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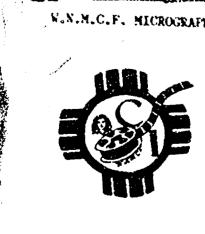
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PREPARED IN COOPERATION WITH DEPARTMENT OF THE INTERIOR THE NEW MEXICO STATE ENGINEER UNITED STATES GEOLOGICAL SURVEY greatest decline during the period 1950-60 was 31.7 feet about EXPLANATION THE WATER TABLE IN THE DEPOSITS OF CENOZOIC AGE ment of ground water 14 miles northeast of Lovington. The shape and approximate altitude of the water table is trolled by the gradient DEPTH TO WATER AND SATURATED THICKNESS OF THE shown (fig. 2) by contour lines based on water-level measureof the material in the 🖟 DEPOSITS OF CENCZOIC AGE ments made mostly during 1952. A few measurements in The 9 and 10 S., were made in later years; the data are comgrain size of the material The depth to water ranges from a little less than 12 feet in and the extent of come parable because the level of the water table in these wells has an area about 13 miles east of Caprock to almost 300 feet along of movement to vary fr the Mescalero Ridge northwest of Maljamor (fig. 5). When not changed appreciably for a number of years. The water true of the Ogaliaia for the Lea County Underground Water Basin was declared in table slopes generally toward the southeast at about 12 feet Sand and gravel; may include some redeposited material from Ogaliala formation and the underlying Cretaceous and Triassic rocks per mile, slightly less than the slope of the land surface. The 1931 it included an area of about 1,080 square miles where the and gravel than throu depth to water was known to be generally 50 feet or less; by irregularities in the surface of the water table are caused by and clay. Data avail 1952 the area in which the depth to water was 50 feet or less differences in the permeability of the aquifer and heavy had been reduced about one-sixth. pumping in certain areas. the order of 150 feet pe The saturated thickness of the deposits of Cenozoic age Records of water levels in observation wells indicate that · Ogallala formation generally ranges from less than 25 feet to about 250 feet. The Irregularly-bedded sund, grit, and local gravel conglomerate cemented by lime or caliche, and local beds of sand, clay, and limestone; may include some redeposited material from the underlying Cretaceoue and Triassic since 1929 the water table has fluctuated erratically in the zone of saturation is thinnest in the northeast part of the east-central part of northern Lea County, but the overall trend during the period 1929-60 has been downward. county where the Ogallala formation is thin and is underlain The declines during the period 1929-40 were localized be- Ground water stored XX. cause of the relatively slight pumpage and average to aboveaverage precipitation. Above-average precipitation from January 1940 to January 1950, caused the water table to rise generally except in the vicinity of McDonald, Lovington, water has been withdrawn for irrigation. The average thick-Yellow and blue clay with thin stringers of brown, and gray, limestone; probably equivalent to the Tucumcari shale Humble City, and Hobbs where pumpage increased appreciably during 1947 to 1950 (fig. 4). During the period 1950-60 ness of the zone in the declared basin was about 100 feet in 1952. discharge of ground we subsurface outflow at t the water table declined over a much larger area than in the MOVEMENT OF GROUND WATER IN THE DEPOSITS OF Dockum group, undivided additional quantity moss previous 10-year period because of increased pumpage and Maroon, red, and gray irregularly-bodded sandstone, bright- and dark-red shale and surdy shale, and purplish limestone pebble bods Ground water moves southeastward down the slope of the along the southern and generally below average rainfall during that time. The Grayburg formation and San Andres limestone, undivided Sandy dolomite with interbedded dolomitic rand; poroun white limestone: known only from logs of oil wells White to light gray crystalline limestone with ragpy poroxity and occe-sional green shale partings; known only from logs of oil wells Sandy porous delomite and ruggy crystolline delomite; known only from logs of oil wells EMMARGED Water well Oil and gas well location near center of field Aquifer ---- In | Fear sampled Hardness ne CaCOg (ppm) = 198 53 = Specific conductance (micrambos at 15°C) Chloride (ppin) - 45 91 - Sulfate (ppm) : 2 - Fluoride (ppm) 130 13. Softum advoration nitin Depth to water, in feet, below land surface datum. Static-level manuscriment unless the figure in followed by the capital tetter. "I" which indicates that the measurement may made while the well was being Data are grouped around the source-of-water symbol. Undetermined information is noted by the absence from the designed position in the group of data Line connecting points of approximately equal depth to water below land-surface datum as of 1952 Dashed where inferred; interval 25 feet المارية المراجع المستسبب Line connecting points of approximately equal saturated thickness of the deposits of Cenozoic age as of 1952 Dushed where inferred; interval 25 feet ------Approximate boundary of bedrock highs that interrupt the water table in the deposits of Cenozoic age EXPLANATION Observation well

Number indicates rise (+) or decline (+),
in feet, of scater level during the period ---+2----Line showing rise (+) or decline (-), in feet, of water level Interval variable, dashed where estimated FIGURE 4 -- MAPS SHOWING WATER LEVEL CHANGES IN EAST CENTRAL 0 2 4 6 8 10 NOMETERS

GROUND-WATER CONDITIONS IN NORTHERN LEA COUNTY, NEW

Sidney R. As



HYDROLOGIC INVESTIGATIONS ATLAS HA-62 (SHEET 2 OF 2)

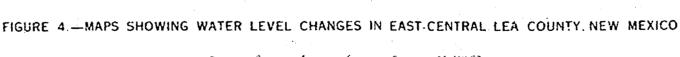
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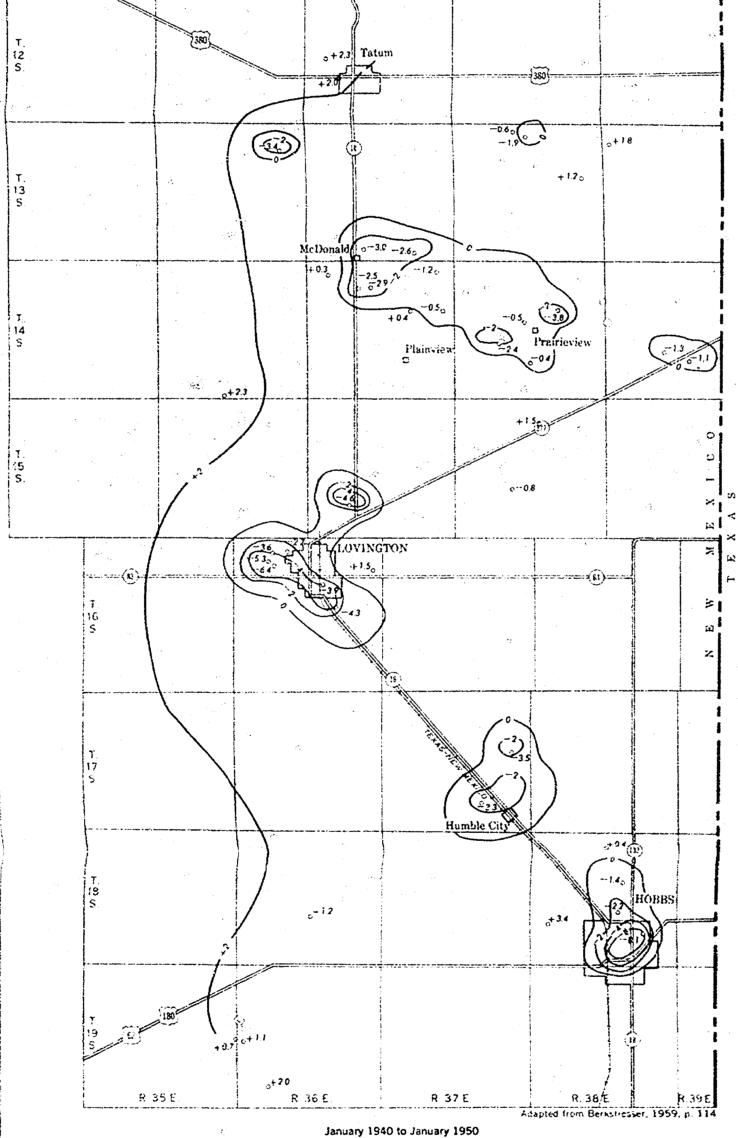
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R 38 E. January 1950 to January 1960

discharge is through wells.

Rgs. 35 to 38 E. the order of 150 feet per year (H. O. Reeder, U.S. Geol. Survey, nial lakes and the springs and seeps where the depth to water water by transpiration. removed by both natural and artificial discharge. Natural total discharge from the Ogallala fermation. Some of the discharge is by subsurface flow out of the area, evaporation springs and seeps discharge along the contact between the Natural discharge.—The greatest part of the total natural springs discharge into the lakes; Ranger Lake and North Lake discharge of ground water from northern Lea County is by receive the greater part of the water discharging to the lakes. subsurface outflow at the New Mexico-Texas State line. An Artificial discharge. - The ground water discharged through additional quantity moves out of the area by subsurface flow wells from the deposits of Cenozoic age is utilized for irriga-Ground water moves southeastward down the slope of the along the southern and western boundary where the contact tion, public supplies, rural-domestic supplies, industrial uses.

is less than 20 feet. Native grass, weeds, mesquite, and hack-Flow from springs and seeps is small in proportion to the

The amount of ground water lost by evaporation and tranof surface water and there are few areas where the water Evaporation from the zone of saturation in general can take along Mescalero Ridge, and south of Mescalero Ridge from Most transpiration by native vegetation is near the peren-

amount 166,000 acre-feet was used for irrigation. About the show the concentration of sulfate (SO4), of chloride (Cl), and same quantities of water evere pumped each year during the of fluoride (F), the hardness, the specific conductance, and the period 1953-57. Because of above average precipitation dur- sodium-adsorption ratio.

zoic age during 1952 was about 185.000 acre-feet; of this of the waters is indicated by the analyses in figure 5 which

Water for domestic use .-- The quality standards for drink-(1946) have been adopted by the New Mexico Public Health Department. These standards were reviewed recently by Welsh and Thomas (1960) and they agree (p. 299) that "the for certain other substances should be considered. The recommended limits for the substances shown in the analyses in figure 5 are 1,000 ppm (parts per million) (preferably 500 ppm) of dissolved solids, or a specific conductivity of less than 1,500 micromhos and preferably less than 750 micromhos; 250 opm of sulphate; 250 ppm of chloride; and 1.5 ppm of fluoride. The preferred limits for one or more substances were exceeded Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Inc., 534 p. in 19 of the 36 analyses of water from the Cenozoic deposits. They were exceeded in the three analyses of water from the Flawn, P. T., 1956. Basement rocks of Texas and southeast

ucumcari shale, and in the three analyses of water from rocks

of pre-Mesozoic age. None of the water occurring in the

Water which has an excess of some of these substances may

generally is necessary to determine its suitability for drinking.

The New Mexico Department of Public Health will analyze,

Sample containers and instructions for sampling can be ob-

Water for industrial use.-Water from deposits of Cenozoic

free of charge, drinking water for residents of the State.

tained from the New Mexico Department of Public Health in

age may be considered satisfactory for most industrial uses.

even though the water is hard. Water from the formations

of Mesozolc age are generally harder and have a higher dis-

solved-solids content than water from Cenozoic rocks. Water

from the rocks of pre-Mesozoic age generally is of such poor

quality that it is suitable for most use only where quality of

water is of little or no importance, such as drilling shotholes

Water for arrigation .-- Water from deposits of Cenozoic age

generally is suitable for irrigation according to the criteria of

the U.S. Department of Agriculture (Richards, 1954). The

total concentration of soluble salts (salinity hazard) ranges

from medium to high; however, the quantity of exchangeable

sodium (alkali hazard) is low, (Richards, 1954, p. 80). The few

wells near Hobbs that have a relatively high concentration of

chloride also tend to have a moderately high alkali hazard.

A high concentration of sulfate in association with a high con-

centration of sodium lessens the alkali hazard. Boron is not

known to occur in concentrations high enough to affect the

age which was analyzed has been of very poor quality with

respect to use for irrigation. Most of the water, which com-

monly is called brine, has an extremely high salinity and

alkali hazard. Ground water in rocks of pre-Mesozoic age is

Contamination. - In some wells potable water in the Ogal-

iala formation is being contaminated with water containing a

high concentration of chloride, sodium, calcium, magnesium.

and other dissolved solids. A well in NW4SE NE4 sec. 15,

T. 18 S., R. 38 E., approximately 2 miles north of Hobbs, was

sampled during 1951, and the analyses showed the water to

be potable. The well was sampled again in 1954 and the

chloride content had increased from 75 to 152 ppm, the sulfate

content had increased to 359 ppm since 1954, and the concen-

tration of chloride had increased to 259 ppm. The hardness

(as CaCO₃) had increased from 296 ppm to 612 ppm during

the 7-year period and the SAR (sodium adsorption ratio) had

incressed from 1.3 to about 2.4. The water had become im-

potable according to the U.S. Public Health Service standards

Contamination apparently is taking place only where the

production of brine with oil has continued for a relatively

long time, as in the vicinity of Hobbs and Monument. Anai-

yses of samples collected periodically from 1951 to 1957 from

a well in SWASWASWA sec. 31, T. 14 S., R. 37 E., and a well

in NW4NW4NW4 sec. 8, T. 15 S., R. 36 E, show little or no

change in the quality of water. There is little oil production

its inception unless water wells are located within a few hundred feet of the source of the contamination because of the

slow rate of movement of ground water in formations of Cen-

Further contamination of the potable ground-water sup-

that the brine does not seep downward.

(1) Line the disposal pits with impervious material so

(2) Return the brine to deep-lying formations either by

(3) Demineralize the brine. This method would signif.

using the brine to repressure oil pools or by using

icantly improve the water situation by removing

plies can be prevented by using any of the following methods

to deteriorate, it is usually too late for remedial measures.

wells solely for waste disposal.

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supplies of potable water.

Contamination may not be detected for many years after

Without exception, the water in the rocks of pre-Mesozoic

not have an undesirable taste or odor; a chemical analysis

Triassic rocks in the area has been analyzed.

Santa Fe or Albuquerque.

and water-flooding of oil and gas fields.

not considered suitable for irrigation.

in the vicinity of these two wells.

or a combination of the methods:

acre-feet of water were in storage in the aquifer at the end ozoic age. When the quality of the water from a well begins

p. 283-309, 3 figs. Survey Misc. Geol. Inv. Map 1-256. 1955, Map of New Mexico showing test wells for oil and gas, oil and gas fields, and pipelines: U.S. Geol. Survey Oil and

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and stock. The amount pumped each year is estimated by content than water from the younger rocks, and the water is Bretz, J. H., and Horberg, C. L., 1949, Caliche in southeastern

HYDROLOGIC INVESTIGATIONS

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cause of the relatively slight pumpage and average to aboveaverage precipitation. Above-average precipitation from January 1940 to January 1950, caused the water table to rise generally except in the vicinity of McDonald, Lovington, Humble City, and Hobbs where pumpage increased appreciably during 1947 to 1950 (fig. 4). During the period 1950-60 the water table declined over a much larger area than in the previous 10-year period because of increased pumpage and CENOZOIC AGE generally below average rainfall during that time. The

ments made mostly during 1952. A few measurements in Tos. 9 and 10 S., were made in later years; the data are comparable because the level of the water table in these wells has not changed appreciably for a number of years. The water table slopes generally toward the southeast at about 12 feet per mile, slightly less than the slope of the land surface. The irregularities in the surface of the water table are caused by differences in the permeability of the aquifer and heavy pumping in certain areas. Records of water levels in observation wells indicate that since 1929 the water table has fluctuated erratically in the east-central part of northern Lea County, but the overall trend during the period 1929-60 has been downward. The declines during the period 1929-40 were localized be-

THE WATER TABLE IN THE DEPOSITS OF CENOZOIC AGE

The shape and approximate altitude of the water table is

shown (fig. 2) by contour lines based on water-level measure-

The depth to water ranges from a little less than 12 feet in an area about 13 miles east of Caprock to almost 300 feet along the Mescalero Ridge northwest of Maljamar (fig. 5). When the Lea County Underground Water Basin was declared in 1931 it included an area of about 1,080 square miles where the depth to water was known to be generally 50 feet or less; by 1952 the area in which the depth to water was 50 feet or less ad been reduced about one-sixth. The saturated thickness of the deposits of Cenozoic age generally ranges from less than 25 feet to about 250 feet. The zone of saturation is thinnest in the northeast part of the county where the Ogallala formation is thin and is underlain by sediments of Cretaceous age. The thickest zone of satuest and where there has been little use of ground water. The zone of saturation locally has become progressvely thinner as water has been withdrawn for irrigation. The average thickness of the zone in the declared basin was about 100 feet in

greatest decline during the period 1950-60 was 31.7 feet about 14 miles northeast of Lovington. DEPTH TO WATER AND SATURATED THICKNESS OF THE DEPOSITS OF CENOZOIC AGE MOVEMENT OF GROUND WATER IN THE DEPOSITS OF

oral communication, 1960).

R. 38 E.

DISCHARGE OF GROUND WATER FROM THE DEPOSITS OF CENOZOIC AGE Ground water stored in the deposits of Cenozoic age is being

ment of ground water in the deposits of Cenozoic age is controlled by the gradient of the water table and the permeability of the materies in the zone of saturation. Variations in the spiration is relatively small because there are no large bodies grain size of the material, the degree of sorting of the deposits, and the extent of cementation of the material cause the rate table is shallow. of movement to vary from place to place. This is particularly true of the Ogaliala formation especially near the base where place only where the water table is within 10 feet of the land and gravel than through the surrounding beds of fine sand and clay. Data available indicate that the average rate of movement of ground water in the Ogallala formation is on

water table throughout most of the area. The rate of move- between the Ogallala formation and the rocks of Triassic age

the U.S. Geological Survey; and the data are published by the unsuitable for some uses. Water from aquifers of pre-Meso-New Mexico State Engineer. water moves more rapidly through stringers of coarse sand surface; such a condition prevails around the perennial lakes, ing the growing season of 1958, however, the amount of water berry and cottorwood trees are the principal users of ground as follows: sediment of Tertiary and Triassic age exposed in the escarpment of Mescalero Ridge in Tps. 11 and 12 S., R. 31 E., other

pumped for irrigation decreased to about 107,000 acre-feet; the use for other purposes remained about the same-- 19,000 The estimated amount of water pumped from the deposits of Cenozoic age for irrigation during the years of record was 95,000

RECHARGE OF GROUND WATER IN THE DEPOSITS

OF CENOZOIC AGE

The deposits of Cenozoic age are recharged chiefly by precip-

itation; in addition there is some recharge from subsurface

flow into the area from Chaves and Roosevelt Counties, from

irrigation return, and from seepage from brine disposal pits.

Recharge to the reservoir by the downward percolation of

water generally cannot take place where the land surjection.

underlain by a thick layer of caliche. Only where the when

is absent, relatively soft, broken by joints, or removed or dis-

turbed by man can water move downward to the water table.

The average annual recharge from precipitation to the zone

of saturation in the southern High Plains is between 'i- and

1/2-inch per year, depending on the amount of precipitation

(Theis, 1937). The area of northern Lea County is about

1,800,000 acres; therefore, the amount of annual recharge

probably varies between 38,000 and 75,000 acre-fect per year.

The area of the Lea County Underground Water Basin is

about 1,400,000 acres; therefore, the average annual recharge

to the declared basin is approximately 29,000 to 58,000 acre-

The greatest amount of recharge from precipitation occurs

The deposits of Cenozoic age receive a small amount of

recharge from surface inflow derived from precipitation that

falls on the Llano Estacado outside Lea County, but near its

northern boundary. The southeast-trending stream channels

carry some runoff into the northern part of the area where it is

caught in shallow closed depressions. Some of this water

reaches the water table by infiltration but most probably is

Ground water in the Ogallala formation in adjacent areas

in Roosevelt and Chaves Counties, New Mexico, flows in a

southeasterly direction and a small amount enters the area as

Some of the water pumped from the deposits of Cenozoic

age for irrigation, domestic, stock, municipal, and industrial

uses is not consumed but instead percolates back to the

aquifer. It may be called return discharge, but it does not

constitute an addition to the supply of water, rather, it repre-

Brine-disposal pits for oil-field water also are a source of

recharge. Data supplied by Alexander Nicholson, Jr., and

Alfred Clebsch, Jr. (1961, p. 102-103) indicate that about 96

percent of the brine discharged to disposal pits for evapora-

GROUND WATER IN STORAGE

where V is the quantity of water in storage. A is the surface

area of the aquifer, p is the porosity of aquifer, and it is the

saturated thickness of the aquifer. The area (A) of the Lea

County Underground Water Basin is about 1,400,000 acres;

the average porosity (p) is about 35 percent; and in 1952, the

saturated thickness (m) averaged about 100 feet. On the

basis of the above figures, it is estimated that about 49,000

of 1952. However, not all of the water in storage in the

reservoir can be recovered for large scale irrigation develop-

ment because of two principal factors. First, it usually is not

economically feasible to pump large quantities of water in

areas where the zone of saturation is or becomes less than 30

feet in thickness. Thus, on the average, only the water in the

upper 70 feet of the reservoir can be considered as available

for large scale pumping. Secondly, much of the water will

be retained by adhesion on the surfaces of the grains which

make up the reservoir. The yield of water from the sedi-

ments is estimated to be 0.2 of the volume of saturated sedi-

ment. Thus about 40 percent of the total amount of water

in storage in the deposits of Cenozoic age in the northern Lea

County Underground Water Basin can be recovered for large-

scale irrigation, or about 20,000,000 acre-feet. If ground

water pumping was distributed evenly throughout the Basin.

the amount in storage would last approximately 100 years at

the present rate of use. But some of the water underlies

areas that are unsuited for farming and will not be used for

this purpose while in other areas the supply will be exhausted

in 40 years or less, from 1952, because of extensive local

Probably enough water for domestic and municipal uses

will be available in the reservoir for a considerable length of

time after water is no longer available for large-scale irriga-

CHEMICAL QUALITY OF THE WATER

Ground water in the deposits of Cenozoic age is suitable for

most uses. Water from the Triassic and Cretaceous forma-

tions generally is harder and has a higher dissolved solids

Cenozoic age can be estimated by using the formula

The total quantity of water in storage in the deposits of

in the areas covered by dune sand, and in those areas where

the shallow closed depressions are most numerous.

lost by evaporation and transpiration.

underflow along its northern boundary.

sents a decrease in the net discharge.

tion instead sceps to the water table.

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V.S.M.C.F. MICROGRAPHICS

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CONTROL OF METERS OF THE STATE OF THE STATE

PREPARED IN COOPERATION WITH THE NEW MEXICO STATE ENGINEER

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FIGURE 3.—SECTION ALONG A-A' FROM MESCALERO RIDGE TO THE NEW MEXICO-TEXAS STATE LINE IN NORTHERN LEA COUNTY, NEW MEXICO

HYDROLOGIC INVESTIGATIONS ATLAS HA-62 (SHEET 1 OF 2)

tion. The loam strips are surrounded, in most places, by unton (Harper and Smith, 1935). The cause of the lineation is soil strips suggest that the lineation may be related to streams at the margins as the water flows to the depressions; only very fine materials can be carried by the weak currents in the ephemeral lakes.

the ground-water supply is considered to be fully appropriated. The climate of northern Lea County is semiarid; the hu-In these areas the users of ground water for irrigation can expect about 40 years of supply at the rate of use in 1953 and extending from that date unless additional supplies are discovered in deeper water-bearing formations. Beyond such a period there will remain in storage sufficient water for stock and municipal use and, to some extent, water for industrial use for many years to come. In other parts of the de-The purpose of this atlas is to make available in convenient form information on the ground-water reservoir in northern Lea County, New Mexico, an area dependent chiefly on ground water for its water supply. The atlas shows by means of

maps the saturated thickness of the principal ground-water reservoir and indirectly the volume of water in storage in northern Lea County. Other maps show the depth to water and areas in which water levels have declined in the past several years. The atlas was prepared as a part of the general program of ground-water investigations being made by the U.S. Geological Survey in cooperation with the State Engineer Office of New Mexico. The information contained in the atlas should lead to a better understanding of the availability of water in this important part of the State. LOCATION AND EXTENT OF THE AREA The area described contains about 2,900 square miles in southeastern New Mexico and includes northern Lea County. and small parts of Chaves and Eddy Counties (fig. 1). The area is bounded on the east by the New Mexico-Texas State line, on the north by the Chaves and Rossevelt County lines, and on the west and south by the Mescalero Ridge. The economy of northern Lea County has changed gradu-

Generalized reports on the geology of the area have been made in connection with regional investigations concerned primarily with the oil- and gas-producing formations of Paleozoic age; few data have been published on the younger recks that contain potable ground water. Selected references pertaining to the geology and hydrology of Lea County are listed at the end of this text. A network of observation wells has been maintained on a continuing basis for a number of years by the Geological Survey in cooperation with the State Engineer Office Related data such as the amount of water withdrawn from the reservoir have also been collected and published in U.S. Geological Survey Water-Supply Papers and the Technical Report series of the New Mexico State Engineer Office.

PREVIOUS WORK

Northern Lea County, New Mexico, is dependent chiefly

on ground water for its water supply. It also is one of many

areas in New Mexico in which ground water is being mined:

that is, more water is being withdrawn from the ground-water reservoir both by natural means and by pumping for irrigation.

municipal, stock, and industrial use than is being recharged to the reservoir. The magnitude of the pumping and the volume

of the water in storage are such that in places the depletion of

the reservoir may be measured in a few tens of years on the

County Underground Water Basin in 1931 subject to regula-

tion of the development of water in this area. New Mexico

water policy is based on the philosophy that the withdrawal

of water from an area of ground-water mining should be lim-

ited to a rate that will permit amortization of the investment

in farms irrigated with ground water over a period of 40 years

(Reynolds, 1960, p. 233-234). In parts of northern Lea County,

clared basin water was still unappropriated in 1960

PURPOSE AND SCOPE

The State Engineer of New Mexico declared the Lea-

basis of the rate of use of water in 1953.

This atlas is an outgrowth of work begun in 1952 to define the thickness of the zone of saturation in the water-bearing materials of the Ogallala formation, the principal aquifer in northern Lea County. Control for thickness of the Ogallala formation was obtained from logs of about 6,000 holes, most of which were shotholes drilled by various oil companies. and geophysical companies in exploration for oil. The author gratefully acknowledges the assistance given the Geological Survey by oil and exploration companies and by personnel of the State Engineer Office who tabulated most of the well logs.

GEOGRAPHY

ACKNOWLEDGEMENTS

TOPOGRAPHY AND DRAINAGE Northern Lea County is on the west side of the Llano Estacado, which is the southern extension of the High Plains in southeastern New Mexico and western Texas (fig. 1) (Fenneman, 1931, p. 9). The Llano Estacado, or southern High Plains, is a plateau which stands about 100 to 300 feet above the surrounding region (fig. 2). The general surface of the Llano is smooth and slopes to the southeast at 10 to 20 feet per mile into Texas. The Mescalero Ridge (figs. 1 and 2) forms the western and southwestern boundary of the Llano Estacado and is the boundary between the High Plains and Peccs Valley sections of the Great Plains Province (Fenneman, 1931, p. 9). The name Mescalero Ridge is a misnomer as this feature actually is an escarpment that faces the Pecos Valley. The steep front along the ridge from T. 9 S. to End Point in T. 19 S. is broken by broad reentrants, such as Sand Gate in the northwest part of the area, and narrow reentrants such as Polecat Canyon in the southern part of T. 10 S., R. 31 E., through which U. S. Highway 380 passes from the Pecos River Valley onto the Llano Estacado. Shallow closed depressions, sometimes called buffalo wallows, are the most characteristic minor topographic features on the Llano Estacado. The floors of the depressions generally range in area from 1 to 150 acres; the average size is probably about I acre. The depth of the depressions generally ranges from 1 to 50 feet. Some of the depressions have been scaled or dammed by ranchers for use as tanks for watering livestock. Some of the depressions contain perennial lakes, but most of them contain water only during the summer rainy The drainage on the Liano Estacado generally is not integrated; a few of the depressions, however, are connected by

shallow and superficial drainage ways. Drainage into the depressions is mainly from the northwest. Much of the runoff from precipitation is caught in the depressions, where the water remains until it infiltrates, is lost by evaporation, or is consumed by plants. The only semblance of through drainage is a shallow broad swale called Simanola Valley, which originates east of Sand Gate and terminates a few miles northwest of Tatum. Six perennial lakes occur in the northern part of the area. The two largest are Lane Salt Lake (T. 10 S., R. 33 E.) 7 miles northeast of Caprock, and Ranger Lake (T. 11 S., R. 36 E.) 8 miles north of Tatum. Four Lakes (T. 11 S., R. 34 E.) is the collective name for the four small lakes about 12 miles northwest of Tatum. For the purpose of this report, however, they will be referred to individually as North Lake, East Lake, Middle Lake, and South Lake (fig. 2). Springs and seeps are present in the beds or on the margins of several of the lakes. North Lake has several islands on which seeps are found. Water in all the perennial lakes is

ground inflow. The soils in northern Lea County include loam, sandy loam.

brackish and is derived from both surface runoff and under-

cultivated scabland or by sand hills. The scabland is chiefly thin, rocky loam, and the sand hills are chiefly sandy loams. The sand hills, like the loams, occur in long narrow strips. The northwest-southeast lineation of the soils and sand hills is well illustrated on the soil map of the area around Lovingunknown; however, the trend, thickness, and location of the of Pertiary age which originated to the west and flowed southeastward at the time the Ogallala formation was being deposited. The lineation may also be related to older sand-dune patterns developed from prevailing southwesterly winds. Generally, only clay is found on the floors of the shallow closed depressions because the coarser materials are deposited

midity is low, the rate of evaporation is high, and the mean annual temperature is about 60°F. The average annual precipitation at Tatum is 16.20 inches, at Lovington 14.82 inches, and at Hobbs 15.26 inches. More than two-thirds of the annual precipitation falls during the growing season, which lasts from April through September. At Hobbs and Lovington the average number of frost-free days per year is 206 and at Tatum is 193 days per year. The average date of the last killing frost at Lovington is April 11 and the first killing frost is November 3. Climatological data, from records of the United States Weather Bureau (1953-59) are summarized in the following table for three stations in northern loa

ally in the period 1929-60 from one based predominantly on stock raising and dry farming to one based on irrigated farming and the production of oil and gas. Prior to 1929 most of the farmers in northern Lea County relied on precipitation for their crops. The general use of ground water for irrigation began during the drought of the early thirties; however, until 1946, irrigation was limited principally to small tracts in the vicinity of Lovington and Hobbs. The amount of irrigated acreage began to increase rapidly in 1946 and by 1954 nearly 93,000 acres were under rrigation; after 1954 the expansion continued but at a much Most of the irrigated acreage (fig. 2) is between Tatum on the north, Hobbs on the south, the Texas border on the east,

and an irregular northward-trending line about 15 miles west of Tatum and Lovington. In 1954 about 66 percent of the rrigated land was used to grow cotton, sorghum, and alfalfa; about 31 percent was used to raise vegetables, fruits, berries, oats, and wheat; and about 3 percent was devoted to pasture. The Lea County Underground Water Basin (fig. 2), as redefined by the New Mexico State Engineer in 1952, is included in the northern Lea County area. Drilling for water in the declared basin is controlled by the New Mexico State Engineer so that the ground water can be conserved and the rights of prior users will be preserved to the extent possible. If the State Engineer determines that additional wells may seriously deplete the supply of water, he can close part or all of the basin to further appropriation of water.

The basin was declared under regulation by order of the State Engineer in 1931, but the amount of water pumped in the basin remained so small that it was not closed to further appropriation of ground water until December 31, 1948. The State Engineer extended the area of the basin October 1, 1952. Some parts were reopened to further appropriation on December 31, 1952 and on February 2, 1953. At present the leclared basin includes an area of about 2,180 square miles. About two-thirds of the cattle and almost all the other livestock in Lea County are raised in northern Lea County. Between 1929 and 1949 the value of all livestock and livestock products sold annually more than doubled. Since 1949, however, sales have steadily declined. The decline has been attributed to the redirection of effort from grazing management to farming and to the production of petroleum products. The oil and gas industry, expanding rapidly since 1944, has become the most important segment of the northern Lea County economy. Between 1926, when the first oil well in Lea County was drilled near Maljamar, and January 1, 1955 when about 3,000 wells were in operation, more than 568 million barrels of oil and mere than 939 million cubic feet of natural gas has been produced. Local plants during 1951 proluced about 112 million barrels of butane and propane, 114 million barrels of gasoline, and 22 million pounds of carbon black from natural gas produced in southeastern New Mexico.

GEOLOGY AND GROUND WATER Rocks of Precambrian through Cenozoic age underlie northern Les County; however, only rocks of Mesozoic and Cenozoic age crop out in the area and only they are known to contain potable ground water. The Ogallala formation is the principle source of ground water in northern Lea County. The deposits of Quaternary age and the underlying rocks of Cretaceous and Triassic age generally yield only small amounts of water. Most of the sediments of pre-Mesozoic age centain brackish and saline water. ROCKS OF PRE-MESOZOIC AGE

Granite and volcanic rocks of Precambrian age underlie

the area at depths which range from 11,000 feet in the north-

western part to about 14,000 feet in the southeastern part (Flawn, 1956, p. 68, pl. 2). Ground water has not been reported in the rocks of Precambrian age and probably little occurs in them. The rocks of Precambrian age are overlain unconformably (Barnes, and others, 1959, p. 25-26) by approximately 3,000 to 6,000 feet of limestone, dolomite, shale, and sandstone of Early Ordovician through Pennsylvanian age. Overlying the Pennsylvanian rocks are 8,000 feet of Permian rocksabout 5,000 feet of dolomite and limestone containing a small proportion of shale and sandstone, and about 3,000 feet of salt and anhydrite. In general, water in the rocks of Paleozoic age contains a large amount of dissolved solids and occurs with oil and gas. Water discharges from the formations of Paleozoic age in two ways-produced with oil and as subsurface flow out of the area. The amount of subsurface flow is unknown, but

with oil from these formations was about 1,900 acre-feet in

1952 and approximately 2,400 acre-feet in 1954. By the end

of 1954 about 20,500 acre-feet of water had been produced. from 2,800 wells drilled since the start of oil production. Some wells did not yield any water while others produced several times the annual average of 7.35 acre-feet of water per well. A source of recharge is the brine pumped from wells in Lea County into other wells which are bottomed in rocks of pre-Mesozoic age. In some cases this type of recharge is used primarily to repressure oil pools which thereby increases the recovery of oil and gas from the reservoir. In other cases the primary consideration is the removal of the fresh-water contamination hazard. In Lea County only a small proportion of the oil-field brines is currently (1960) artificially recharged to the rocks of pre-Mesozoic age. ROCKS OF MESOZOIC AGE

Rocks of Mesozoic age in northern Lea County range in

thickness from 1.400 to 2.100 feet and consist of shale and

sandstone of Triassic age and siltstone and limestone of Cre-

The Dockum group in northern Lea County comprises an

The amount of water produced from rocks of Triassic and Cretaceous ages is small, but the small production does not necessarily indicate that the quantity available is insignificant. The meager production may be due in part to the general lack of exploration and development. Rocks of Mesozoic age have been penetrated by only a few water wells most of which: are in the northern third of the area where the Ogallala formation is relatively thin and contains little water. Rocks of Triassic age, -Rocks of the Dockum group of Triassic age unconformably overlie rocks of Permian age and range in thicknes from 1,400 to 2,000 feet (Nyc, 1980, p. 370). The Dockum group underlies the entire area, but it is exposed only along the escarpment of the Mescalero Ridge from the southern part of T. 10 S., R. 31 E., to the northern part of T. 14 S., R. 31 E.

> upper part and a lower part that are distinctive but which grade into one another. The lower part of the group has a maximum thickness of 600 feet and consists mostly of reddish sandstone but includes a relatively small proportion of variegated shale and limestone. The upper part of the group has a maximum thickness of about 1,200 feet. This part is predominantly a reddish shale but includes minor amounts of varicgated shale, sandstone, conglomerate, and limestone (Adams, 1929, p. 1051; Nye, 1932, p. 237-238). Approximately 165 feet of the Dockum group is exposed in the SW4 sec. 3, T. 11 S., R. 31 E. (Nye, 1932, p. 236). The lower 40 feet of the exposure consists of light-greenish-gray to grayish-green shaly sandstone that contains thin beds of chocolate-colored and greenish-colored shale and grit made up of shale pellets. Overlying the shaly sandstone is 30 feet of light-green and chocolate-colored sandy shale that includes thin beds of micaceous shaly sandstone. The sandy shale is overlain by 90 feet of poorly exposed chocolate-colored to reddish-brown shale that contains some green shale. Silicified wood is the only fossil material reported found in the Dockum group in this area (Nye, 1932, p. 237). The rocks of Triassic age usually can be distinguished from rocks of Permian age by the difference in color—the shale of Triassic age is deep purplish to brownish red while that of Permian age is generally brick red—and by the presence of mica flakes in the rocks of Triassic age. The rocks of Triassic age contain some water but they are not considered to highly productive aquifers. Seven wells in

tap the Dockum group and it is possible that more water could be developed in the rocks of Triassic age in northern Rocks of Cretacrous age. - The Tocumeari shale of Cretaceous age unconformably overlies the Dockum group in the northeastern part of Lea County. A few shot-hole logs from south of Lovington record gray, blue, yellow, and green shale. which may be Cretaceous in age as reported by Bates (1942, The fossils listed below, which were collected at North Lake in sec. 32, T. 10 S., R. 34 E., were identified: Serpula? sp., Gryphaen corrugato Say, Erogyra texana Roemer, Erogyra plexa Cragin, Preten (Neithea) texanus Roemer?, and Plientula of incongrue Conrad. The fossils indicate that the enclosing rocks are of Early Cretaceous age and probably are equivalent. to the Tucumcari shale. The Tucumcieri shale generally consists of fessiliferous dark gray siltstone and thin heds of brownish sandy limestone,

northern Lea County obtain water from the upper part of the

Deckum group. Several wells in southern Lea County also

grayish limestone and sandstone. In outcrops the siltstone beds weather to yellow and the sandy limestone teds usually have the appearance of yellowish sandstone because weathering dissolves the calcium carbonate from around the sand The Tucumcari shale is about 150 feet thick in the northeast corner of Lea County but it thins southwestward and pinches out along an irregular line extending from T.9 S., L 33 E., to T. 14 S., R. 38 E. The Tucumcari shale crops out along the western and northern edges of North Lake, and, reportedly, along the eastern edge of Ranger Lake (Conover and Akin, 1912, p. 295) and along the northwestern part of Middle Lake (Dane and Bachman, 1958). The greatest observed thickness of the Tucumcari shale is in a gully on the west side of North Lake where a composite section approximately 17 feef thick was measured. The Tucumcari at the exposure consists of dark gray siltstone and thin interbedded stringers of limestone. several of the stringers wedge out laterally into siltstone. In the lower part the stringers are light brown, sandy, crystalline limestone; in the upper part they are light gray and fine grained. Here the contact between the Tucumcari shale and the overlying alluvium is exposed and is unconformable.

Limited quantities of ground water occur in the Tucumcari shale. Beds of sandstone near the base of the formation constitute the principal squifer. Water is pumped from several wells which penetrate the rocks of Cretaceous age. At one time some of the water in these rocks was under sufficient artesian pressure to flow at land surface, but since 1940 all the artesian wells in the area. have gradually cessed to flow. Well owners generally attribute the cossation of flow to the widespread drilling of shotholes for seismic surveys. The shotholes penetrated the water-bearing stratum and since the holes were not cased the artesian water leaked into the overlying Ogallala formation and dissipated the hydraulic pressure. The characteristics of a well in the SW4 sec. 20, T. 12 S., R. 37 E., which produces water from rocks of Cretaceous age have been studied by the U.S. Geological Survey (Conover and Akin, 1942). The well was completed in 1940 at a total depth of 185 feet. Sediments of Cretaceous age were penetrated from 25 feet below land surface to the bottom of the well, and artesian water was found in a bed of sand at a depth of 188 to 185 feet. The well flowed about 25 gpm (gallons per minute) when first drilled and had a static head of about 14 feet above

Fragments of Lower Cretaccous fessils and of the Tucumenri

shale were noted in the alluvium at this outcrop.

DEPOSITS OF CENOZOIC AGE Deposits of Cenozoic age in northern Lea County range in thickness from 0 to \$50 feet and consist of continental deposits of Pliocene age and sand and alluvium of Pleistocene and Posser sees. The Congraic formations crop out over most of age was cut on rocks of Mesozoic age. The slope of the sur-

land surface; reportedly, flow ceased about 1946.

face is generally southeastward and the relief is moderate (figs. 2 and 3). Two cycles of emsion of the bedrock surface are indicated by the contour map. Stream channels found beneath the Ogaliala formation of Pliocene age trend southeastward and probably were cut after the close of the Mesoroic era. Stream channels beneath the alluvium south of Mescalero Ridge trend in a southwestward direction and were cut during the Cenozoic era after the Ogallala formation had been removed by erosion.

The Ogallala formation of Pliocene age lies unconformably upon rocks of Mesozoic age. The formation underlies the Llano Estacado everywhere except for a few small areas where it has been removed by erosion. The Ogallala ranges in thickness from 0 to about 350 feet and averages approximately 200 feet. It is thickest near the Mescalero Ridge in Tps. 14 and 15 S., Rs. 31 and 32 E. 11 ranges in thickness from about 75 to 225 feet in the vicinity of Lovington and McDonald where it averages about 150 feet. Most of the variation in thickness is due to irregularities of the surface of the Mesozoic rocks on which the Ogallala was deposited rather than to post-Ogallala erosion (Nye, 1980,

The Ogaliala consists mostly of fine to very-fine sand but includes minor quantities of clay, silt, coarse sand, and gravel, The lower one-third of the Ogallala contains a higher proportion of coarse sediments than the upper two-thirds. Usually the coarse sediments occur as lenticular beds in the finer material. Extensive beds of coarse sand and gravel are found in some of the buried stream channels cut into the Mesozoic Most of the formation is unconsolidated, although near the top and locally within it the sediments have been comented by calcium carbonate to form beds of valiche. The degree of cementation of the caliche varies greatly. However, in general the Ogallala is most firmly comented near the top of the formation and where the sediments are fine and contain much silt (Nye, 1932, p. 235). The bed of caliche at the top of the formation forms topographic prominences because of its resistance to erosion. It generally occurs at the top of most plateaus in the southern High Plains and is usually called the cap rock. There is no sharp break between the caliche cap rock and the underlying sediments because the amount of tementation decreases gradually downward. In some places the cap rock is so dease that it breaks with a semiconchoidal fracture; elsewhere it may be soft and chalk like. Usually it is not stratified or bedded, but locally it is flaggy and is used as a building material. The partially cemented material beneath the cap rock is used extensively as road metal, particularly in the oil and

gas fields. Sand and gravel from the Ogallala formation are

The following stratigraphic section, measured by the author

and Alfred Cleasch, Jr., shows the general character of the

Section of the Opallala formation on the south ride of U.S. Highway 21.

used in construction and road building.

upper part of the Ogallala formation:

in SEA sec 21, T. 15 S. R 30 E. Caliche, hard, weathers to knobby slope: Sand, brown, fine-grained, locally well cemented with caliche. Forms sertical cliffs Sand, brown, fine-project, moderately comented with coliche near top; grades into overlying unit, contains pendants of calche. Forms Sand, brown, fine-grained, poorly comerced ... Sand, brown, fine-grained, well communed, contains vertical joints filled with caliche. Forms Sand, brown, fine-grained, sightly comented . . Sand, brown, fine-grained, contains (regularly) distributed biobs of entotes massive Sand, brown, fine-grained, contains vertical joints filled with exhelic, massive Sand, teorem, Carrettained, poorly remented, con tains several thin discontinuous moderately remented beds . Sand, brown, fine-grained, moderately cereer ted, rase hardened on weathered suface. Forms Sand, brown, time-grained, poorly consented Sand, brown, fine-grained, slightly comented. 9.1-15 Sand, brown, fine-grained, poorly comented in lower half, moderately equential in upper

Sand, brown, fine-grained, poorly comented.

Base of section covered

Total section exponed

Sand, soil, and alluvium of Pleistocene and Recent age unconformably overfie the Ogallala formation on the Liano Estacado and the Pockum group west and south of Mescalero Ridge. The thickness of the sestiments ranges from 0 to about 30 fixt on the Liano and from 0 to about 40 feet on rocks of the Dockum group. The material overlying the Ogailals formation is off-white to light brown and was derived from the Ogallala on the Liane, the material overlying the Deckum group is mostly red because it was derived from the red beds The Ogailala formation of Pliocene age and the alluvium, soil, and sand of Pleistocene and Recent ages form a singlehydrologic unit and in this atlas their hydrologic characteristies will be discussed together. Ground water in the formations of Cenozeic age is unconfined and occurs mainly in the unconsolidated or poorly consolidated sand and gravel of the Ogalizla formation beneath the caliche cap rock. The water-bearing properties of the formation vary vertically and horizontally. The vertical variation is due chiefly to the amount of calcium carbonate cement in the Ogailaia. As a rule, the amount of calcium carbonate cement decreases dewnward and is practically negligible at depths of 35 to 50 feet below the surface. This perosity and permeability increase downward as the comentation decreases. Lateral variations in the water-bearing properties of the sand and gravel below the zones of comentation are the result of variations in the coarseness and degree of sorting of the particles. The yield of wells, or the amount of water pumped in galions per minute, ranges widely throughout the area. The maximum yield recorded in normal operation of the pumps in 1953 was about 1,700 gpm. Some wells used for irrigation pump as little as 200 gpm but wells yielding less than about 300 gpm are generally considered unsatisfactory for unigation use. The yields of wells differ greatly in relatively short distances and may be attributed to formation differences or differences in well construction. The law yield in some wells may be due in part to poor development or construction of these wells, inasmuch as wells of higher yield have been developed nearby. Perched ground water is found in beds of caliebe that have a honeycomb-like structure. These beds have bedding planes

Irrigation wells tap the alluvium in the area south of the Mescalero Ridge in the vicinity of Nadine and Monument. Stock wells have been constructed in the alluvium at Sand-Gate, but no large-production wells have been drilled, so the potential of the aquifer there is unknown. Generally the alluvium on the Liano is above the water table although perched ground water could occur in those places where the alluvium is relatively thick and overlies an impervious section of

The sale of the Bookskin of they true \$1.00 to to

enlarged by solution and are locally referred to as "honey-

combed rock" or "water rock" (Nye, 1930, p. 372). The quan-

tity of ground water derived from this type of reservoir is

GROUND-WATER CONDITIONS IN NORTHERN LEA COUNTY, NEW MEXICO

the High Plain

IGURE I.—INDEX MAP SHOWING THE LOCATION OF THE NORTHERN

HYDROLOGIC INVESTIGATIONS ATLAS HA-62 (SHEET 1 OF 2)



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