk (Cisco)	67,450	185,250	0	0	67,450	185,250	0	0
	County regular	1,896,525	1,387,229	56,342	0	1,839,818	1,140,334	365	246,895
	Area Total	3,340,320	3,116,275	61,357	0	3,278,598	2,869,380	365	246,895
10	Albany, South (Atoka)	0	8,030	0	0	0	0	0	8,030
	County regular	8,164	60	2,629	0	5,535	60	0	0
	Area Total	8,164	8,090	2,629	0	5,353	60	0	8,030
11	P & R	2,555	1,095	2,555	0	0	1,095	0	0
	County regular	2,500	3,600	0	0	2,500	3,600	0	0
	Area Total	5,055	4,695	2,555	0	2,500	4,695	0	0
12	County regular	8,857	0	1,557	0	7,300	0	0	0
	Area Total	8,857	0	1,557	0	7,300	0	0	0
13	Matilda Perkins	22,636	0	0	0	22,636	0	0	0
	County regular	428,940	254,770	1,236	0	427,704	254,770	0	0
	Area Total	451,576	254,770	1,236	0	450,340	254,770	0	0
14	County regular	3,285	122,841	1,825	0	1,460	122,841	0	0
	Area Total	3,285	122,841	1,825	0	1,460	122,841	0	0
15	Coates (Bluff Creek)	300	146,000	300	0	0	146,000	0	0
	Coates (Cook)	365	0	365	0	0	0	0	0
	County regular	191,505	208,755	23,548	2,555	167,957	206,200	0	0
	Area Total	192,170	354,755	24,213	2,555	167,957	352,200	0	0
16	County regular	48,562	625	15,529	0	33,033	625	0	0
	Area Total	48,562	625	15,529	0	33,033	625	0	0
17	Double D (Canyon)	7,300	0	0	0	7,300	0	0	0
	Kadane-Beaumont (Strawn)	510,202	0	0	0	510,202	0	0	0
	County regular	4,010	0	4,010	0	0	0	0	0
	Area Total	521,512	0	4,010	0	517,502	0	0	0

Table 7.—Reported Oil-Field Brine Production and Disposal in 1961 and 1967, Shackelford County—Continued

AREA[1/]	FIELD[2/]	BRINE PRODUCTION		DISPOSAL INTO PITS		INJECTION WELLS		MISCEL-LANEOUS	
		1961	1967	1961	1967	1961	1967	1961	1967
18	Oily Pass (Cook)	360	0	360	0	0	0	0	0
	3-Sisters (Cook)	1,460	0	1,460	0	0	0	0	0
	County regular	968	0	968	0	0	0	0	0
	Area Total	2,788	0	2,788	0	0	0	0	0
19	County regular	31,601	150	5,671	0	25,930	150	0	0
	Area Total	31,601	150	5,671	0	25,930	150	0	0
20	County regular	9,127	1,100	8,032	0	1,095	1,100	0	0
	Area Total	9,127	1,100	8,032	0	1,095	1,100	0	0
21	Ibex	100	0	100	0	0	0	0	0
	Ibex (Caddo)	0	1,700	0	0	0	1,700	0	0
	Ibex (Strawn, zone 3)	1,460	0	1,460	0	0	0	0	0
	County regular	12,920	31,185	12,920	0	0	32,885	0	0
	Area Total	14,480	32,885	14,480	0	0	32,885	0	0
22	Boa (Caddo)	0	7,434	0	0	0	680	0	6,754
	Hudman	4,015	0	4,015	0	0	0	0	0
	Hudman (Marble Falls)	0	2,385	0	335	0	2,050	0	0
	Mugginsville	365	0	365	0	0	0	0	0
	Mugginsville (Marble Falls)	0	300	0	300	0	0	0	0
	Woolfolk (Marble Falls)	29,200	2,100	0	0	29,200	2,100	0	0
	County regular	1,900	548	1,900	0	0	548	0	0
	Area Total	35,480	12,767	6,280	635	29,200	5,378	0	6,754
23	Edgar Davis (Hope)	54,500	73,000	0	0	54,500	73,000	0	0
	Morrisett, West (Palo Pinto)	41,832	3,285	0	0	41,832	3,285	0	0
	Windham (Gardner)	43,700	54,700	0	0	43,700	54,700	0	0
	Windham, West (Palo Pinto)	25,500	0	0	0	25,500	0	0	0
	Windham West (3400)	14,600	14,690	0	0	14,600	14,690	0	0
	County regular	20,025	48,985	0	0	20,025	48,985	0	0
	Area Total	200,157	194,660	0	0	200,157	194,660	0	0
24	Pannel (Mississippian)	0	4,200	0	0	0	4,200	0	0
	V.G., East (Gardner)	4,800	0	500	0	4,300	0	0	0
	County regular	0	17,700	0	0	0	17,700	0	0
	Area Total	4,800	21,900	500	0	4,300	21,900	0	0
25	County regular	13,825	0	1,825	0	12,000	0	0	0
	Area Total	13,825	0	1,825	0	12,000	0	0	0
26	Elliot (Mississippian)	36,500	34,200	36,500	0	0	34,200	0	0
	County regular	8,843	350	1,460	350	7,308	0	75	0
	Area Total	45,343	34,550	37,960	350	7,308	34,200	75	0

Table 7.—Reported Oil-Field Brine Production and Disposal in 1961 and 1967, Shackelford County—Continued

AREA[1]	FIELD[2]	BRINE PRODUCTION 1961	BRINE PRODUCTION 1967	DISPOSAL INTO PITS 1961	DISPOSAL INTO PITS 1967	INJECTION WELLS 1961	INJECTION WELLS 1967	MISCELLANEOUS 1961	MISCELLANEOUS 1967
27	Hubbard Creek	548	0	548	0	0	0	0	0
	Hubbard Creek (Lake)	7,180	5,800	7,180	0	0	5,800	0	0
	Hubbard Creek (Ranger)	8,945	180	8,945	180	0	0	0	0
	Moran, East (3700)	0	5,145	0	0	0	5,145	0	0
	Moran, East (3800)	0	552	0	0	0	552	0	0
	Moran, East (Mississippian 3900)	0	1,800	0	0	0	1,800	0	0
	Moran (Moran)	0	365	0	0	0	365	0	0
	Moran, North	0	36,500	0	0	0	36,500	0	0
	Moran (Strawn, 2400)	11,000	29,935	11,000	0	0	29,935	0	0
	Rattlesnake Mountain (Ellenburger)	62,150	0	0	0	62,150	0	0	0
	Rattlesnake Mountain (lake)	4,923	1,900	1,643	0	3,280	1,900	0	0
	Sedwick (Lake)	45,000	0	0	0	45,000	0	0	0
	Sedwick, East	7,000	0	7,000	0	0	0	0	0
	Sedwick (Marble Falls)	9,850	0	9,850	0	0	0	0	0
	Sedwick, South (Lake)	49,300	82,120	0	0	49,300	82,120	0	0
	County regular	1,016,996	1,099,601	42,941	0	974,055	1,099,601	0	0
	Area Total	1,222,892	1,263,898	89,107	180	1,133,785	1,263,718	0	0
28	C and S (Cook, lower)	600	0	600	0	0	0	0	0
	Hamby, East (Morris)	360	0	360	0	0	0	0	0
	Sherry Ann (Ellenburger)	4,750	0	0	0	4,750	0	0	0
	Sherry Ann (Gardner)	36,815	0	0	0	36,815	0	0	0
	Sherry Ann, West (Ellenburger)	36,200	0	0	0	36,200	0	0	0
	V.G., East (Gardner)	0	2,899	0	0	0	2,899	0	0
	Windham (Ellenburger)	100,375	0	0	0	100,375	0	0	0
	Windham (Tannehille)	139,187	5,840	0	0	139,187	5,840	0	0
	County regular	71,634	200,145	8,489	0	63,145	200,145	0	0
	Area Total	389,921	208,884	9,449	0	380,472	208,884	0	0
29	County regular	10,368	1,141	10,368	0	0	1,141	0	0
	Area Total	10,368	1,141	10,368	0	0	1,141	0	0
30	Chastain (Lake)	60	0	0	0	0	0	60	0
	Area Total	600	60	0					
	County Total	10,668,640	9,649,746	403,491	5,885	10,264,650	9,382,182	500	261,679
	Percent of Total			3.8	<.1	96.2	97.2	<.1	2.7

1/ Areas shown on Figure 11.

2/ Oil or gas fields as assigned by the Railroad Commission of Texas.

Table 8.—Oil and Gas Tests Selected as Data-Control Points

WELL	OPERATOR	LEASE AND WELL	SURVEY	DATE OF ELECTRICAL LOG
30-12-101	Hill and Hill	Bossie 1	Sec. 2, D&SE RR	------------
13-701	Roeser and Pendleton	J. P. Morris Est. 1	Sec. 169, ETRR Co.	------------
901	Roeser and Pendleton & Continental Oil Co.	W. I. Cook 113-A-15	Sec. 113, ETRR Co.	Feb. 12, 1949
14-801	Sunray DX Oil Co.	Joe B. Matthews 1	Sec. 30, ETRR Co.	Nov. 23, 1964
15-501	Roark & Hooker	Pitzer 1	Sec. 534, TE&L Co.	Feb. 28, 1964
16-403	Sinclair Oil & Gas Co.	Willie G. Green 1	Sec. 815, TE&L Co.	Oct. 1, 1954
28-101	Am. Liberty Oil Co.	Manley 1	Sec. 41, Blk. 13 TPRR Co.	Apr. 26, 1951
29-601	E. H. R. Sabens	Green A-1	Sec. 71, Blk. 13 TPRR Co.	Dec. 19, 1948
701	Sojourner Drilling Co.	Alice Walker 1	Sec. 74, Blk. 13 TPRR Co.	Dec. 28, 1952
30-301	Intex Oil Co.	Elliot 1	Sec. 19, L.A.L.	Nov. 10, 1948
31-101	M. J. Mitchell	Mabel Carter 2	Sec. 70, L.A.L.	Dec. 23, 1950
32-101	James H. Snowden	R. A. Elliot 1	Sec. 26, B.O.A.	Nov. 16, 1948