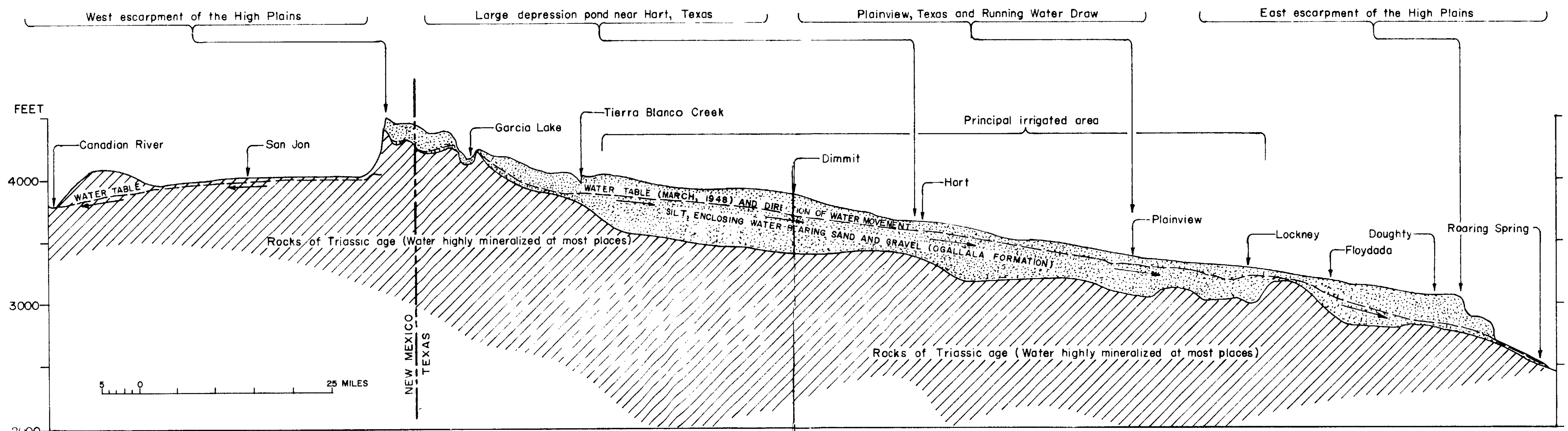


FIGURE 6.8. Crosssection southeastward across the Llano Estacado, New Mexico-Texas *

The dominant water-bearing formation, the Ogallala formation, is a completely isolated reservoir—it terminates at an escarpment on all sides and it is underlain by relatively impermeable rocks (chiefly of Triassic age).

* Copied from pages 100 and 101, "High Plains, or Llano Estacado, Texas-New Mexico" by Carl Gaum; The Physical and Economic Foundation of Natural Resources, Vol. 4, Subsurface Facilities of Water Management and Patterns of Supply -- Type Area Studies.

NO. 31.210. ONE DAY BY HOURS (DIVIDED INTO QUARTERS) X 100 DIVISIONS. CODEX BOOK COMPANY, INC., NORWOOD, MASSACHUSETTS. PRINTED IN U.S.A.

EXHIBIT #1 - CASE 1635
BEFORE THE OIL CONSERVATION COMMISSION, REGULAR HEARING MAY 13, 1959

PRODUCTION DECLINE CURVE - PROJECTED TO ABANDONMENT - MAPENZA OIL COMPANY STANOLIND STATE #1-A
HOBBS POOL, LEA COUNTY, NEW MEXICO

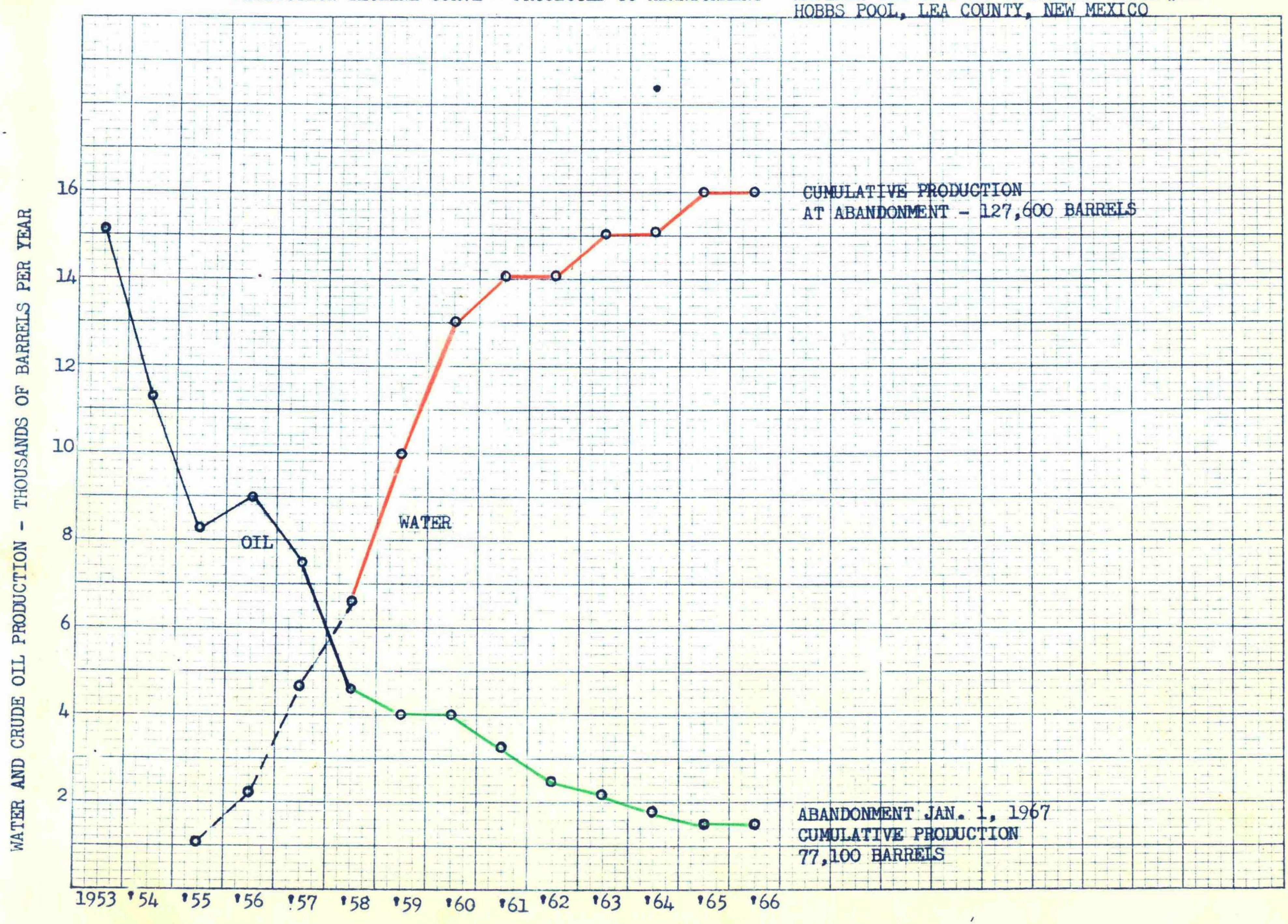


EXHIBIT #1-A - CASE 1635
BEFORE THE OIL CONSERVATION COMMISSION, REGULAR HEARING MAY 13, 1959

PRODUCTION STATISTICS RELATING TO EXHIBIT #1 - PRODUCTION DECLINE CURVE

YEAR	BARRELS OIL	BARRELS WATER
Cumulative to 3-1-59	56,300	14,600
Balance 1959	4,000	10,000
1960	4,000	13,000
1961	3,300	14,000
1962	2,500	14,000
1963	2,200	15,000
1964	1,800	15,000
1965	1,500	16,000
1966	1,500	16,000
Totals To Depletion	77,100	127,600

EXHIBIT #2 - CASE 1635
BEFORE THE OIL CONSERVATION COMMISSION, REGULAR HEARING MAY 13, 1959

MAXIMUM CONTAMINATION
(If All Water Produced is Placed in 40 Acres of Fresh Water Zone)

RECOVERABLE WATER RESERVE

40 Acres x 50' Net Sand = 2,000 Acre Feet Sand

2,000 Acre Feet x 30% Porosity = 600 Acre Feet Water

600 Acre Feet x 7,760 Barrels/Acre Foot - 4,656,000 Barrels Recoverable Water of 90 ppm Chloride Content

HOBBS FIELD WATER TO BE PRODUCED TO DEPLETION

Produced to April 1, 1959	14,600 Barrels
To be Produced to January 1, 1967	113,000
Total placed in Pit, with 5,000 ppm Chloride Content	127,600 Barrels (16.4 Acre Feet of Water)

RESULTANT CONTAMINATION

127,600 x 5,000	=	638,000,000	
4,656,000 x 90	=	419,040,000	
4,783,600 Barrels Total Water		1,057,040,000	ppm Chloride Content

Resultant ppm Chloride in Reservoir - $\frac{1,057,040,000}{4,783,600}$ = 221 ppm *

* 250 ppm is accepted by all authorities as approved potable water.

EXHIBIT #3 - CASE 1635
BEFORE THE OIL CONSERVATION COMMISSION, REGULAR HEARING MAY 13, 1959

CONTAMINATION LESS OVERBURDEN CAPACITY

30' Surface Overburden x 40 Acres = 1,200 Acre Feet

1,200 Acre Feet x 10% Porosity = 120 Acre Feet Necessary to Fill Before Water Reservoir is Reached

IF ONLY 5 ACRES IS WET (UNDER 467' SQUARE) BY PERCULATION, THEN VIRTUALLY ALL 16.4 ACRE FEET OF HOBBS FIELD WATER IS CONTAINED IN THE OVERBURDEN - AND <u>NO</u> CONTAMINANT REACHES THE FRESH WATER.

EXHIBIT #4 - CASE 1635
BEFORE THE OIL CONSERVATION COMMISSION, REGULAR HEARING MAY 13, 1959

EXPECTED LOSS OF REVENUE TO STATE OF NEW MEXICO AND ITS AGENCIES
IF PREMATURE ABANDONMENT IS MADE

20,800 Barrels Oil (See Exhibit #1 and #1-A)

2,600 Barrels (1/8th) are State Royalty at $2.70

$ 7,020 - Loss to: Blind Asylum - 1/2 at $3,510
Deaf & Dumb School - 1/2 at $3,510

2,280 - Loss to State from Production Taxes
@ 4.64% of (20,800 - 2,600) Barrels x $2.70

$ 9,300 - Total Loss to State and Agencies

EXHIBIT #5 - CASE 1635
BEFORE THE OIL CONSERVATION COMMISSION, HEARING ON MAY 13, 1959

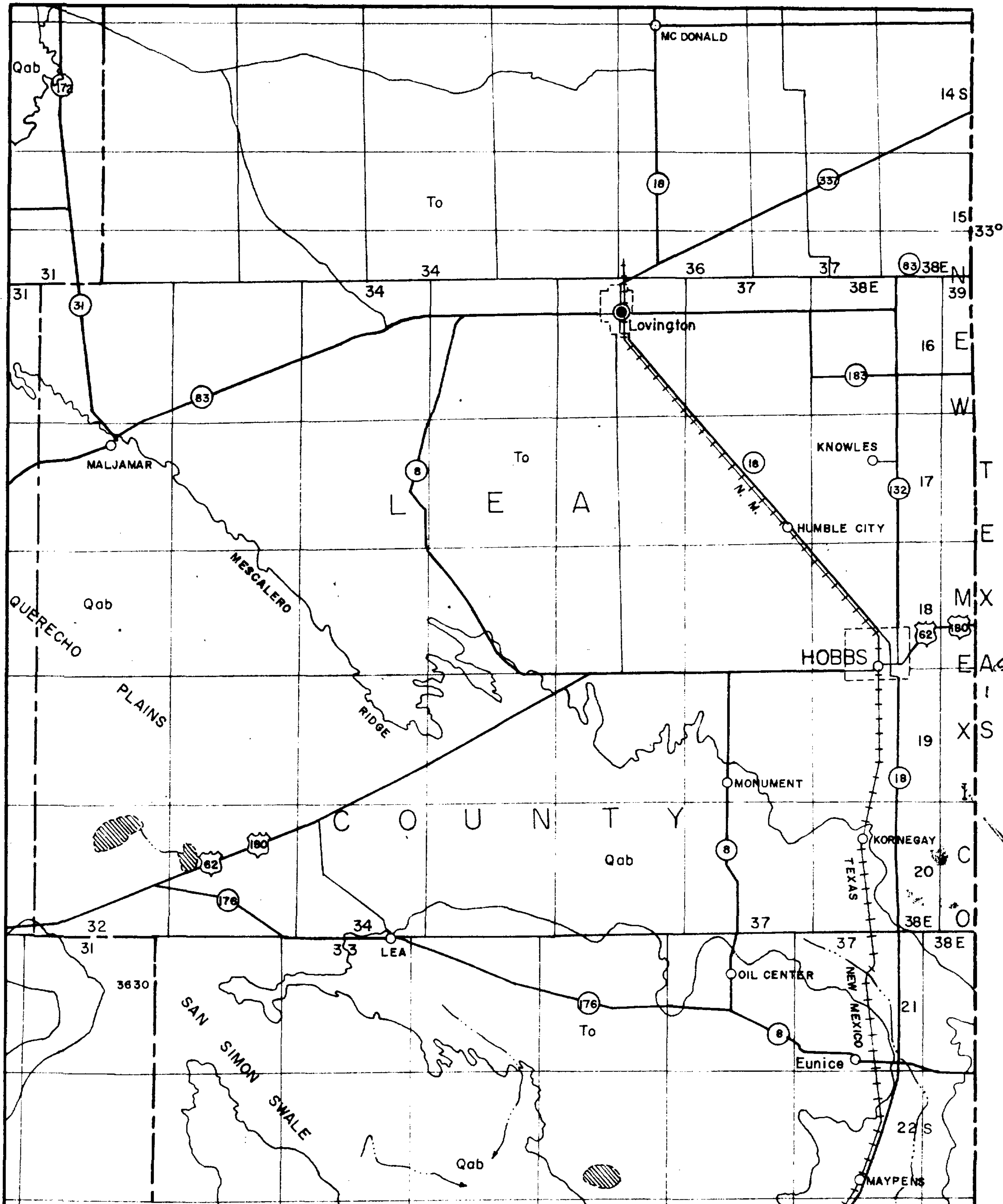
ECONOMIC ANALYSIS
PRESENT WORTH OF FUTURE NET REVENUE
(PARTICIPATING IN SALT WATER DISPOSAL SYSTEM)

	BALANCE 1959	1960	1961	1962	1963	1964	1965	1966	TOTAL
Projected Production - Barrels	4,000	4,000	3,300	2,500	2,200	1,800	1,500	1,500	20,800
Gross Value at $2.70	$10,800	$10,800	$ 8,910	$ 6,750	$ 5,940	$ 4,860	$ 4,050	$ 4,050	$56,160
Less:									
1/8th Royalty To State	1,350	1,350	1,114	844	743	608	506	506	7,021
1/16th ORR	675	675	557	422	371	304	253	253	3,510
Mapenza Gross Revenue	$ 8,775	$ 8,775	$ 7,239	$ 5,484	$ 4,826	$ 3,948	$ 3,291	$ 3,291	$45,629
Less:									
N.M. Production Taxes at 4.64%	407	407	336	254	224	183	153	153	2,117
Lea Co. Semi-Annual Production Tax @ 2%	176	176	145	110	96	79	66	66	914
Lea Co. Property Tax @ $60	60	60	60	60	60	60	60	60	480
Mapenza Gross After Above Taxes	$ 8,132	$ 8,132	$ 6,698	$ 5,060	$ 4,446	$ 3,626	$ 3,012	$ 3,012	$42,118
Less Lifting Costs As Follows:									
Labor	350	600	600	600	600	600	600	600	4,550
Overhead & Supervision	245	420	420	420	420	420	420	420	3,185
Power Bill	350	600	600	600	600	600	600	600	4,550
Oil & Water Chemicals	105	180	180	180	180	180	180	180	1,365
Rod Jobs & Pump Repair	231	396	396	396	396	396	396	396	3,003
Total Lifting Costs	1,281	2,196	2,196	2,196	2,196	2,196	2,196	2,196	16,653
Mapenza Net Revenue Subject to Salt Water Disposal Costs	$ 6,851	$ 5,936	$ 4,502	$ 2,864	$ 2,250	$ 1,430	$ 816	$ 816	$25,465
Salt Water Disposal Costs	4,000	200	500	250	250	800	300	300	6,600
Replacement of Equipment	-	3,000	-	3,000	-	-	-	-	6,000
Mapenza Net Revenue Subject to Federal Income Tax	$ 2,851	$ 2,736	$ 4,002	$ (-386)	$ 2,000	$ 630	$ 516	$ 516	$12,865
Federal Income Tax	428	410	600	-	300	95	77	77	1,987
Mapenza Net Revenue	$ 2,423	$ 2,326	$ 3,402	$ (-386)	$ 1,700	$ 535	$ 439	$ 439	$10,878
Present Worth Factor @ 6% Discount Compounded Annually	.967	.890	.840	.792	.747	.705	.665	.627	-
Mapenza Present Worth of Future Net Revenue	$ 2,343	$ 2,070	$ 2,858	$ (-386)	$ 1,270	$ 377	$ 292	$ 275	$ 9,099
Plus Salvage Value									1,540
Mapenza Present Worth of Future Net Revenue & Salvage									$10,639

EXHIBIT #5-A - CASE 1635
BEFORE THE OIL CONSERVATION COMMISSION, REGULAR HEARING MAY 13, 1959

ECONOMIC LIMIT OF PRODUCTION

90 BOPMo. @ $2.70		$243
Less 3/16th Royalty		46
		197
Less 4.64% Production Tax		9
		188
Less Lea County Property Tax		5
		$183
Less Lifting Costs:		
Labor	$ 50	
Overhead, Supervision	35	
Power Bill	50	
Oil & Water Chemical	15	
Rod Jobs & Pump Repair	33	
		183
Net Revenue Per Month		$000



taken from Preliminary Geologic Map of
the Southeastern Part of New Mexico
1958

BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng EXHIBIT No. 1
CASE 1635

B ... OIL C ... SSION
SA... MEXICO
State Eng EXHIBIT No. 2
CASE 11635

Extracted from

HIGH PLAINS, OR LLANO ESTACADO, TEXAS-NEW MEXICO

by Carl Gaum, United States Geological Survey

THE PHYSICAL AND
ECONOMIC FOUNDATION OF NATURAL RESOURCES

VOLUME IV
SUBSURFACE FACILITIES OF WATER MANAGEMENT AND
PATTERNS OF SUPPLY--TYPE AREA STUDIES

Interior and Insular Affairs Committee
House of Representatives, United States Congress
1953

GROUND WATER

The Water-Bearing Formation

In the Llano Estacado--as in most other parts of the High Plains--the story of ground water is linked closely with the history of the building and subsequent dissection of a vast piedmont alluvial apron east of the Rockies (see ch. 4). The Ogallala formation, comprising the materials of which this alluvial plain was built, is the dominating ground-water reservoir of the region (see fig. 6.8). The boundaries of this formation are essentially the boundaries of the reservoir, and indeed of the Llano Estacado. Over all the High Plains, wherever the Ogallala formation is thin or absent the prospects for obtaining large ground-water supplies are poor indeed.

At some places on the Llano Estacado the Ogallala formation is mantled by dune sand, by alluvium in stream channels, or by the clayey materials washed into the countless land-surface depressions. Some of these materials may contain sufficient water for domestic or stock use but, as surficial materials, their principal function is that they determine the rate of infiltration and downward percolation of rainfall. A mantle of sand or gravel facilitates recharge to the underlying ground-water reservoir; clay and silt retard or even inhibit recharge.

At some places the Ogallala formation is thin or absent, and there the older rocks become critical to prospective ground-water users. Under most of the Llano Estacado the rocks immediately under the Ogallala are impermeable, or they contain mineralized water, so that generally they are not sources of usable water. In the southwestern part of the plain, however, the Ogallala is underlain in part by limestone and sand which are capable of yielding moderate quantities of water to wells, locally as much as 1,000 gpm.

The Ogallala formation is composed of silt and clay, sand, gravel, and caliche; commonly there is a wide variation in materials within short distances, both laterally and vertically. Commonly, though not universally as encountered in wells, the material is of coarser texture in the lower part of the formation, and predominately silt and clay in the upper part. From this it may be deduced that in the first stages of the alluvial-plain building the streams had greater carrying power but subsequently, as the mountains were worn down and the plains built up, they deposited finer material. Lateral variation in materials is believed to be related to distance from main channels of the depositing streams. For example, the thickest and most productive water-bearing sands are found in a wide strip roughly parallel to the present White River; outside this strip there are buried ridges and hills of older rocks.

Over the Llano Estacado the Ogallala formation ranges in thickness from a feather edge to 600 feet or more. In the 7,000-square-mile irrigated area in Texas the average thickness is probably 300 feet, of which about 200 feet is saturated. Rough calculations indicate that the saturated zone under that area contains about 150 million acre-feet of water. This irrigated area covers somewhat less than one-fourth of the Staked Plain, and the saturated thickness there probably is greater than average. Allowing for these factors, a total storage of 400 million acre-feet under all the plain probably is conservative.

The water in the Ogallala has been used successfully for irrigation for many years. It is hard, commonly does not exceed 500 ppm (parts per million) of dissolved solids, and its "percent sodium" is less than 30. Wells that also penetrate into the underlying limestone and sand commonly yield water of poorer quality, with dissolved solids as great as 2,000 ppm.

Recharge, Movement, and Discharge of the Water

Recharge to the ground water reservoir in the Ogallala formation is by infiltration from rainfall, from depression ponds, or from streams. Recharge directly from rainfall can occur only when a storm provides more than enough water to satisfy any depletion in "field capacity" of the soil, so that some can penetrate through the soil zone to the ground water reservoir. The possibilities for such penetration vary greatly. Most of the Staked Plain is underlain by sediments that are cemented by calcium carbonate to form caliche, which probably is permeable enough to permit some local penetration. Much less permeable are the widespread clayey subsoils of the "tightlands." By far the greatest opportunities for infiltration and penetration of rainwater are in the sandy soils, and particularly in the sand dunes which are of wide extent in some parts of the Llano Estacado. Recharge of the ground-water reservoir in wet years is clearly recorded in wells in these sand-dune areas.

The numerous depression ponds are also sources of recharge to the ground-water reservoir, as shown by records from wells adjacent to them. Penetration probably is greatest when the pond level is highest, and then diminishes with declining pond level until at low stages the chief loss from the pond is by evaporation. Many depressions are floored by silty clay that greatly slows or stops penetration.

Infiltration from streams necessarily is a minor item of ground-water recharge, chiefly because the amount of streamflow is very small, but also because at many places the stream beds are relatively impermeable or are about at the level of the water table Nevertheless, there are some sandy channels several feet above the water table, where conditions are favorable for ground-water recharge whenever there is runoff.

All these methods of recharge are intermittent, and largely contingent on exceptionally heavy precipitation. Because of this, and because of the great extent and variability of facilities for recharge, direct quantitative determinations of recharge are well-nigh impossible. However, under natural conditions the average rate of recharge over a long period of time must be balanced by the natural discharge from the ground-water reservoir. Measurement of the natural discharge, which is comparatively uniform from year to year, thus provides also an estimate of average recharge.

Water in the Ogallala formation moves generally eastward, and is discharged by springs and seeps along the eastern escarpment. There is also some natural loss of ground water along the western escarpment and within the plains, wherever the water table is close to the land surface. In particular, ground water is transpired by salt grass, marsh grass, sedges, and trees that occupy an aggregate area of thousands of acres, chiefly along stream channels.

According to studies made in 1938, the natural discharge along 75 miles of the eastern escarpment, and within a 9,000-square-mile area that includes the principal irrigated area in Texas, was about 30,000 acre-feet a year. This discharge may be equivalent to the average yearly recharge in approximately one-third of the Llano Estacado. Thus, average yearly recharge to the entire ground-water reservoir is considered to have been at least 75,000 acre-feet, and possibly as much as 150,000 acre-feet.

Since 1938 the position of the water table has not changed appreciably in the areas of natural discharge along the eastern escarpment, but it has declined several feet beneath the lowlands along stream courses Thus it is likely that the natural discharge today is only slightly less than in 1938.

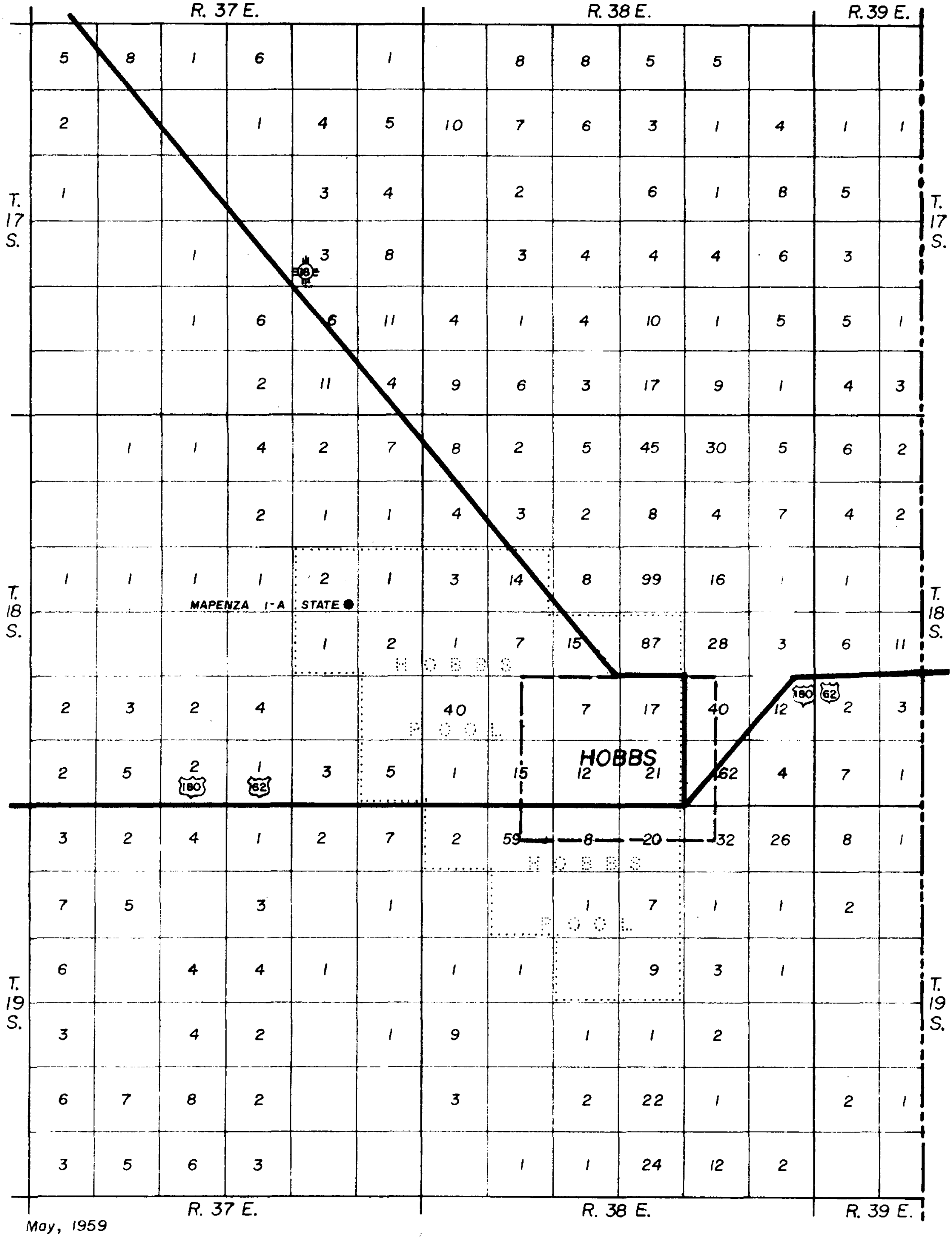
BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng. EXHIBIT No. 4
CASE 1635

Number of Applications to Appropriate Water

in Nine Townships, Lea County, New Mexico

	R. 37 E.	R. 38 E.	R. 39 E.
T. 17 S.	94	165	23
T. 18 S.	58	635	45
T. 19 S.	100	253	14
Subtotal	252	1,053	82
Total	1,387		

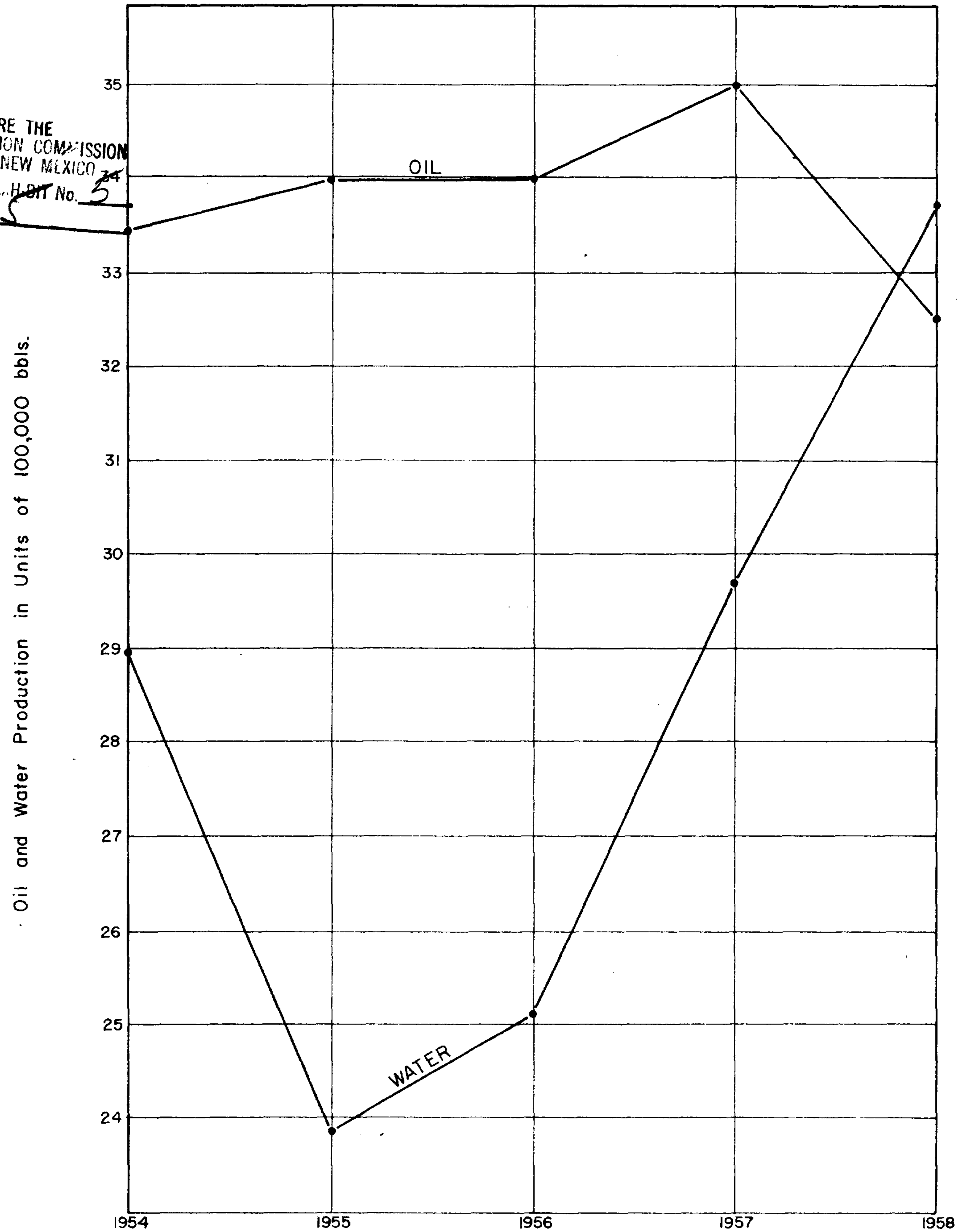
May, 1959



Number of Applications to Appropriate Water, Per Section, in Nine Townships, Lea County, New Mexico

BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
EXHIBIT No. 5
CASE 1635

HOBBS POOL PRODUCTION 1954-1958



	1954	1955	1956	1957	1958
Oil Production	3,345,688	3,398,492	3,400,776	3,505,731	3,252,618
Water Production	2,895 094	2,385,838	2,512,476	2,972,749	3,369,929

Extracted from

OIL AND GAS PRODUCTION
by
Engineering Committee, Interstate Oil Compact Commission
University of Oklahoma Press
1951

p. 45 **The Water-drive Reservoir**

"The performance of water-drive reservoirs is typified by a slight decline in pressure, very little change in producing gas-oil ratios, and a steady increase in the volume of water produced per well. The first water production comes from those wells near the water-oil contact. As the reservoir is depleted, the water-oil contact moves up structure. Eventually water is produced from all wells in the structure."

Extracted from

PHYSICAL PRINCIPLES OF OIL PRODUCTION
by
Morris Muskat
McGraw-Hill Book Company, Inc.
1949

BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng EXHIBIT No. 5
CASE 1635

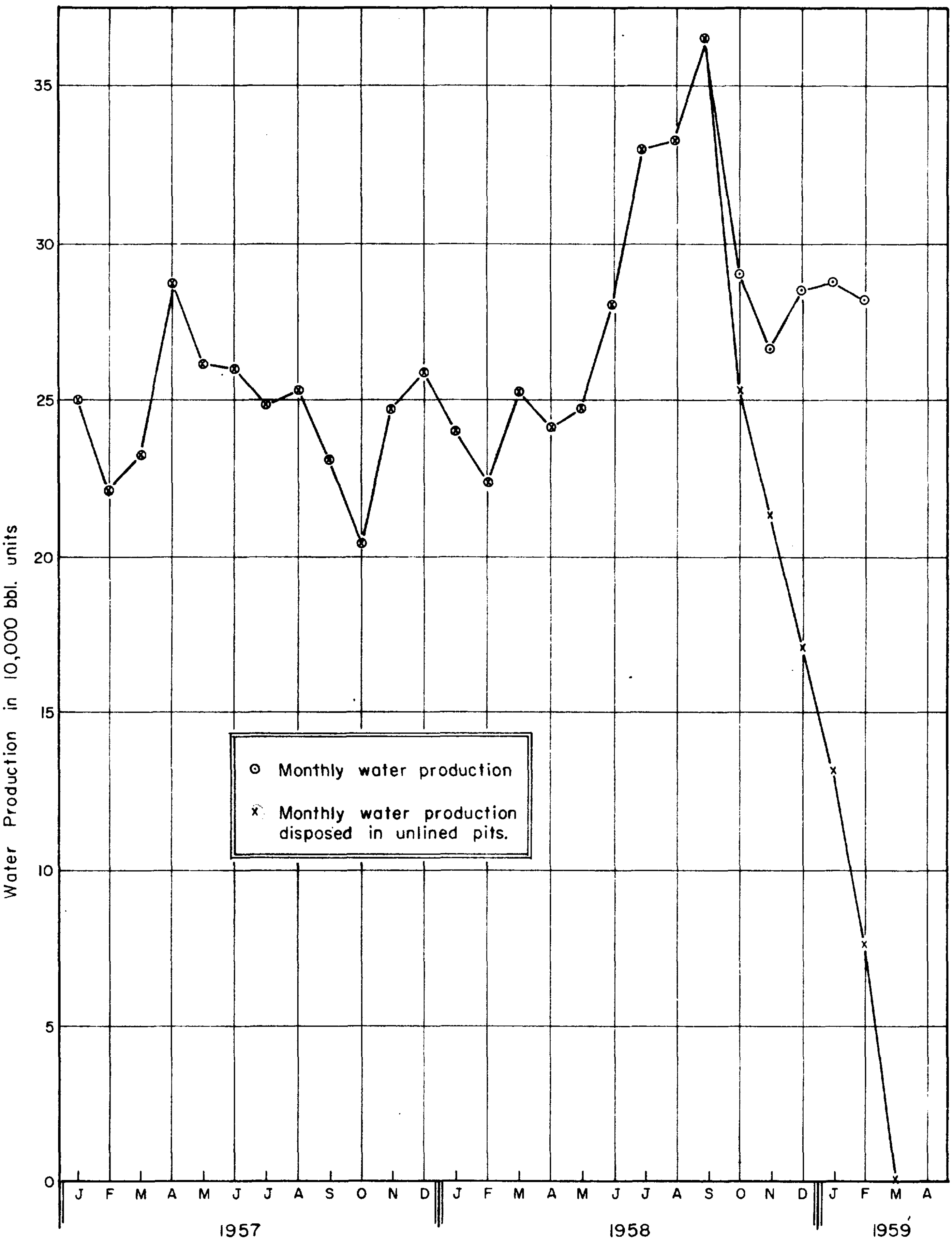
pp. 368-369

"There are commercially productive oil fields that are effectively sealed, throughout their producing life, from contact or interaction with water-bearing strata. However, the majority thus far discovered are bounded by and in fluid intercommunication with water-bearing reservoirs. The existence of such water reservoirs is usually established by the "dry" holes-generally water productive only-delineating the oil-productive area.. .....Because of the lower compressibility of water its fractional expansion in volume on pressure release will be lower than for the oil. However, when a mobile contiguous water reservoir is present at all, its area will often be very much greater than that of the oil reservoir, so that in spite of its lower compressibility the total expansion volumes may exceed the whole of the original reservoir oil volume. Thus, whereas the great majority of known oil fields have areas less than 10 sq. miles,* water reservoirs extending over 1,000 sq. miles are not at all uncommon. Moreover, while there is little specific evidence on the subject, it may be anticipated that at least in some water reservoirs the decline in pressure may be followed by gas evolution, similar to that in the oil zone, and may thus result in an effective compressibility even larger than that of the bubble-point oil.

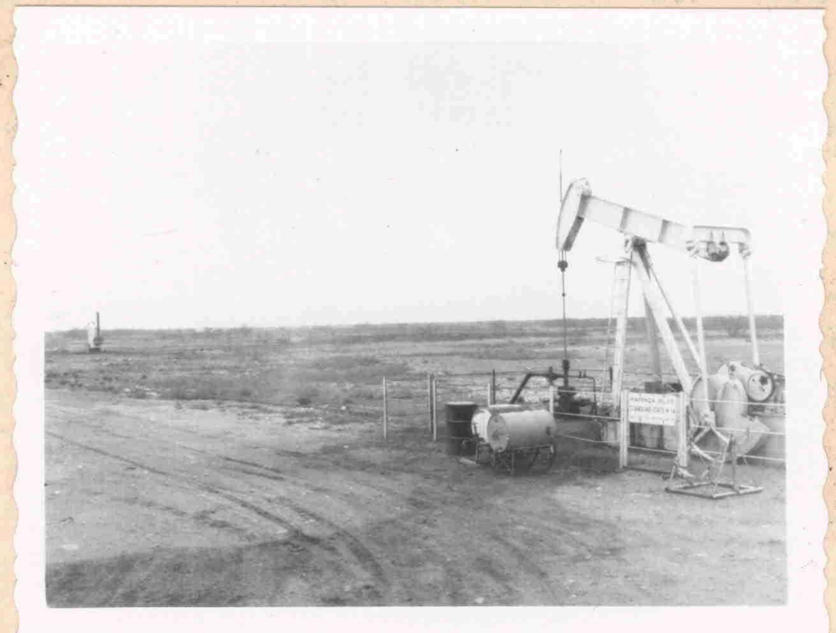
"In addition to the expansion in volume of the fluid content of a water reservoir due to pressure release, an additional source of water that may be available for ultimate entry into the adjacent oil-bearing reservoir is provided by the drainage of surface waters into exposed outcrops of the formation. In general, however, the contribution, if any, due to surface waters is very small as compared with the expansion volume of the original water content and may be neglected, except when otherwise it is known to be of significance."

*In fact a statistical analysis shows that in this county it is only in Pennsylvania and in the Texas Panhandle that a majority of the fields cover surface areas exceeding 1,000 acres.

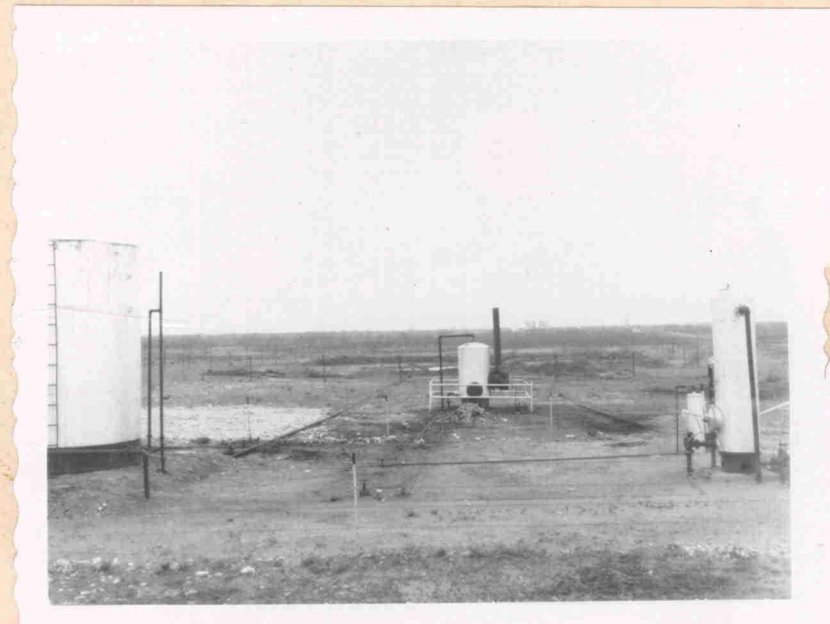
DISPOSITION OF HOBBS POOL WATER PRODUCTION



BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEX.
EXHIBIT No. 7
CASE

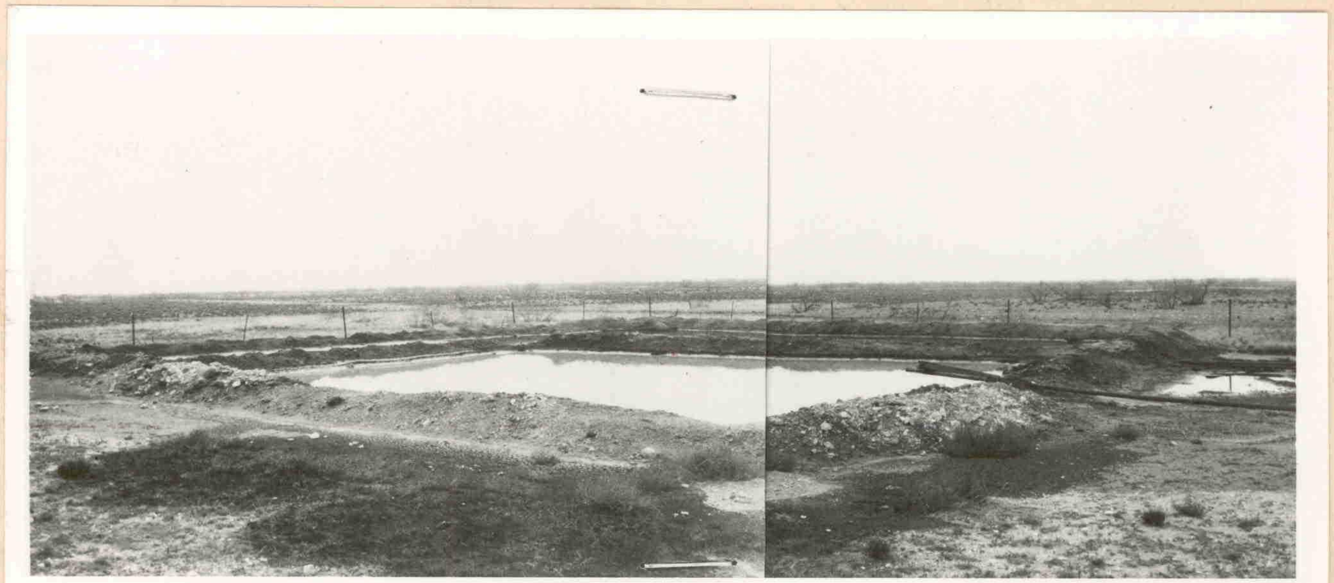


Mapenza 1-A State, looking northwest towards evaporation pit



BEFORE THE
OIL CONS[illegible]ION COMMISSION
SANTA FE, NEW MEXICO
State Eng. EXHIBIT No. 8
CASE 1635

Mapenza battery and separators, looking north towards evaporation pit



Mapenza evaporation pit, located 18.37.14.440, looking northeast

CALCULATIONS OF EVAPORATION FROM MAPENZA 1-A STATE DISPOSAL PIT, HOBBS, NEW MEXICO

A. No oil film on water surface.

Estimated annual evaporation from land pan, Hobbs, New Mexico. Based on 10 year average at Portales, New Mexico, 91.10", multiplied by factor, 1.084, to correct for difference in evaporation rate due to difference in elevation. [a,c]	98.75"
Estimated annual evaporation of brine, Hobbs, New Mexico. [b]	59.25"
Annual average precipitation, Hobbs, New Mexico. Based on 32 year average. [c]	14.99"
Net annual evaporation, Hobbs, New Mexico.	44.26"
	= 3.688'

B. Oil film on water surface.

Estimated annual evaporation from land pan, Hobbs, New Mexico. Based on 10 year average at Portales, New Mexico, 91.10", multiplied by factor, 1.084, to correct for difference in evaporation rate due to difference in elevation. [a,c]	98.75"
Estimated annual evaporation from free water surface, Hobbs, New Mexico. [d]	69.13"
Estimated annual evaporation of oil field brine containing a small amount of oil. Preliminary experiments indicate oil field brine containing a small amount of crude oil evaporates one-third as fast as fresh water.	22.81"
Annual average precipitation, Hobbs, New Mexico. Based on 32 year average. [c]	14.99"
Net annual evaporation, Hobbs, New Mexico.	7.82"
	= 0.65'

Applying these figures to the Mapenza pit dimensions:

A. 80' x 80' x 3.688' = 23,603 cu.ft./yr.
= 4,204 bbls./yr.

B. 80' x 80' x 0.65' = 4,160 cu. ft./yr.
= 741 bbls./yr.

Annual water production Mapenza 1-A State	5,448 bbls.
Annual evaporation, condition A	4,204 bbls.
	1,244 bbls.

Annual water production Mapenza 1-A State	5,448 bbls.
Annual evaporation, condition B	741 bbls.
	4,707 bbls.

BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng EXHIBIT No. 9
CASE 11635

CALCULATIONS OF EVAPORATION FROM MAPENZA 1-A STATE DISPOSAL PIT, HOBBS, NEW MEXICO
(Continued)

a. New Mexico A W R Coordination Committee, 1953, "Tenative Plans for Development of Land and Water Resources, New Mexico Portion, A W R River Basins", p. 54.

b. Hale, W. E., et al, 1954, "Possible Improvement of Quality of Water of the Pecos River by Diversion of Brine at Malaga Bend, Eddy County, New Mexico", Water Resources Division, U. S. Geol. Survey, p. 39.

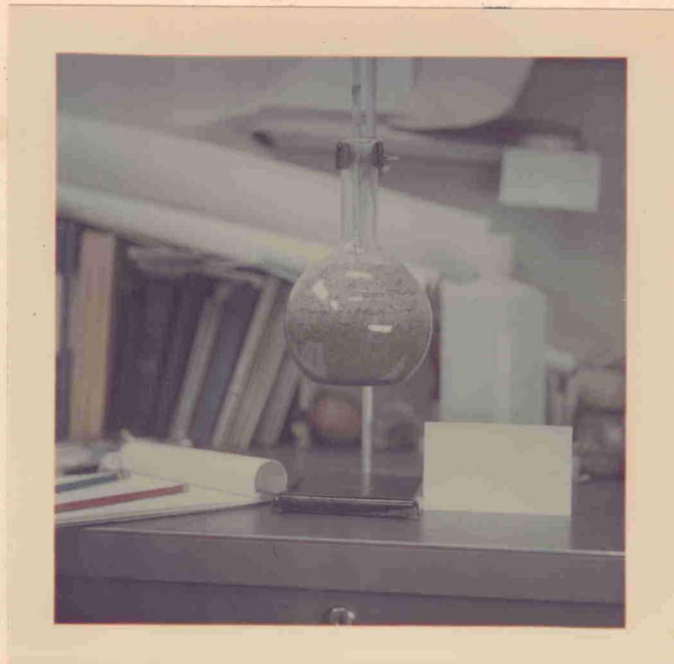
c. State Engineer Office, 1956, "Climatological Summary of New Mexico", Tech. Rept. No. 6.

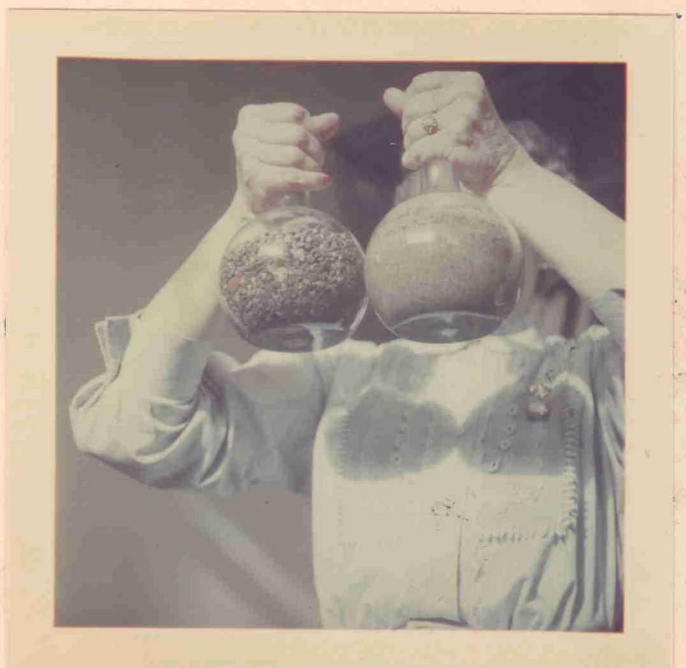
d. State Engineer Office, 1956, "Climatological Summary of New Mexico", Tech. Rept. No. 5.

BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng EXHIBIT No. 10
CASE 1635 -

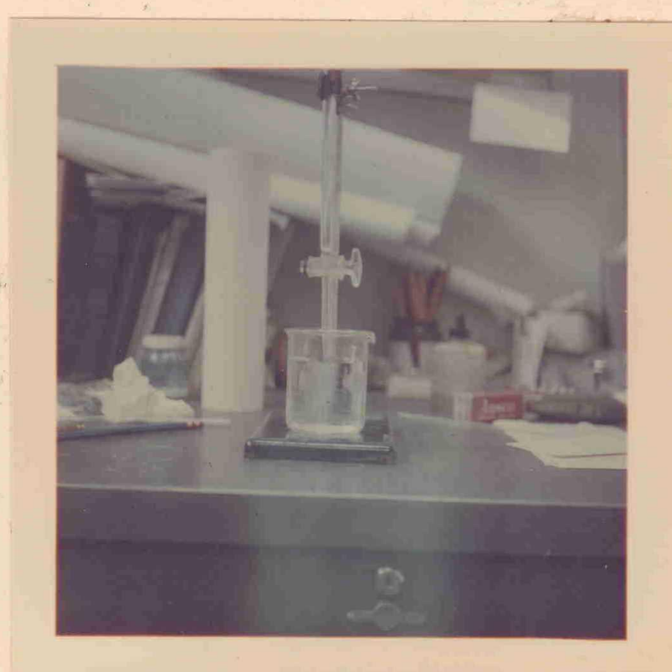
Set-up of barium bromide experiment(1127)

Blue barium bromide at bottom of flask thirty minutes after introduction(1157)





Pea-gravel and sand 26 hours and $4\frac{1}{2}$ hours, respectively, after introduction of blue barium bromide



Introduction of 20 ml of brine into 200 ml of distilled water

BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng EXHIBIT No. 11
CASE 1135

Extract From

GEOLOGY AND GROUND-WATER RESOURCES OF A PART OF SOUTH-CENTRAL KANSAS

WITH SPECIAL REFERENCE TO THE WICHITA MUNICIPAL WATER SUPPLY

By

Charles C. Williams and Stanley W. Lohman

University of Kansas Publications
Bulletin 79
July 1949
pp. 173-183

"Intrusion of Oil-field Brines"

"In the oil fields of the area considerable brine is produced with the crude petroleum, although the relative amounts of oil and salt water produced vary widely in different wells and in wells from different producing formation, and depend in part on the age of the oil field. Typical oil-field brines from this area contain from about 14,000 to about 145,000 parts per million of chloride (Schoewe, 1943, pp. 52-59).

"Schmidt and Devine (1929, p.8) list the following means by which the disposal of oil-field brines may be effected: (1) "evaporation" ponds, (2) evaporation for recovery of dissolved constituents, (3) diversion into surface streams, and (4) return to subsurface formations. In this area, as in most other parts of Kansas, oil-field brines have been disposed of mainly by methods (1) and (4), as method (2) generally is not practicable unless a sufficient quantity of rare salts can be recovered, and method (3) is prohibited by law.

"The disposal pond or so-called "evaporation" pond was the most commonly used means of handling salt water in the oil fields of the area until relatively recently, owing to the comparatively low initial and operating costs (Pl. 30). Such pits commonly have an area of from 500 to 10,000 square feet and a depth of from 1 to 15 feet (Pl. 31). In most parts of the area where such ponds are used, however, most of the brine escapes by seepage into the pervious surficial materials and thence into the ground-water reservoirs or the streams or both. The intrusion of salt water from "evaporation" ponds into ground-water reservoirs has been proven in many places by analyzing samples of water from nearby wells or test holes, and by experiments indicating that the rate of disappearance of the water is several times as great as it should be, based on an approximate average rate of evaporation for Kansas. Thus Wilhelm and Schmidt (1935, p. 18) computed that of the average daily production of 16,000 barrels of brine put into "evaporation" ponds in the Ritz-Canton oil field, in McPherson County, probably only about 1,720 barrels a day were evaporated, leaving about 14,280 barrels of salt water a day that either entered the fresh-water formations or the surface streams. Some of the resulting contamination of ground waters in the Ritz-Canton area is shown on Plate 29, and has been described in detail by Wilhelm and Schmidt (1935).

"Through the efforts of the Kansas State Board of Health, most ponds are being replaced by safer means of disposal but large quantities of brine already have been allowed to enter bodies of fresh ground water through disposal ponds, by careless spilling of brine on pervious surficial materials (Pl. 31C), from leaky oil-well or disposal-well casings, or from improperly plugged holes. The most satisfactory means of disposal yet devised for inland areas is the return of brines to deep subsurface formations, either through abandoned oil wells, "dry" holes, or wells put down especially for disposal (Jones, 1945).

"**INTRUSION OF OIL-FIELD BRINE IN THE BURRTON OIL FIELD.** - The Burrton oil field, one of the most productive in the state, occupies a large area in the Arkansas River Valley in eastern Reno County, and extends about 1½ miles into western Harvey County. The field is underlain by beds of sand, gravel, silt, and clay to depth of 100 to more than 250 feet, which in turn rest upon shale of Permian age. The aluvium contains a large supply of ground water that is fresh except near Arkansas River, as described above, and where local salt-water intrusion from oil-field brines has taken place. Salt-water intrusion in this field is a potential hazard to the new well field of the City of Wichita situated 6 miles downstream and for this reason it has been given special attention by the State Board of Health and by the State and Federal Geological Surveys.

"The Burrton oil field was discovered in February 1931 before the widespread development of brine-disposal wells; hence for many years all the oil-field brine produced in this field was run into so-called evaporation ponds. Chloride surveys made by the State Board of Health indicated that salt-water intrusion was taking place, and that farm wells near the ponds yielded water high in chloride. Through the efforts of the State Board of Health the producers were encouraged to return the brine to subsurface formations by mean of disposal wells. According to Ogden S. Jones, Geologist in Charge of the Oil-Field Section of the Division of Sanitation of the State Board of Health, of an average of 44,047 barrels of brine produced daily in 1939, 34.7 percent was handled by deep disposal wells, 27.5 percent by disposal wells of shallow or intermediate depth, and 37.8 percent by brine ponds. Shallow disposal wells into the Wellington salt proved to be unsatisfactory, as the high pressure under which the brine was forced down these wells caused brine to escape to the surface around the casings of nearby wells, and thereafter efforts were made to eliminate the use of shallow disposal wells. According to Mr. Jones, the completion of additional deep disposal wells in this field by late 1944 allowed the return of about 95 percent of the brine through deep disposal wells, about 3 percent through disposal wells of intermediate depth, and only about 2 percent to brine ponds. As soon as possible, it is hoped that all brine can be conducted to deep disposal wells. When this goal is reached, salt-water intrusion in this field should virtually cease, except for occasional leaks in brine lines and disposal wells. During the years in which many evaporation ponds were in use, however, a large quantity of brine found its way into the ground-water reservoir.

"Studies made in the Burrton oil field by the State Board of Health have included periodic sampling of representative ground and surface waters;

determinations of direction of ground-water movement using fluorescein; construction of maps showing the locations of all brine ponds, brine tanks, and pipe lines, and repressuring and disposal wells; and the sinking of auger holes adjacent to brine ponds in order to determine the chloride content of the ground water.

"Additional studies of salt-water intrusion were made in this field in 1938 by the State and Federal Geological Surveys in cooperation with the State Board of Health and the City of Wichita. In the course of this work 35 driven wells were put down in order to study the lateral and vertical migrations of oil-field brines. The wells were driven at selected points on the downstream sides of disposal ponds, and the water samples were taken at vertical intervals of 5 feet, using a pitcher pump. The chloride content of the waters sampled was determined in a portable laboratory mounted on a truck (Pl. 4). It was found in general that the brine, being heavier than fresh water, sinks with surprisingly little diffusion or dilution until it encounters an impervious stratum. It then flows laterally in a relatively thin layer on top of this impervious stratum. In material containing discontinuous lenses or beds of impervious clay and silt, the brine may follow a "stair-step" course from one impervious bed to another, moving gradually downward and laterally.

"The results of surveys at two typical areas in the Burrton oil field that have suffered salt-water intrusion are given in Table 21, and the locations of the test wells are shown in Figures 27 and 28. In both areas tested the ground water moves in a general southwesterly direction (Pl. 1).

"It will be noted that there has been very little dilution of the brine within the distances sampled in survey B (Fig. 28) but considerable dilution has taken place at most of the points tested in survey A (Fig. 27), although the moving brine seems to have followed certain "pipes" or "veins" of more permeable material rather than having diffused uniformly. Thus the movement of brine from disposal pond B in Figure 27 seems to have been more directly toward test well 20, but in a general way toward test wells 20-23.

"The results given in Table 21 indicate that in most of the test wells the maximum concentration of chloride is found just above a relatively impervious stratum--generally one through which it was difficult to drive the well point. In some test wells, however, impervious strata served to separate relatively fresher water above from salty water below as in no. 7 at 37-39 feet, no. 9 at 14-31 feet, no. 18 at 38-40 feet, no. 27 at 19-31 feet, and no. 28 at 19-31 feet. In a few test wells, such as no. 4, the maximum chloride content was found just above an impervious stratum and fresher water was encountered just below this bed, suggesting that the salty water was unable to reach the lower water-bearing bed. In some test wells, such as no. 20, there was a surprisingly sharp separation between layers of fresh and salt waters, but in others, such as nos. 6, 21, 22, and 23, the chloride concentration increased gradually with increase in depth.

"Two of the test wells (4 and 23) put down in survey A were left cased so that further observations could be made; the rest of the test holes put down in the two surveys were filled, pulled and plugged. The pipe in test well 4 was pulled back from an initial depth of 66.5 feet to 13 feet, but the pipe in test well 23 was left at the original depth of 59 feet. The periodic measurements of water levels and chloride determinations in these test wells through January 9, 1945 are given in Table 22. A rather gradual but noticeable increase in the chloride content took place in test well 23 throughout most of the period of record, but in test well 4 the significant increase did not occur until April 14, 1942 and later. As indicated in Table 22, the chloride content at a depth of 49 feet in test well 4 was 171 parts per million so that doubtless the chloride content at this depth by January 9, 1945 was considerably higher than 2,380 parts per million-- the value for a depth of only 13 feet.

Table 21.--Chloride content at given depths in test wells, in parts per million.

Depth (feet)	Chloride content	Depth (feet)	Chloride content	Depth (feet)	Chloride content
(Survey A)		Test well 5 (Cld.)		Test well 10 (Cld.)	
Test well 1		25-27	80	44-46	653
8-10	74	30-32	123	49-55	664
13-15	90	34-36	213	53-55	945
18-20	74	39-46	(b)	55-	(b)
23-25	69				
28-30	68	Test well 6		Test well 11	
33-35	71	21-23	58	16-18	107
38-40	71	26-28	57	21-23	92
43-45	71	31-33	63	26-28	137
48-50	69	36-38	121	31-33	152
50-52	67	41-43	342	36-38	272
52-	(a)	46-48	626	41-43	516
		50.5-52.5	398	46-48	470
Test well 2		52.5-	(b)	48-	(b)
9-11	108				
14-16	74	Test well 7		Test well 12	
19-21	68	12-14	56	23-25	97
24-26	68	17-19	(a)	28-30	142
29-31	71	22-24	49	33-35	177
30.5-32.5	71	27-29	60	38-40	362
32.5-	(a)	32-34	65	43-45	591
		37-39	(a)	48-50	691
Test well 3		40-42	216	50-52	(b)
11-13	74	42-44	416		
16-18	69	44-46	(b)	Test well 13	
21-23	68			28-30	152
26-28	69	Test well 8		33-35	182
31-33	72	15-17	136	38-40	446
36-38	97	20-22	156	40-42	501
41-43	115	25-27	101	42-	(b)
46-48	105	30-32	180		
48-	(a)	35-37	272	Test well 14	
		40-42	476	12-14	51
Test well 4		45-47	523	17-19	62
15-17	54	47-49	(b)	22-24	93
20-22	55			27-29	130
25-27	59	Test well 9		32-34	232
30-32	66	9-11	107	37-39	441
35-37	160	14-31	(a)	40.6-42.6	486
40-42	128	34-36 (c)	252	42.6-	(b)
42-44	136	36-38 (c)	307		
47-49	171			Test well 15	
52-62	(a)	Test well 10		11-13	70
62-64	55	9-11	382	14-16	31
64.5-66.5	53	14-16	63	19-21	(a)
		19-21	72	24-26	63
Test well 5		24-26	130	29-31	79
10-12	41	29-31	173	34-36	118
15-17	40	34-36	302	39-61	(a)
20-22	69	39-41	481	61-63	53

Table 21.---Chloride content at given depths in test wells, in parts per million--Continued

Depth (feet)	Chloride content	Depth (feet)	Chloride content	Depth (feet)	Chloride content
Test well 15 (Cld.)		Test well 21 (Cld.)		Test well 26 (Cld.)	
65-67	55	47-49	571	60-	(a)
67-	(d)	52-54	1,870		
		54-56	1,720	Test well 27	
Test well 16		55.5-57.5	1,620	14-16	1,800
28-30	116	57.5-	(b)	19-21	(a)
33-35	247			23-25	24,800
37.5-39.5 (c)	377	Test well 22		28-30	43,200
		26-28	68	30-33	(b)
Test well 17		31-33	69		
24-26	84	36-38	109	Test well 28	
29-31	86	41-43	235	14-16	630
34-36	255	46-48	820	19-31	(a)
39-41	272	51-53	1,280	33-35	17,900
44-46	142	52-54	1,170	38-40	42,200
48-50	216			40-42	(b)
50-51	(b)	(Survey B)			
		Test well 23		Test well 29	
Test well 18		18-20	77	24-26	2,550
28-30	70	23-25	75	29-31	25,000
33-35	81	28-30	69	34-36	44,600
38-40	(a)	33-35	84	39-41	46,500
40-42	323	38-40	203	41-42	(b)
43-45	292	43-45	342		
46-48	107	48-50	701	Test well 30	
48-49	(b)	50-52	741	26-28	28,400
		53-55	1,430	31-33	46,500
Test well 19		56-58	1,690	35-37	47,100
20-22	71	57-59	(b)	37-38	(b)
25-27	71				
30-32	83	Test well 24		Test well 31	
35-37	97	14-16	1,790	12-14	267
40-42	91	19-21	6,530	17-19	1,530
42-44	85	24-26	7,800	22-24	7,800
44-	(d)	29-31	18,900	27-29	32,000
		31-33	25,000	32-34	40,900
Test well 20		33-34	(b)		
28-30	69			Test well 32	
33-35	69	Test well 25		32-34	14,200
38-40	71	24-26	21,500	37-39	39,500
43-45	70	29-31	43,400	39-40	(b)
47-49	2,240	34-36	41,500		
49-50	(b)	36-38	49,000	Test well 33	
		38-39	(b)	23-25	1,900
Test well 21				28-30	6,800
22-24	72	Test well 26		33-35	39,000
27-29	70	22-24	42,800	38-40	50,300
32-34	69	27-29	41,500	41-43	50,900
37-39	68	29-31	47,100	43-44	(b)
42-44	67	31-60	(b)		

Table 21.--Chloride content at given depths in test wells, in parts per million --Concluded

Depth (feet)	Chloride content	Depth (feet)	Chloride content	Depth (feet)	Chloride content
Test well 34		Test well 35			
22-24	1,920	19-21	1,100		
27-29	8,500	24-26	7,820		
32-34	37,000	29-31	36,500		
37-39	45,900	34-36	39,600		
39-40	(b)	36-37	(b)		

(a) No water obtained; probably clay or silt.
(b) Drove hard, no water obtained; probably hard clay or silt.
(c) Drove hard, probably hard silty or clayey sand.
(d) Could not drive deeper.

Table 22.-- **Water** level and chloride content of water in test wells 4 and 23 from 1938 through 1944

DATE	Test well 4 (Depth 13 feet)		Test well 23 (Depth 59 feet)	
	Depth to water level (feet)	Chloride content (parts per million)	Depth to water level (feet)	Chloride content (parts per million)
Nov. 22, 1938	8.89	53	......	......
Dec. 23	.....	....	10.63	1,690
July 17, 1939	9.29	69	10.86	1,930
May 14, 1940	9.52	67	11.11	2,680
Dec. 5	10.35	72	11.92	1,770
Apr. 8, 1941	10.03	70	11.65	2,430
July 16	8.36	73	10.06	2,350
Oct. 20	9.25	86	10.90	2,510
Apr. 14, 1942	8.57	550	10.25	2,390
July 13	7.69	890	9.12	3,060
Oct. 7	4.80	1,170	6.59	3,400
Apr. 8, 1943	6.13	1,480	7.79	3,440
July 24	6.04	1,700	7.66	3,520
Oct. 12	8.47	1,870	10.05	3,900
Apr. 5, 1944	7.52	2,380	9.01	3,970
July 11	....	......	7.27	3,640
Sept. 26	7.00	2,370	8.55	3,880
Jan. 9, 1945	7.57	2,380	5.14	4,070

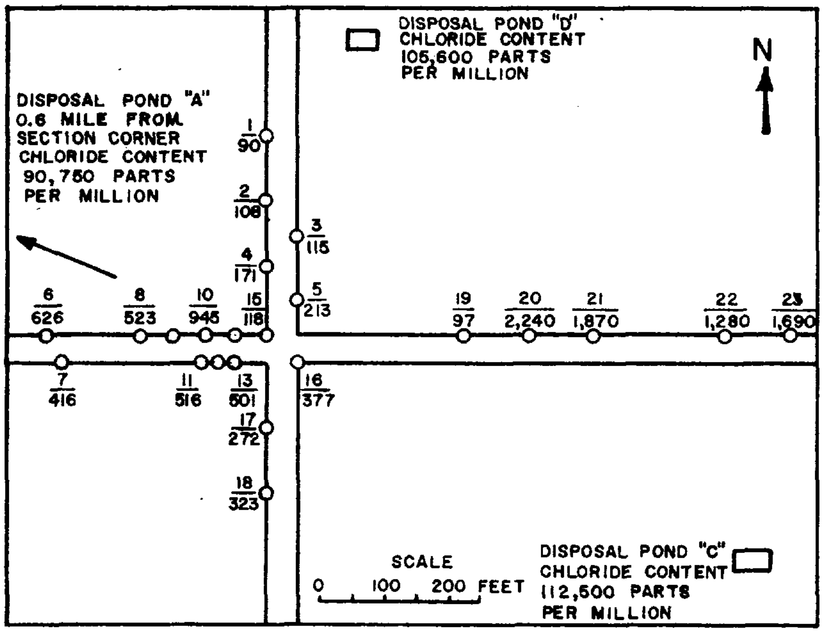


FIG. 27. Map of an area in the Burrton oil field showing location of test wells and brine-disposal ponds in survey A. Upper number corresponds to number of test well in Table 21; lower number is maximum chloride content of water, in parts per million.

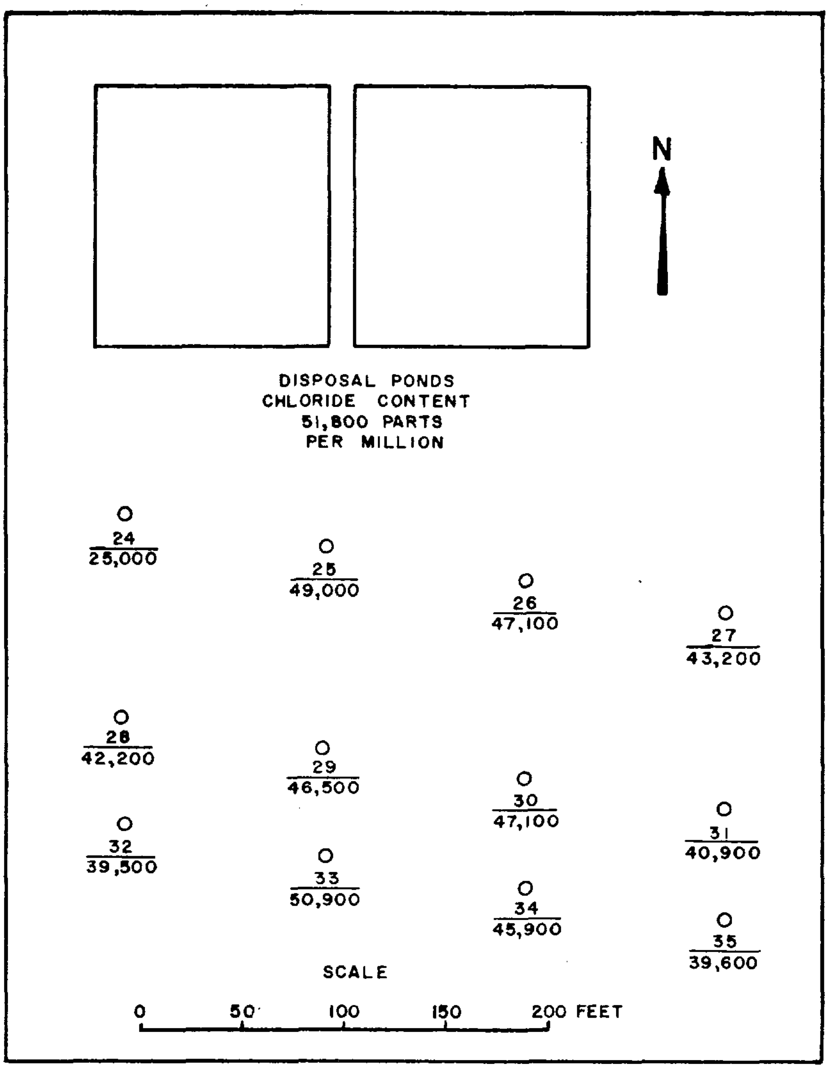


FIG. 28. Map of an area in the Burrton oil field showing location of test wells and brine-disposal ponds in survey B. Upper number corresponds to number of test well in Table 21; lower number is maximum chloride content of water encountered, in parts per million.

BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng EXHIBIT No. 12
CASE 1635

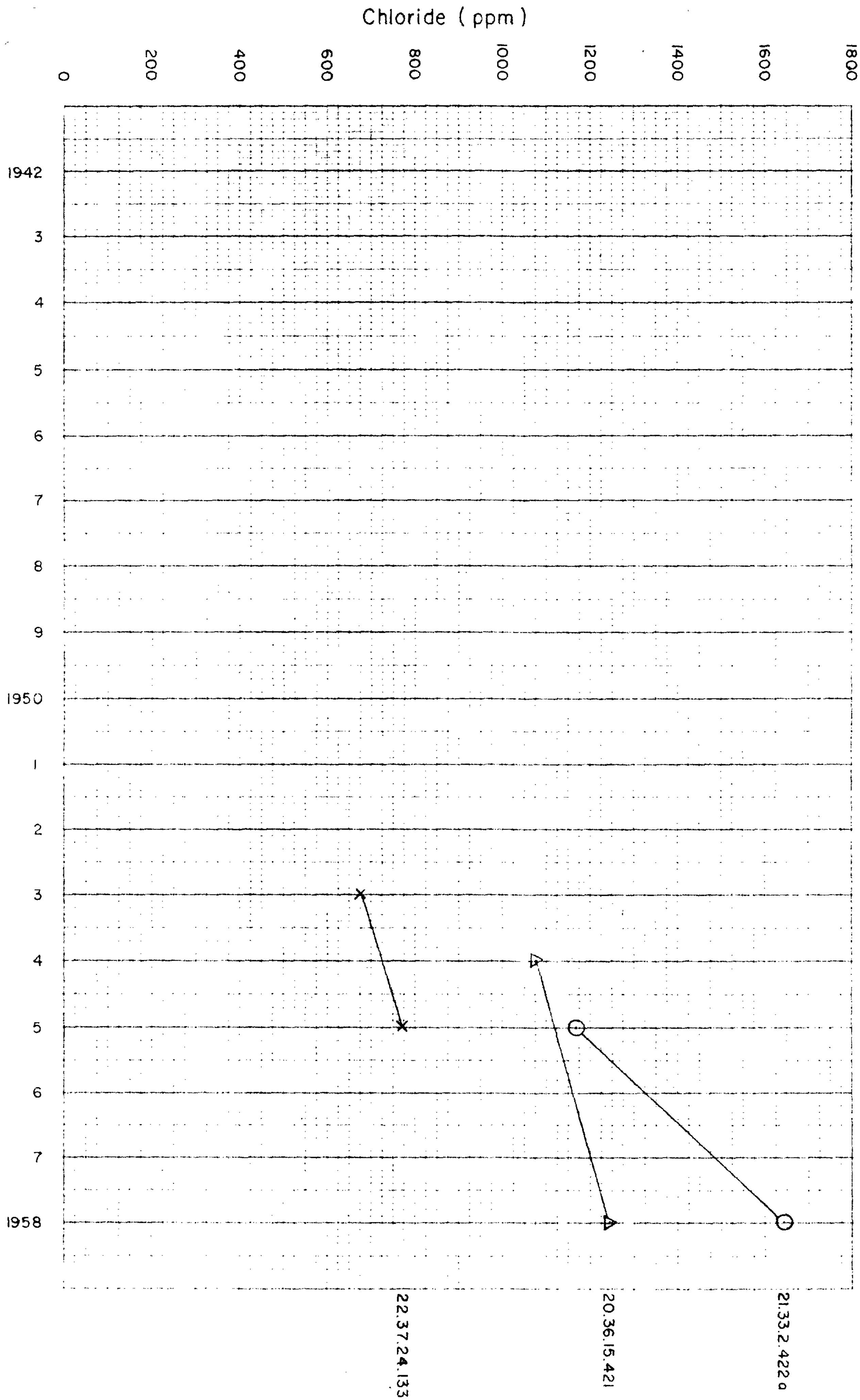
CHLORIDE CONTENT OF WATER FROM SELECTED WELLS

LEA COUNTY, NEW MEXICO

Analyses by Quality of Water Branch, U. S. Geological Survey

WELL LOCATION*	OWNER	CHLORIDE CONCENTRATION (ppm) 1942	1951	1953	1954	1955	1958
18.38.15.241a	G. Staley		75		152	206	225
34.120	City of Hobbs	59	54	67			75
20.36.15.421	H. Record				1,080		1,240
38.19.320	Continental Oil				39		49
21.33.2.422a	D. Berry					1,170	1,640
38.6.133b	---			105			340
22.36.2.444	---					205	415
22.37.24.133b	G. Sims			675		770	
25.37.13.312a	City of Jal				51	64	75

* According to U. S. Geol. Survey numbering system for New Mexico; numbers represent Township, Range, Section, and tract within a section.



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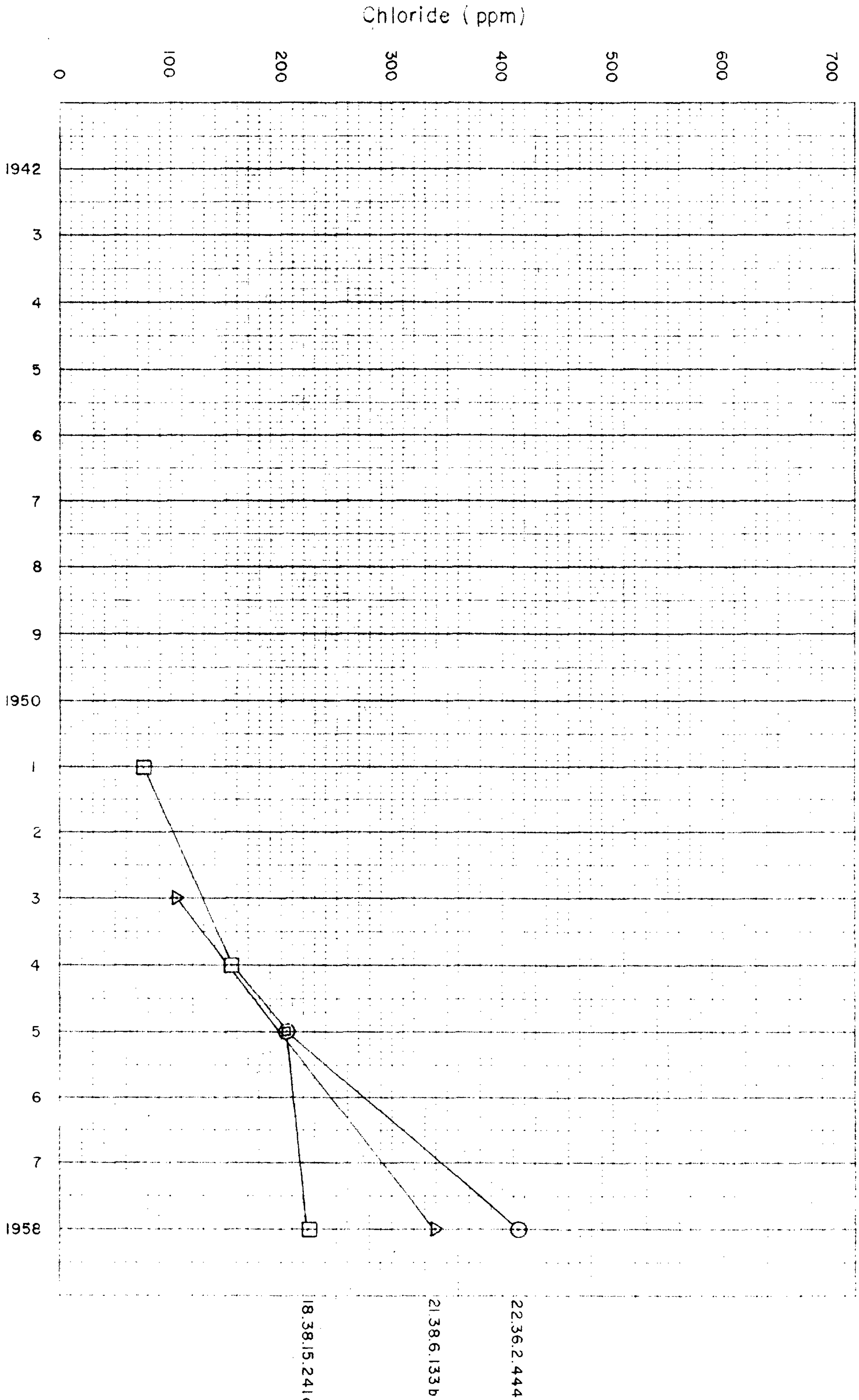

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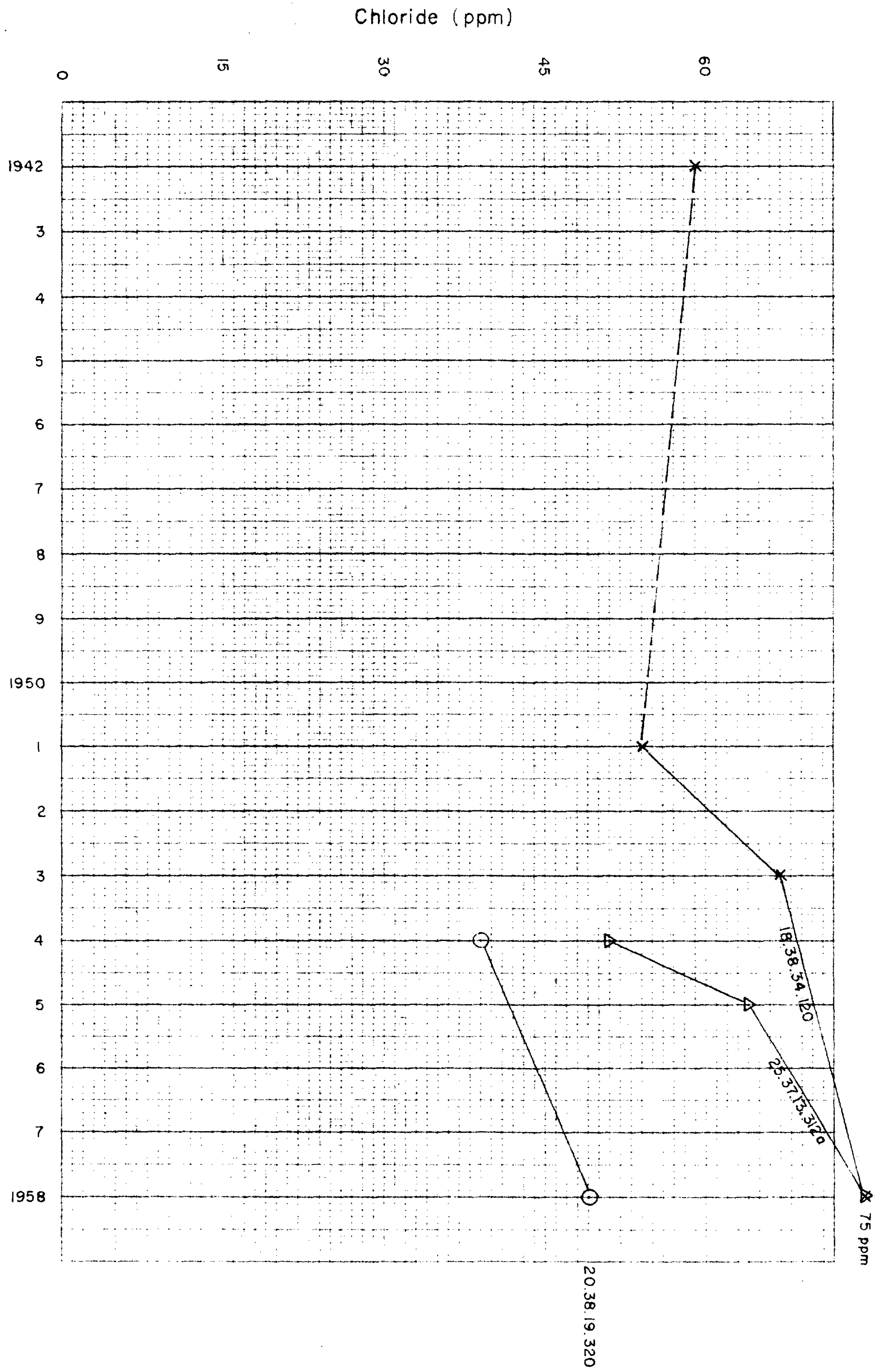

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CHLORIDE CONTENT OF WATER FROM SELECTED WELLS

LEA COUNTY, NEW MEXICO

WELL LOCATION*	OWNER	CHLORIDE (ppm)	DATE	REMARKS
12.38.19.230	R. Houston	1,470	1957	Anal. by Halliburton potable until 1957, rept
18.38.20.112	W. Jackson	494	1957	Anal. by Shell Oil
30.223	G. Goins	343	1957	do
19.38.4.121	Phillips Pet.	327	1957	do
20.37.4.111	J. Cooper	450	1954	Anal. by U.S.G.S.; rept. potable before 1953.
22.36.1.333	Gulf Oil	1,750	1953	Anal. by U.S.G.S.: rept. potable until 1951.
25.37.15.223	Sun Oil	610	1953	Anal. by U.S.G.S.

* According to U. S. Geol. Survey numbering system for New Mexico; numbers represent Township, Range, Section, and tract within a section.

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BEFORE THE
OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO
State Eng EXHIBIT No. 3
CASE 1635

Chemical Analyses of Water from Tertiary Deposits*

In November, 1929, samples of water from the Tertiary deposits were taken from 15 representative wells in various parts of the area for partial chemical analysis. They were analyzed by W. L. Lamar, of the United States Geological Survey, and the results were published in the previous report. On July 31 and August 1 and 2, 1930, samples of water from the Tertiary deposits were taken from 5 representative wells in different parts of the area for complete chemical analysis. These results are given in the table.

Analyses of Water from Tertiary deposits in Lea County, New Mexico

(Parts per million. Analyzed by L. A. Shinn, U. S. Geological Survey.)

	1	2	3	4	5
Silica (SiO_2)	52	44	43	57	57
Iron (Fe)	.04	.12	.1	.12	.12
Calcium (Ca)	93	88	79	70	68
Magnesium (Mg)	20	13	12	13	12
Sodium (Na)	65	46	41	35	33
Potassium (K)	2.9	3.4	3.8	3.5	3.8
Carbonate (CO_3)	0	0	0	0	0
Bicarbonate (HCO_3)	178	210	207	215	212
Sulphate (SO_4)	187	117	100	70	63
Chloride (Cl)	81	54	41	34	35
Nitrate (NO_3)	3.8	1.8	4.5	2.1	1.0
Total dissolved solids	624	485	435	404	403
Total hardness as $CaCO_3$ (calculated)	314	273	247	228	219
Date of collection, 1930	Aug. 2	Aug. 1	July 31	July 31	July 31

1. Well, 53 feet deep in NW¼NW¼, Sec. 28, T. 12 S., R. 36 E., owned by J. E. Whip.
2. Well, 102 feet deep, in NW¼SE¼, Sec. 25, T. 13 S., R. 36 E., owned by J. P. McClish. Temperature 64 degrees F.
3. Well, 142 feet deep, in NW¼NW¼, Sec. 10, T. 16 S., R. 36 E., owned by Southern Union Gas Co. Temperature 65 degrees F.
4. Well, 60 feet deep, in NW¼SW¼, Sec. 30, T. 17 S., R. 38 E., owned by G. S. Pruett. Temperature 64 degrees F.
5. Well, 120 feet deep, in central S½ of Sec. 34, T. 18 S., R. 38 E., owned by Hobbs Water Co. Temperature 68 degrees F.

*Nye, S. S., Progress Report on the Ground-Water Supply of Southern Lea County, New Mexico; State Engineer of New Mexico Tenth Biennial Report, 1930-32, p. 240.