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REPORTS

DATE:

10/7/1987

Texaco

RECEIVED
OCT 13 1987
OIL CONSERVATION DIVISION
SANTA FE

October 7, 1987

Mr. Michael L. Cook, Director
Office of Drinking Water
United States Environmental
Protection Agency
401 "M" Street, S.W.
Washington, D.C. 20460

Re: OSW Report to Congress on
Exploration and Production Wastes
Damage Case NM01: SWD Well

Dear Mr. Cook:

The subject report is in final draft form and will be presented to Congress in December, 1987. I have been pursuing the resolution of the subject damage case through an analytical study of the facts. The EPA contractor alleges that Texaco's Salt Water Disposal Well, the State of New Mexico "BO", Well No. 3, had leaked and continues to leak salt water to the Ogallala Aquifer found at approximately 100 feet below the surface in Lea County, New Mexico.

In 1977, Texaco was sued by Mr. Paul Hamilton, a rancher and farmer in the area, on the grounds that Texaco's SWD well had polluted the Ogallala, causing damage to Hamilton's crops through his irrigation well. The court ruled in favor of Texaco. In 1981, Mr. Hamilton succeeded in having the case reopened. Utilizing monitoring well data, Dr. Daniel Stephens presented testimony for the plaintiff purporting to show the Texaco well as the only source of contamination in the Ogallala. However, Mr. Hamilton had previously sued Amerada Petroleum on the grounds that Amerada's SWD pit had leaked to the Ogallala, contaminated his irrigation well, and caused damage to his crops. Amerada settled with Mr. Hamilton for $25,000.

The 1981 jury trial resulted in a judgment in favor of Mr. Hamilton for $75,000. Since Amerada was adjudged a joint tort feasor in the case, the judgment was reduced to $37,500 against Texaco.

Texaco did not appeal this case because the judgment awarded the plaintiff fell well below the dollar amount Texaco had previously offered to settle this case based upon plaintiff's claim that Texaco's pits were a possible source of contamination. Under these circumstances, Texaco simply chose to pay the judgment instead of incurring the cost and expense of a lengthy appeal and retrial of the suit. Texaco's decision not to appeal should not be viewed as an admission that its well was a source of contamination, especially in light of the later evidence. We believe the study by Dr. Stephens in 1984 supports our original contention that the percolation pits, which were authorized at that time, caused the contamination of the Ogallala Aquifer.

To provide you with a background on the technical analysis, I have attached several exhibits which I believe demonstrate that the percolation pits in the area have probably caused contamination of the Ogallala.

At the 1982 trial, Dr. Stephens presented as Exhibit 3 (attachment No. 1) a water level contour map of the Ogallala along with temperature readings from five test wells. The "nose" contoured around the Texaco disposal well was construed by Dr. Stephens as a recharge point in the aquifer. Data points were limited west of the injection well.

In a report published by Dr. Stephens in 1984, a similar map was presented utilizing new data (attachment No. 2), taken from monitoring wells west of the Texaco well. The undulation shown around the Texaco well in the 1982 trial has been shifted to the west to encompass the old Amerada pit area in Section 23. Apparently, Dr. Stephens recognized that the later data indicated that the Amerada pit contributed to the contamination. He states that conclusion in the body of his published report.

In the same report, Dr. Stephens presented a chloride contour map (attachment No. 3). Here he has also encompassed the Amerada pit, indicating concentrations in excess of 10,000 ppm based on the later data. The chloride contour map comports with data Texaco secured early on relative to chloride concentrations of produced water in pits in the area. The map supports our position that the plume of contamination originated from the percolation pits and has migrated south-southeast following the direction and flow shown in the John Runyan study in 1978 (attachment No. 4). The Texaco well happens to be in the crestal path of the water flow in the Ogallala.

Dr. Stephens' chloride concentration map, assuming a fully saturated, 100-foot water column in the Ogallala, requires a disposal volume of some 1.5 million barrels to accommodate the contouring closure. It has been reported that approximately 750,000 barrels of produced water were disposed of in the Amerada pit during the 1950s. We believe that this volume could be in error by a factor of two or more. A structure map (attachment No. 5) shows Texaco's New Mexico "BO" and "BR" state leases to be structurally higher than Amerada's Robinson and Robinson "A" leases in this strong water drive reservoir. Attachments No. 6 and No. 7 are plots of oil cut versus cumulative oil for the combined Texaco New Mexico "BO" and "BR" state leases and the combined Amerada Robinson and Robinson "A" leases. The slope of each plot, which is a measure of the rate of increase in water production, was determined for the production data prior to June 1, 1958. The slope for Texaco's structurally higher leases is approximately twice that of Amerada's leases. This is opposite to what would normally be expected in a strong water drive reservoir. Thus, the volume of produced water disposed of in the Amerada pit could easily have equalled or exceeded the 1.5 million barrels required to accommodate the contouring closure of Dr. Stephens' chloride concentration map. Plots of cumulative water versus cumulative oil production are also attached (attachments No. 8 and No. 9) to show the impact of strong water drive reservoirs. Cumulative oil production versus time is presented in attachments No. 10 and No. 11.

In regard to the temperature readings shown on Dr. Stephens' Exhibit 3 (attachment No. 1), the higher temperatures near the injection well is not unusual. The well fluids going down the tubing leave the wellhead at over 120°F and are at a much higher temperature than the subsurface media and reservoir fluids. At the Ogallala level, the temperature has probably not changed but a few degrees, perhaps down to 115°F. This produces a heat transfer effect to the Aquifer, causing a thermal high in the vicinity of the wellbore. The heat transfer calculations are presented in attachment No. 12 for a multi-layered cylinder and temperature data measured by Texaco in October 1981. The predicted temperature is in good agreement with the measured temperature being approximately 1°F higher than the measured temperature after nine years of injection. The velocity of movement in the Ogallala causes a distension of this effect which follows the general geometry of the flow lines in the Aquifer. Continuous injection at 500-600 psi produces a rather effective hot water heater through the Ogallala section.

Obviously, the EPA contractor did not have access to <u>all</u> of this information before making the call that the Texaco well has caused contamination to the Ogallala and "continues to operate." The latter allegation, i.e., that the State of New Mexico allows the well to continue to operate (pollute) the Ogallala is completely misleading and without foundation. I have attached a chronology of mechanical events in the well history to demonstrate the continuous mechanical integrity of the injection well.

The EPA report also alleges that the New Mexico UIC program is deficient compared to the Texas program (p. IV-56). The test pressure requirement of 300 psi in New Mexico versus 500 psi in

Texas in and of itself is not significant. The 10 percent falloff applied to the differential of 200 psi would equate to 20 psi. This is hardly a pressure falloff value which would identify the presence of a leak or failed MIT. The EPA contractor is obviously unfamiliar with pressure testing in the oil-field. In fact, the attached mechanical history shows this well to have been consistently tested above 500 psi in establishing mechanical integrity.

Mr. Cook, I bring this rather lengthy discussion to your attention because I believe the UIC programs in New Mexico and other states are in jeopardy as a result of the EPA contractor failing to present the real evidence in such damage cases. It is essential that the record be corrected. It is imperative that these UIC programs be defended with the facts.

As time is running out for further input to OSW's final report, I would hope that your office could review these data and appeal to the OSW to clarify the faulty documentation surrounding this case in particular. I would be more than happy to immediately visit with you or your staff to discuss this issue further. Please call me at 713-650-5572 if I can be of any assistance.

Sincerely,

M. A. Sirgo PDE

M. A. SIRGO, JR.

MASjr:lc
Attachments

cc: Mr. William J. LeMay, Director
Oil Conservation Division
P. O. Box 2088
Santa Fe, NM 87504-2088

Mr. Robert W. Hall
U.S. EPA
Office of Solid Waste
401 "M" St., S.W.
Washington, DC 20460

Mr. John Blackburn
API
1220 "L" St., N.W.
Washington, DC 20005

LIST OF ATTACHMENTS

1. Water level contour map from 1981 lawsuit - Dr. Stephens.
2. Water table contour map from 1984 report by Dr. Stephens.
3. Chloride contour map from 1984 report by Dr. Stephens.
4. Chloride contour map with water migration direction from John Runyan study in 1978 (Paul Hamilton Water Contamination Study).
5. Structure map - Top of Devonian.
6. Oil cut vs cumulative oil - Texaco's New Mexico "BO" and "BR" State leases.
7. Oil cut vs cumulative oil - Amerada's Robertson and Robertson "A" leases.
8. Cumulative water versus cumulative oil - Texaco leases.
9. Cumulative water versus cumulative oil - Amerada leases.
10. Cumulative oil versus time - Texaco leases.
11. Cumulative oil versus time - Amerada leases.
12. Heat transfer calculations NM "BO" 3 well.
13. Summary of NM "BO" 3 well history.
14. Daniel B. Stephens Report: "Oil-Field Brine Contamination - A Case Study, Lea Co., NM", 1984.
15. Letter from Richard L. Stamets to Daniel B. Stephens commenting on the 1984 report.

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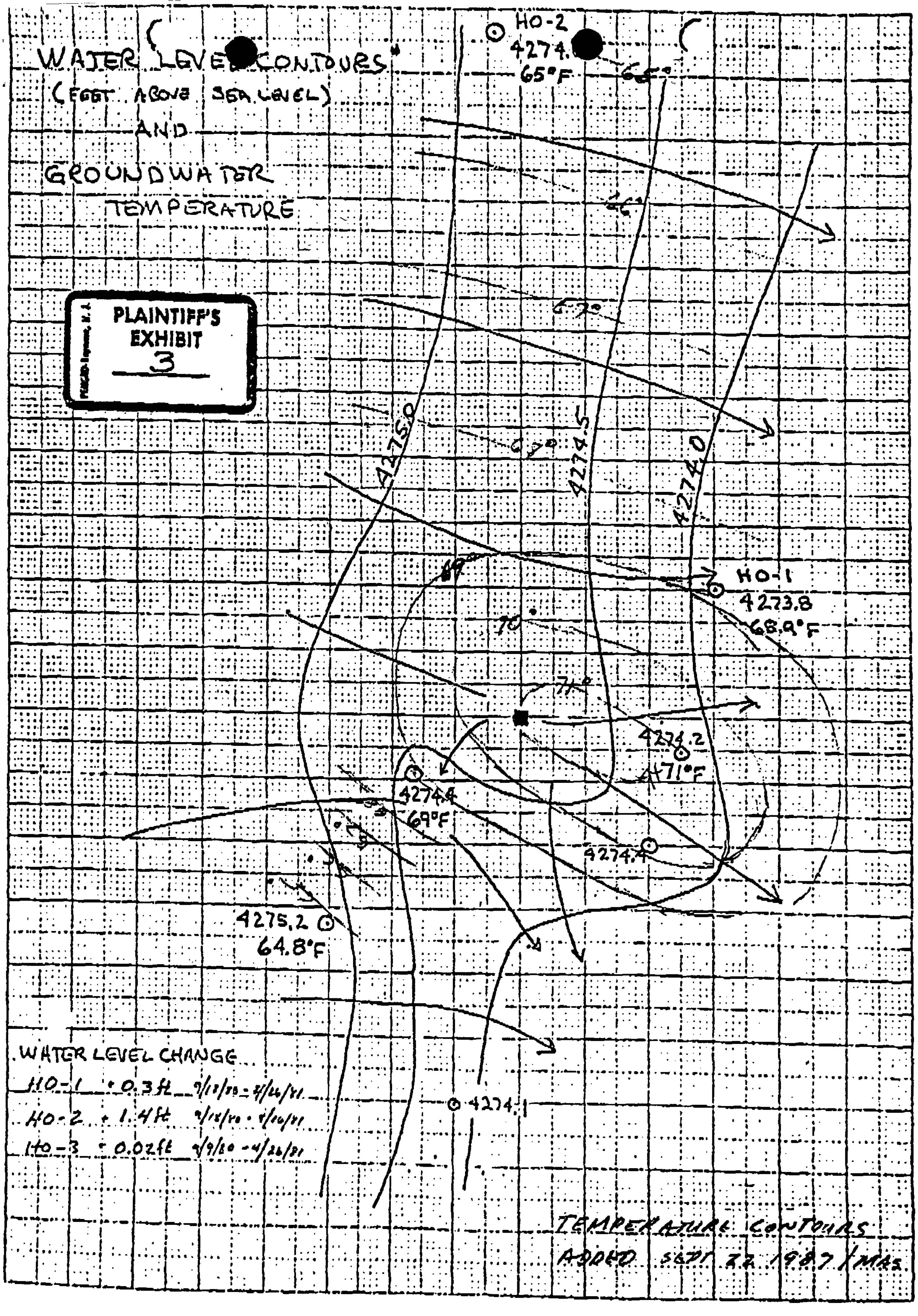


ATTACHMENT No 1

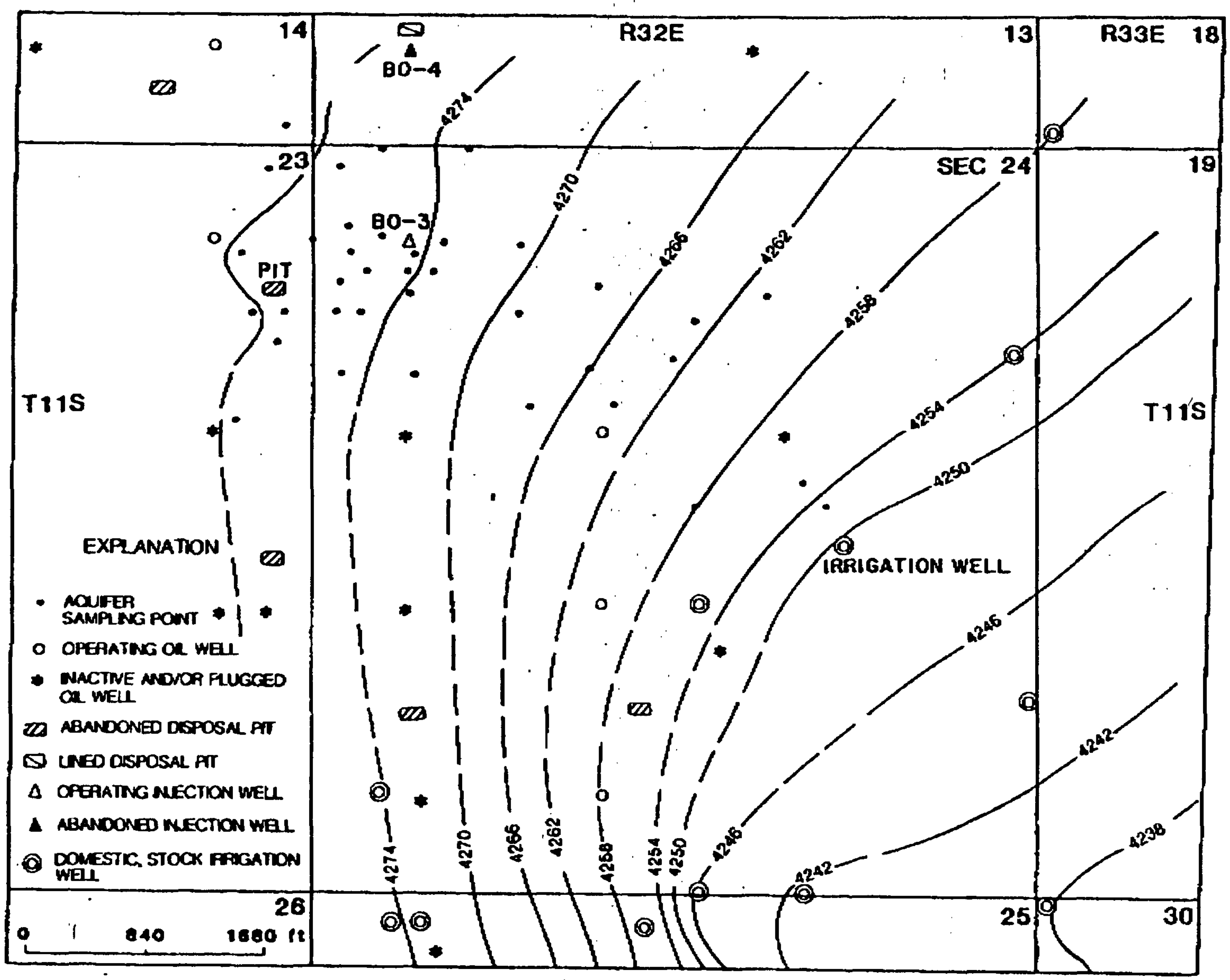


Figure 1. Water table contour map May 27, 1978 and well locations (modified from S.E. Galloway, NM State Engineers Office, Roswell)

Attachment No 2

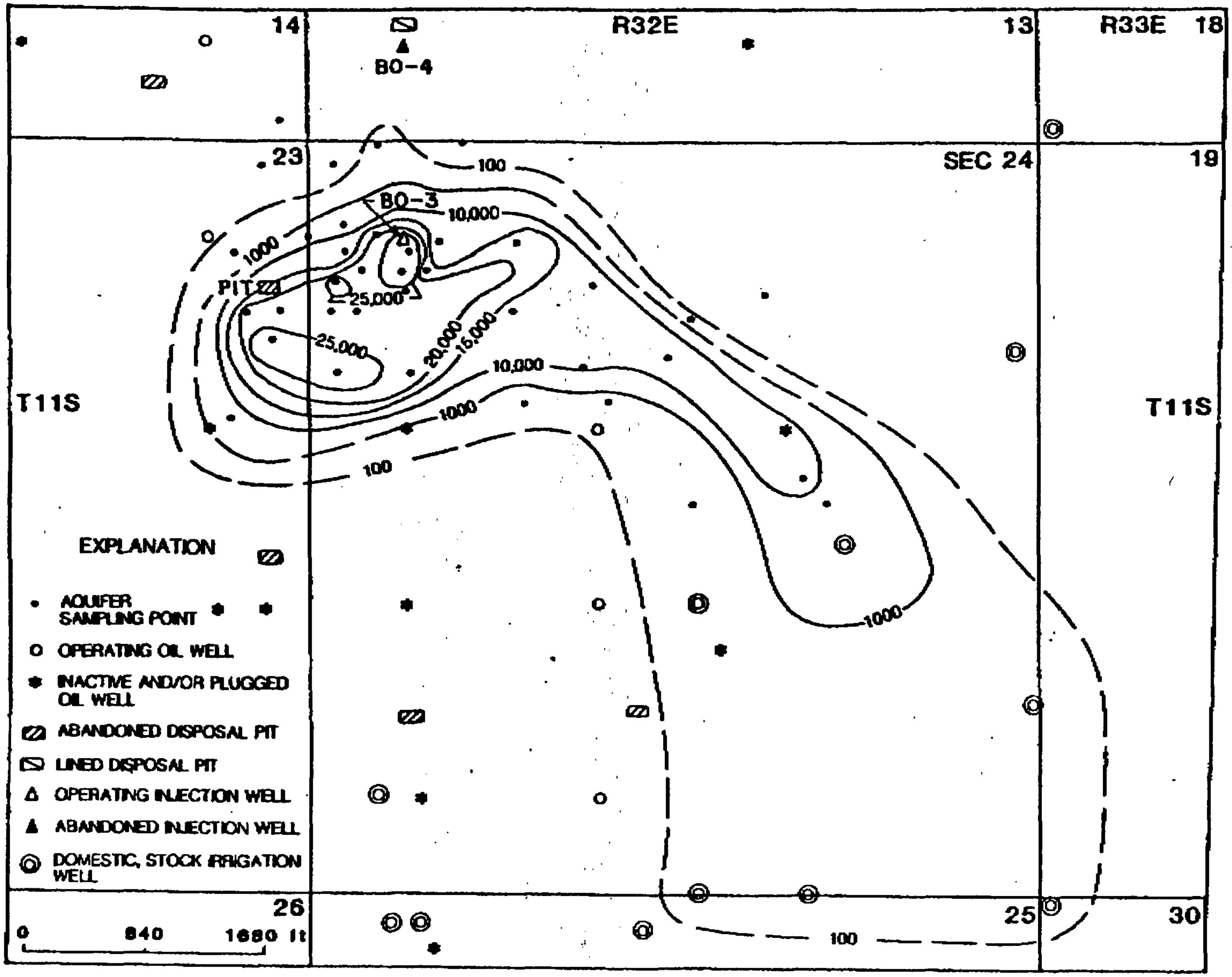
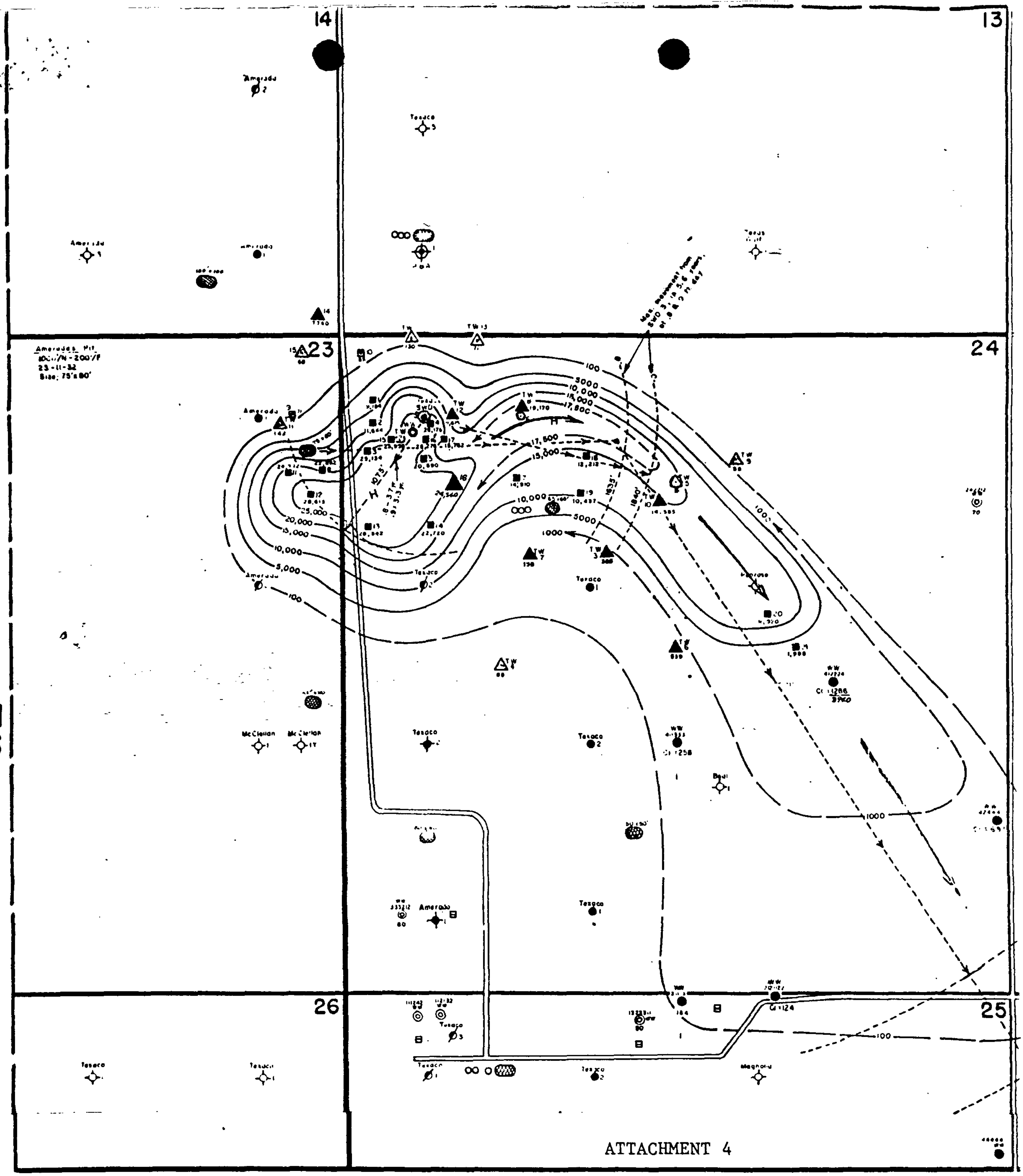


Figure 3. Chloride concentration contour map May 25, 1978 (modified from J. Runyan, NM Oil Conservation Division)

ATTACHMENT 3



PAUL HAMILTON WATER CONTAMINATION STUDY

MOORE DEVONIAN POOL

MAP SCALE: 1 inch = 500 feet

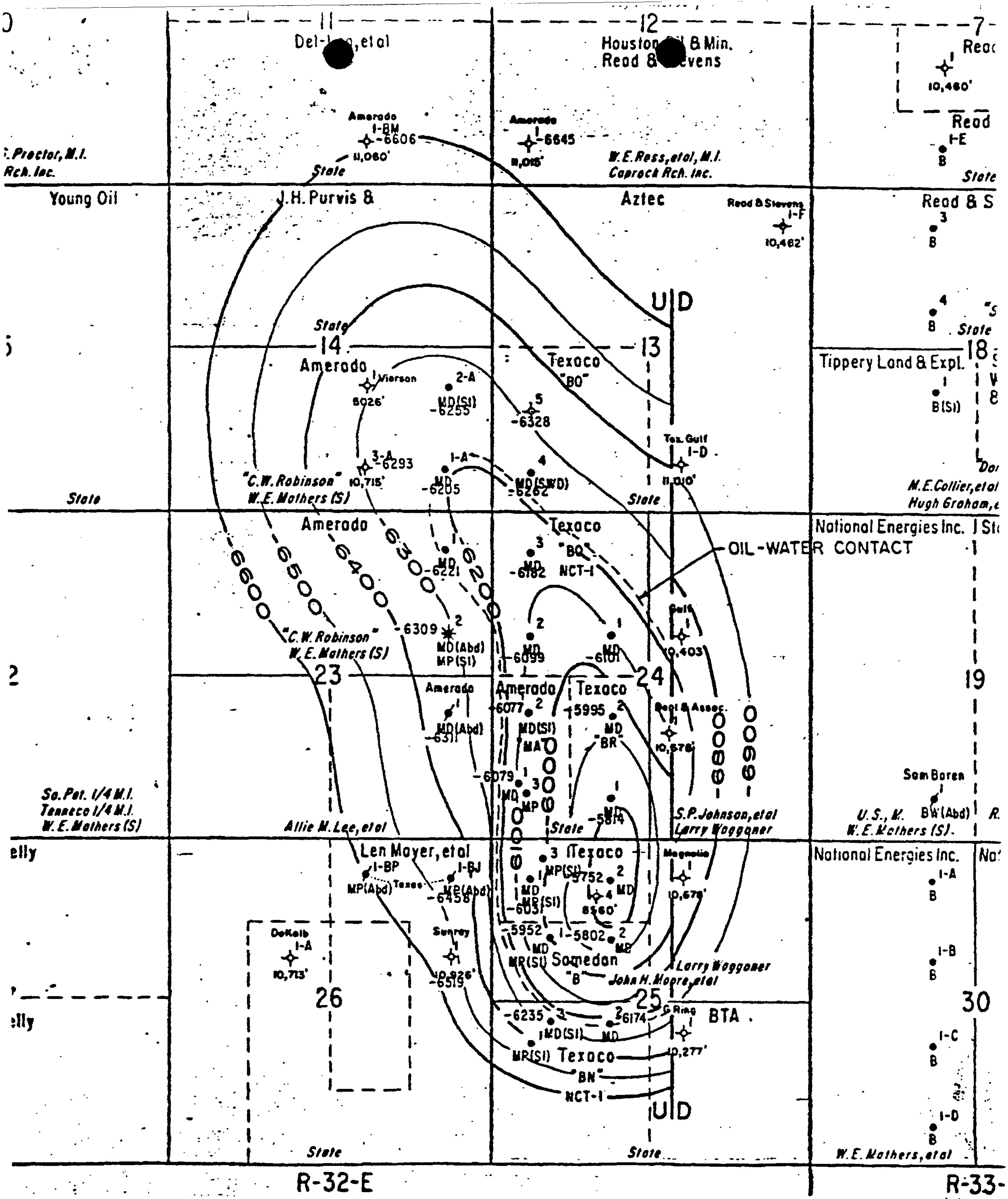
LEGEND

- WATER TEST WELL - HAMILTON.
- WATER TEST WELL - TEXACO.
- WATER WELL.
- HOUSE.
- OIL WELL.
- TEMP. ABD. OIL WELL.
- P&A OIL WELL.
- P&A SWD WELL.
- SWD WELL.
- OPEN BATTERY.
- ABD. (Covered) C.T.T. PIT.

WATER RATE & MOVEMEN MAP

BASED ON WATER MOVEMENT RAT OF .8 & .9 FEET PER DAY FROM T POSSIBLE SOURCES OF CONTAMINA

Attachment No 4



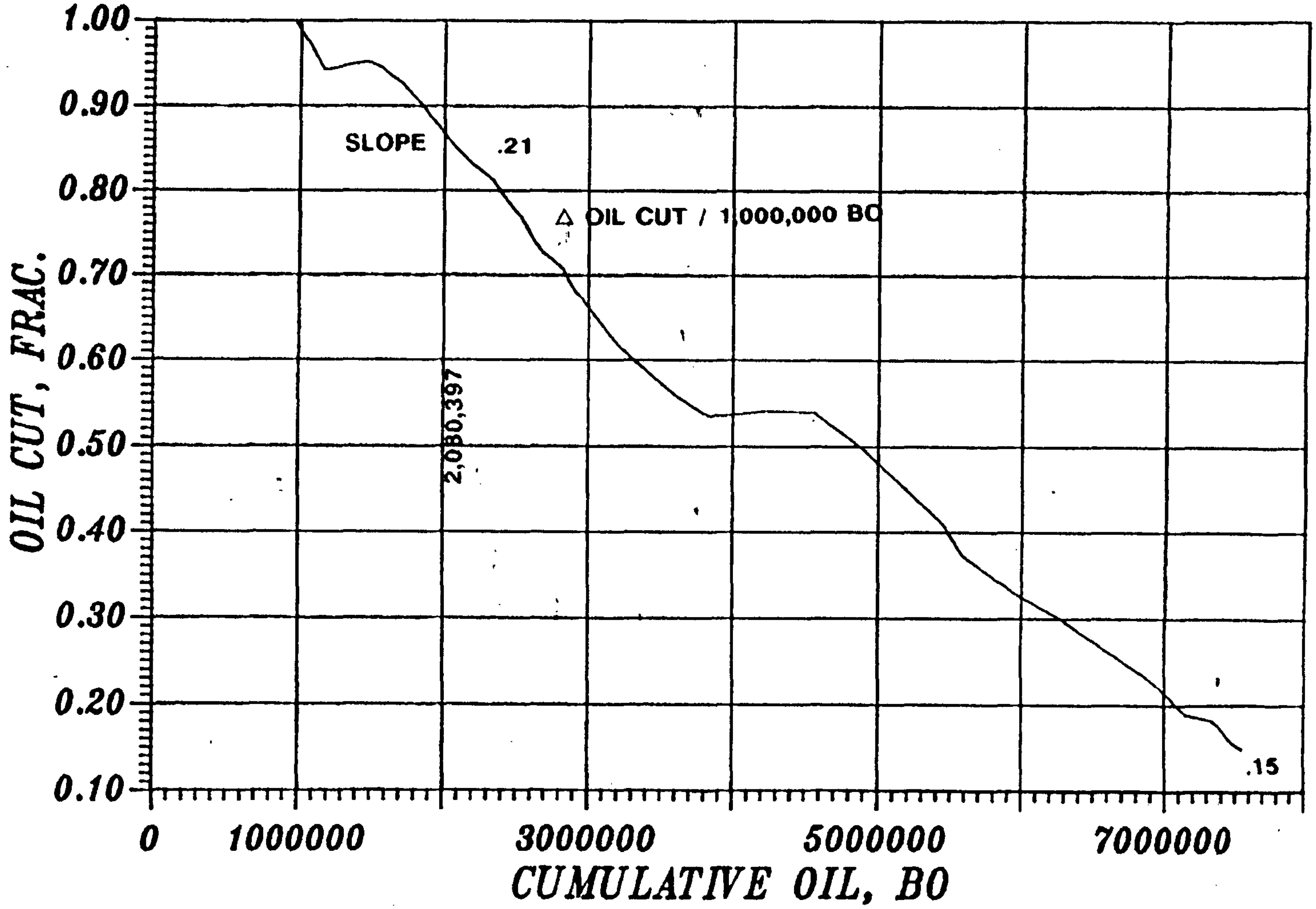
DEVONIAN
PERMO PENN.
Y PENN. NORTH

STRUCTURE MAP
TOP OF DEVONIAN

TEXACO I

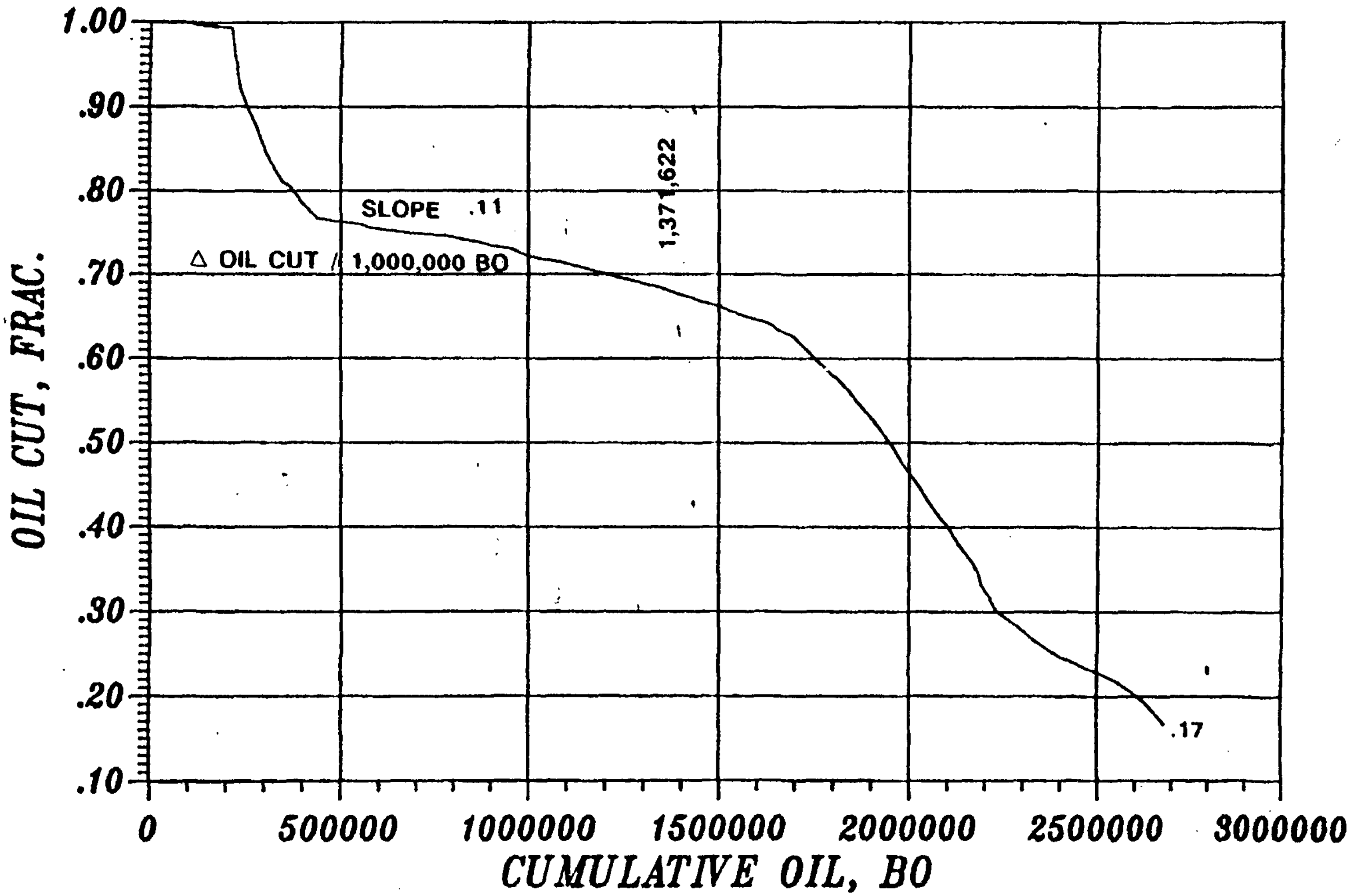
Attachment No 5

TEXACO INC.
NM "BO" AND "BR" STATE LEASES



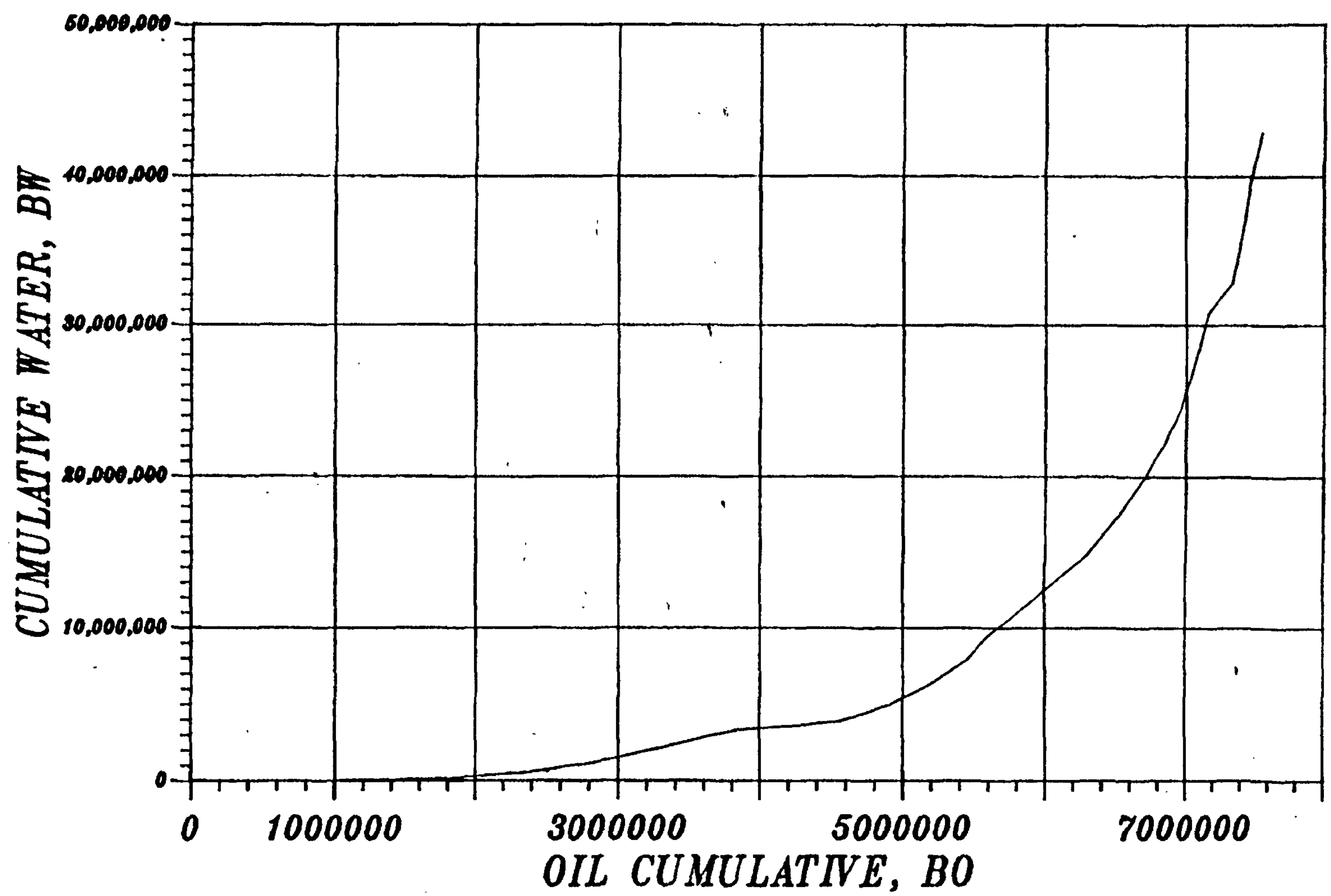
Attachment No 7

AMERADA HESS
ROBINSON AND ROBINSON "A" LEASES



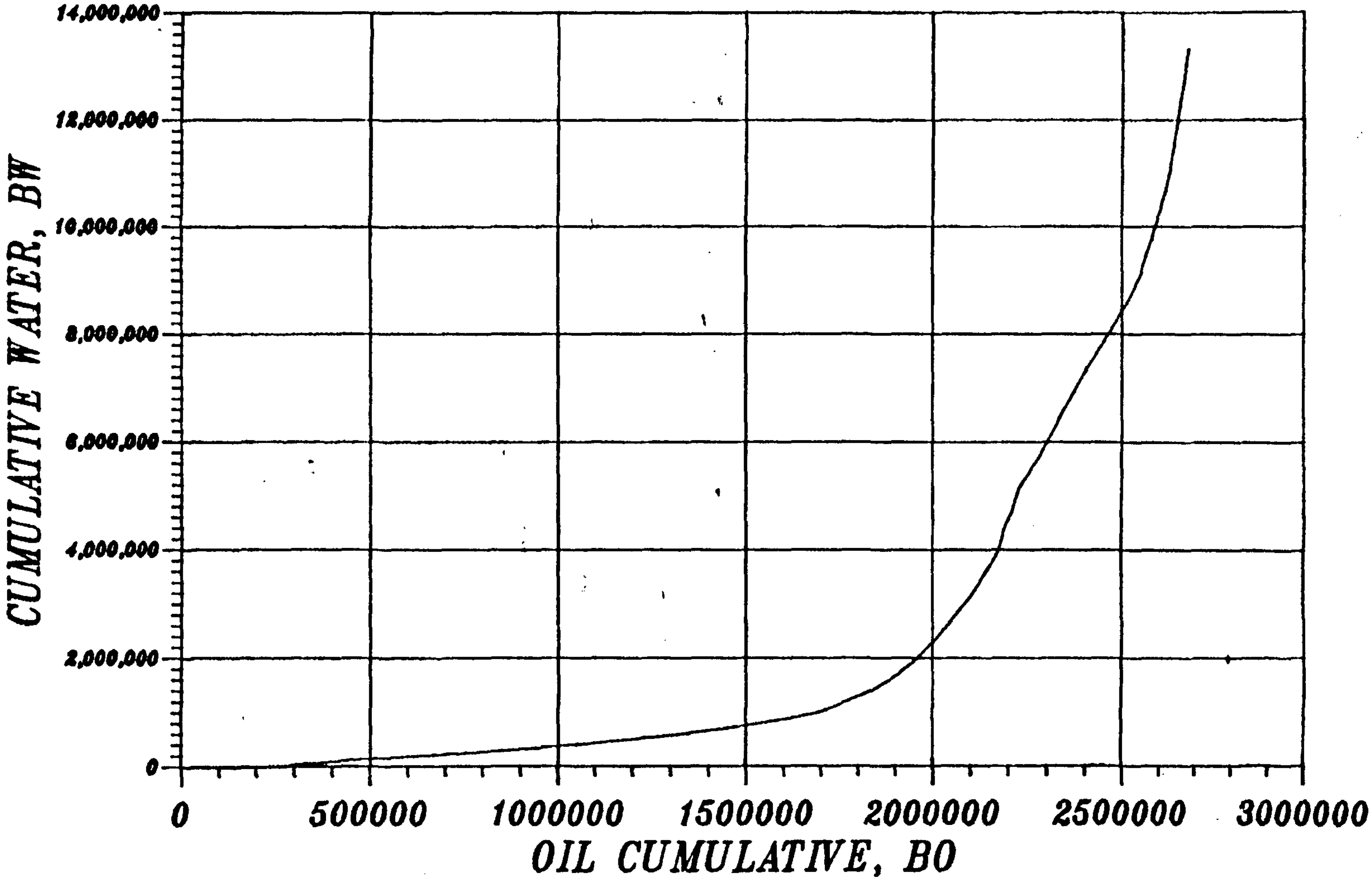
Attachment No 8

TEXACO INC.
NM "BO" AND "BR" STATE LEASES

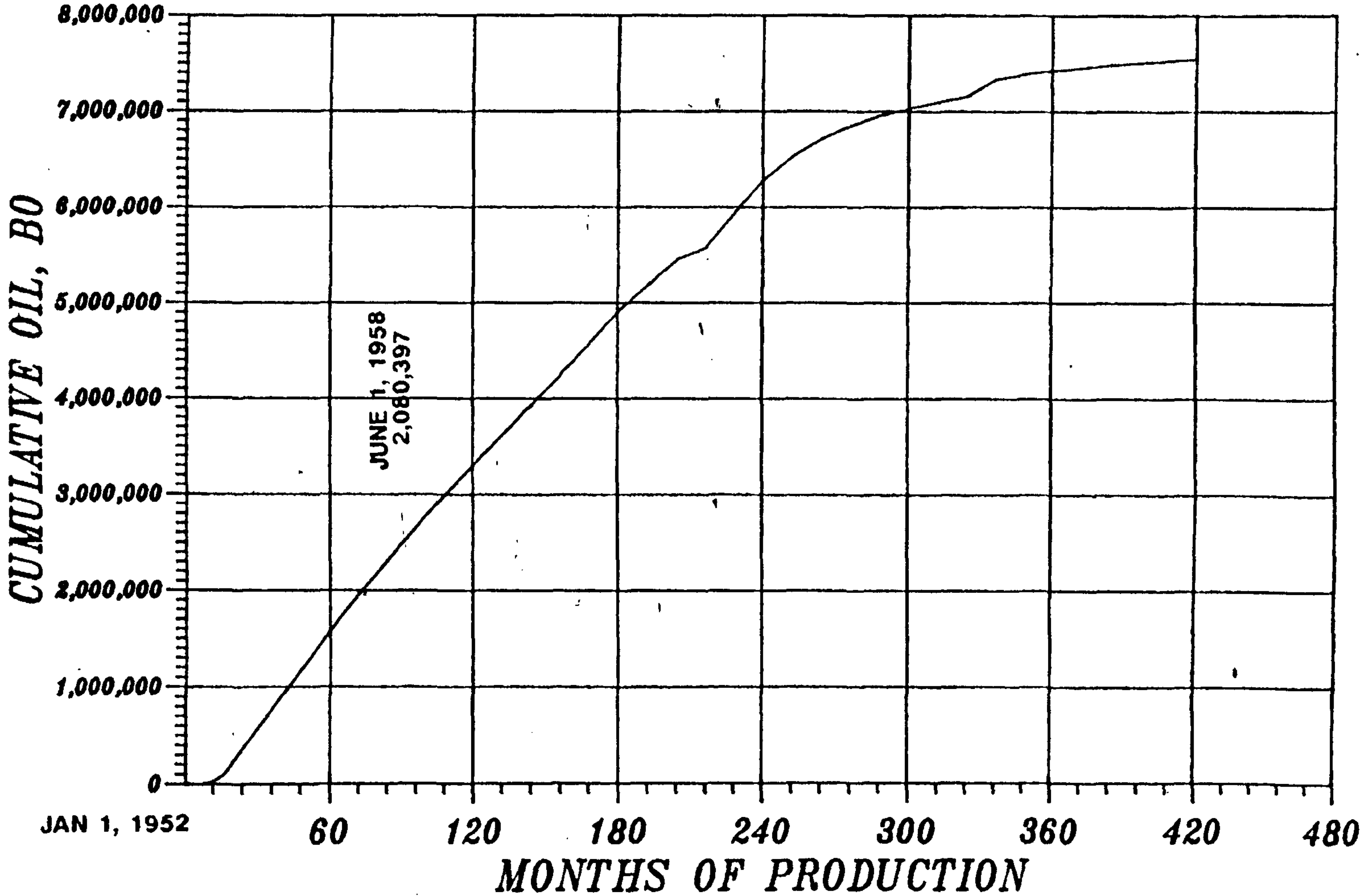


Attachment No. 9

AMERADA HESS
ROBINSON AND ROBINSON "A" LEASES

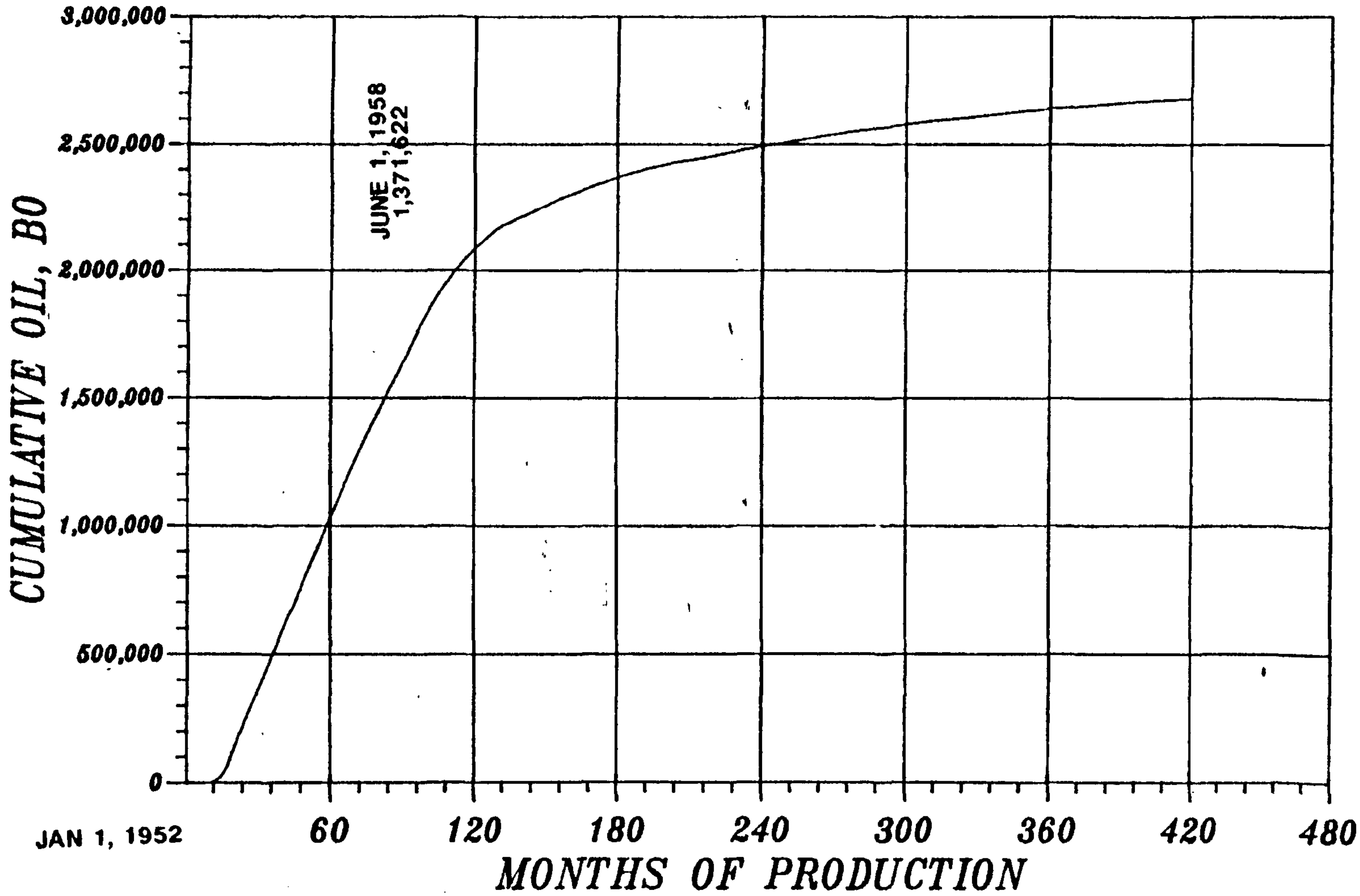


TEXACO INC
NM "BO" AND "BR" STATE LEASES



Attachment 10

AMERADA HESS
ROBINSON AND ROBINSON "A" LEASES



Attachment 11

HEAT TRANSFER CALCULATIONS

$$Q = \frac{T_{iw} - T_b}{\sum R_T}$$

$$\sum R_T = \frac{1}{h_{iw} 2\pi r_1 L} \quad \text{[Injection Water in Tubing]} \quad + L_n \frac{r_2}{r_1} \left(\frac{1}{2\pi K_s L} \right) \quad \text{[Tubing Resistance]}$$

$$+ L_n \frac{r_3}{r_2} \left(\frac{1}{2\pi K_w L} \right) \quad \text{[Water between Tbg \& Csg]} \quad + L_n \frac{r_4}{r_3} \left(\frac{1}{2\pi K_s L} \right) \quad \text{[Casing Resistance]}$$

$$+ L_n \frac{r_5}{r_4} \left(\frac{1}{2\pi R_w L} \right) \quad \text{[Water between Casing]} \quad + L_n \frac{r_6}{r_5} \left(\frac{1}{2\pi K_s L} \right) \quad \text{[Casing Resistance]}$$

$$+ L_n \frac{r_7}{r_6} \left(\frac{1}{2\pi R_c L} \right) \quad \text{[Cement between Casings]} \quad + L_n \frac{r_8}{r_7} \left(\frac{1}{2\pi K_s L} \right) \quad \text{[Casing Resistance]}$$

$$+ L_n \frac{r_9}{r_8} \left(\frac{1}{2\pi K_c L} \right) \quad \text{[Cement between Csg \& Hole]} \quad + L_n \frac{r_{10}}{r_9} \left(\frac{1}{2\pi K_f L} \right) \quad \text{[Distance to observation Well]}$$

	radius ID	radius OD
3-1/2" tubing	.128 (r_1)	.146 (r_2)
5-1/2" casing	.204 (r_3)	.229 (r_4)
8-5/8" casing	.33 (r_5)	.360 (r_6)
13-3/8" casing	.53 (r_7)	.558 (r_8)
17-1/4" hole	-	.719 (r_9)
distance to observation well	-	60 (r_{10})

T_{iw} = Temp. Injection Water
T_b = Temp. background
L = 40 ft.
h_{iw} = 300
K_s = 45
K_w = .363
K_c = .762
K_f = 1.83

The Sum of Thermal resistances of this system is 0.018.

If: T_{iw} = 115°F (estimated) T_b = 70° F (measured)
Then: Q = 2500 btu/hr or 21,915,000 btu/year.

The volume of the ogallala at a 60' radius (location of TH-20) from BO-3 is: 28,212,450 lb-mass.

The rise in temperature at TH-20 is
21,915,000/28,212,450 = 0.78° F/year.

Water Temperatures were measured at six observation wells including BO-3 in October 1981. The predicted temperature after nine years of salt water disposal (injection began at BO-3, September 1972) is 77° F (70° F + 7.02° F).

The measured temperature at TH-20 in October 1981 was 76° F.

Attachment 12

Joe E King
District Manager

Texaco USA

PO Box 728
Hobbs NM 88240
505 393 7191

September 22, 1987

William J. LeMay, Director
Oil Conservation Division
P. O. Box 2088
Santa Fe, NM 87504-2088

RE: Chronology of Events
Texaco Inc.
New Mexico "BO" State Well #3-SWD
Moore Field
Lea County, New Mexico

Dear Mr. LeMay:

Enclosed in this letter you will find a chronological summary of events that have taken place in Texaco's NM "BO" State Well No. 3 since its initial completion in May, 1953 to the present. After reviewing these events I am confident that you will find that the integrity of this salt water disposal well to be above reproach since its conversion in September, 1972. If you have any questions or comments concerning the subject well please contact me at this office.

Yours very truly,

Joe E King

TLT:mad

Attachments

Attachment No 13

12/19/85	Fish tubing and old packer; run new IPC tubing and packer. Pressured casing/tubing annulus to 500# and held for 30 minutes.
12/30/85	Ran injection profile indicating 79 % of injectant going below loggers TD of 10,650' and no upwards channel around casing shoe at 10,600' or 5-1/2" packer at 8372'.
9/12/85	Replaced injection packer; set packer at 8524'; pressured casing/tubing annulus to 500# and held.
2/21/82	Replaced injection packer (set at 8530') pressured casing/tubing annulus to 600# and held for 33 minutes.
11/3/81	Ran 6 casing/tubing annulus tests; five tests pressured up to 600# and recorded pressure leak-off over period of 30 minutes; final pressures ranged from 400# to 500#; the sixth pressure test was at 400# bleeding off to 0# after 2 hours and 35 minutes.
8/27/81	Replaced tubing string; set injection packer at 8860'; pressure tested casing/tubing annulus to 600# for 30 minutes.
4/23/80	Corrected tubing leak at 2745'; set injection packer at 8637'; pressured casing/tubing annulus to 500# for 30 minutes.
1/10/80	Corrected tubing leak at 2806'; set injection packer at 8387'.
4/9/79	Replaced tubing string; set packer at 8454'; pressure tested casing/tubing annulus to 600# for 30 minutes.
5/4/78	Conducted fluid level test; shutdown injection pumps at 12:30 pm; a stabilized fluid level of 1550' was established after 6 hours.
4/20/78	Conducted casing/tubing annulus test; pressured up to 600# for 30 minutes; pressured up to 560# for 40 minutes-final pressure 530#.

Attachment No 13

3/25/78	Conducted a casing test; pressured up casing/tubing annulus to 500#; bled to 400# after 75 minutes; no pressure on 8-5/8" and 13-3/8" casing strings. annulus bled to zero. Repressured annulus to 400# and again no pressure on the 8-5/8" and 13-3/8" casing string; pressure bled off to 340# after 15-1/2 hours.
2/10/78	Changed out injection packer; set at 8400'.
12/8/77	Ran injection profile; no upward channelling of injectant; all injectant going into open hole section or below TD.
9/22/77	Installed risers on all casing strings with valves above ground; 100# on casing/tubing annulus and 525# on 8-5/8" casing; both pressures bled down completely.
10/6/77	Obtained a water sample from water supply well near subject well; total hardness 1330 ppm and chlorides 1051 ppm.
3/3/76	Change out injection packer and acidize open hole section. (10,600'-10,767').
5/5/75	Change out injection packer; set at 8265'.
1/3/75	Acidize open hole section (10,600'-10,767') with 2000 gals acid.
3/27/74	Corrected tubing leak at 3000'; set injection packer at 7952'.
9/19/72	Squeeze perforations 10,536'-10,556' with 75 sacks cement; drilled deeper from 10,600' to 10,767'; acidized open hole with 1000 gals acid; ran injection tubing and packer; set at 8660'; convert to water disposal.
August/56	Squeeze perforations 10,565'-10,600'; re-perf from 10,536' to 10,556'.
May/53	Well was initially completed from perforations 10,565' to 10,600'.
	13-3/8" casing set at 318' in a 17-1/4" hole with 350 sacks cement; cement circulated at surface.
	8-5/8" casing set at 3504' in an 11" hole with 2300 sacks of cement; cement circulated at surface.
	5-1/2" casing set at 10,600' in a 7-7/8" hole with 600 sacks cement; cement top at 7910' log temperature survey.

Attachment No 13

David G. Boyer

Hydrologic Report 7

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Selected papers on water quality and pollution in New Mexico

Proceedings of a Symposium on
Water Quality and Pollution in New Mexico
April 12, 1984, Socorro, NM

Compiled by William J. Stone
New Mexico Bureau of Mines and Mineral Resources

Sponsored by
Water Pollution Control Bureau, New Mexico Environmental Improvement Division
New Mexico Bureau of Mines and Mineral Resources
Geophysical Research Center, Research and Development Division,
New Mexico Institute of Mining and Technology

SOCORRO 1984

Attachment No. 14

OIL-FIELD BRINE CONTAMINATION - A CASE STUDY, LEA CO., NM

Daniel B. Stephens, Associate Professor of Hydrology
Charles P. Spalding, Graduate Student
New Mexico Institute of Mining and Technology
Socorro, New Mexico 87801

ABSTRACT

Salt-water disposal practices in the Moore-Devonian oil field near Caprock, NM produced a plume of contamination approximately one mile long in the Ogallala aquifer near Caprock, NM. Maximum chloride concentrations are nearly 26,000 mg/l. The plume heads in the vicinity of an abandoned brine pit and an operating salt-water disposal well which injects brine underground at a depth of about 10,000 feet. There are also numerous pipelines, operating oil wells, and extensive areas scarred from brine spills. A court of law found that the abandoned pit and the injection well contributed to the contamination problem.

Ground-water monitoring near injection wells is not required by State regulation; however, such observation wells emplaced when injection begins and monitored routinely would provide data necessary to protect fresh water resources. In areas of multiple potential sources of seepage, ground-water monitoring may also protect owners and operators of disposal facilities from liability.

INTRODUCTION

The Ogallala aquifer is the sole source of potable ground water in much of southeastern New Mexico. The Ogallala is composed mostly of unconsolidated sand and gravel, and well yields are high. The availability of such an abundant supply of fresh ground water at shallow depths makes possible large-scale irrigated agriculture. In parts of eastern New Mexico this aquifer is underlain by oil reservoirs. Large quantities of brine are often produced along with oil.

The purpose of this article is to briefly describe a case of contamination of the Ogallala aquifer caused by brine seepage from oil-field activities, and to discuss existing legislation designed to protect aquifers from underground injection. It is not our intent to focus on one possible source of contamination or another, nor do we want any personal bias to be read into our description of the case study; instead we want to use this example to demonstrate that ground-water monitoring could be an effective addition to salt-water disposal practices and regulations. Thus, we have omitted discussion of technical details which, although important, do not pertain directly to the question of ground-water monitoring near salt-water disposal wells.

Attachment No 14

SITE DESCRIPTION

The study area is located in southeastern New Mexico, about 50 miles east of Roswell, just south of Caprock in northern Lea County. The topography is nearly flat, but slopes very gently eastward. Native vegetation consists mostly of sparse grasses. The mean annual precipitation is about 15 inches (38 cm) (Ash, 1963). The Ogallala Formation underlies the area and is about 100 feet (30 m) thick. The upper 20 feet (6.1 m) contains caliche which appears highly fractured in outcrops. The middle section of the Ogallala consists mostly of sand, and the lower 5 to 20 feet (1.5 to 6.1 m) contains sand with gravel in most parts of the study area. Ground water generally flows to the southeast, but the water table is influenced by irrigation pumping (Figure 1).

The Ogallala Formation was deposited during the Late Tertiary by ancestral streams from mountains to the west. The streams cut channels into underlying shale and claystone of the Triassic Chinle Formation, forming an unconformity with a very irregular surface. The very low permeability of the Chinle, also referred to as "the red beds," makes an excellent hydraulic barrier at the base of the Ogallala. The Chinle Formation is approximately 1600 feet (490 m) thick in this area (Sweeney et al., 1960). Underlying the Chinle is a thick sequence of Paleozoic sedimentary rocks, many of which bear hydrocarbons. Notable among these is a Devonian dolomite approximately 10,000 feet (3000 m) below land surface. Within the study area this oil-bearing formation is called the Moore Devonian Pool.

salt stringer below red beds or interbedded [illegible]

BRINE CONTAMINATION

In the 1950's, oil wells were drilled at approximately one-quarter mile (400 m) intervals in the Moore Devonian Pool. The proportion of saline water produced with the oil gradually increased with continued development. From about January 1953 to May 1958, approximately 752,000 barrels (119,500 m^3) of produced salt water were disposed into an unlined surface pit (Figure 1) in the northeast corner of section 23 (Runyan 1978a). The State banned the use of pits for saline water disposal in 1969, because of associated wide-spread problems of aquifer contamination. To handle the produced saline water in the Moore Devonian field, an oil well in the southwest part of section 15 (Figure 1) was converted to a salt-water disposal well. From 1966 to 1972 approximately 20 million barrels of salt water were collected from the Moore Devonian field and injected through this well, designated BO-4, back into the Devonian strata (Evelyn Downs, personal communication, N.M. Oil Conservation Div. [NMOCD], 1984). In 1972, it was discovered that the BO-4 injection well was so corroded that a repair of the well was not practical; the well was plugged and abandoned. The oil well one-

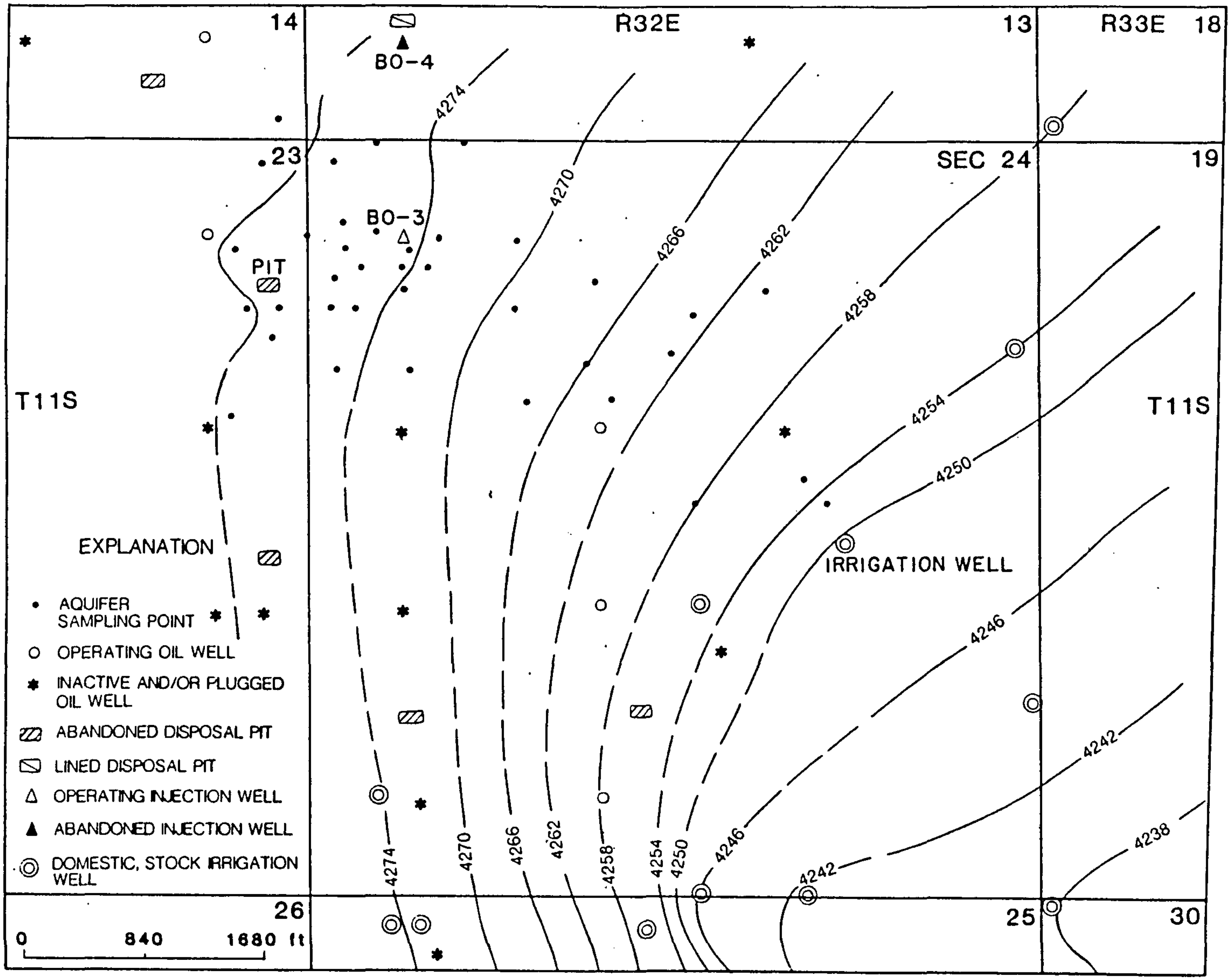


Figure 1. Water table contour map May 27, 1978 and well locations (modified from S.E. Galloway, NM State Engineers Office, Roswell)

Attachment No. 14

quarter mile to the south, BO-3, in the northwestern corner of section 24, was then converted to a salt-water disposal well (Figure 1). Construction details of the converted oil well BO-3 are given in Figure 2; these are essentially the same as BO-4. From October 1972 through July 1977, approximately 20 million barrels of salt water were injected through BO-3 into the Devonian formation at a depth exceeding 10,500 feet (Evelyn Downs, personal communication, NMOCD, 1984).

An irrigation well, completed in 1973, approximately 3900 feet (1190 m) southeast of BO-3 injection well began producing water from the Ogallala with a chloride concentration exceeding 1200 mg/l in July 1977. Crops irrigated from this well were severly damaged and the bank soon foreclosed on the farm property. There was no evidence of crop damage prior to 1977, and it is assumed that ground water quality at this well was near background, which is less than 100 mg/l chloride.

Test drilling and sampling from 1977-1978 (Runyan, 1978a,b) showed that there was a plume of saline water which appeared to originate in the northwest corner of section 24 and the northeast corner of section 23 (Figure 3). The highest concentrations of chloride occurred around the BO-3 injection well and southeast of the abandoned brine disposal pit; in places these concentrations were more than 100 times the recommended drinking water standards. The hydraulic gradients indicated in Figure 1 suggest that the probable source of contamination was either the old pit or the BO-3 injection well. Average ground-water flow velocity is on the order of at least a few hundred feet per year, on the basis of hydraulic conductivity and effective porosity data obtained from an aquifer pumping test near BO-3 (Water Resource Associates, Phoenix, written communication, 1982), irrigation well performance data (NM State Engineer Office, Roswell, NM, open file records), and hydrogeologic reports (Ash, 1963; Haven, 1966; Nicholson and Clebsch, 1961). Assuming a simple solute-transfer model, saline water from the pit which may have entered the Ogallala shortly after 1958, should have travelled well beyond the irrigation well in question by 1977.

A ground-water monitor well completed in 1978, near the base of the Ogallala, 60 feet southeast of BO-3,was sampled and analyzed. Figure 4 shows that in this well, sampled over a two year period, ground water had a chloride concentration which was generally similar to the injection water, except for the obvious peak. Moreover, the chloride concentration in this observation well was relatively unchanged over nearly a three to five year period when compared with data in Figure 3. Unless there was a subsurface barrier inhibiting saline ground-water movement, or a continuous source of saline water introduced to the aquifer, fresh ground water should have displaced much of the contamination from the vicinity of BO-3.

On the other hand, there is also evidence which suggests

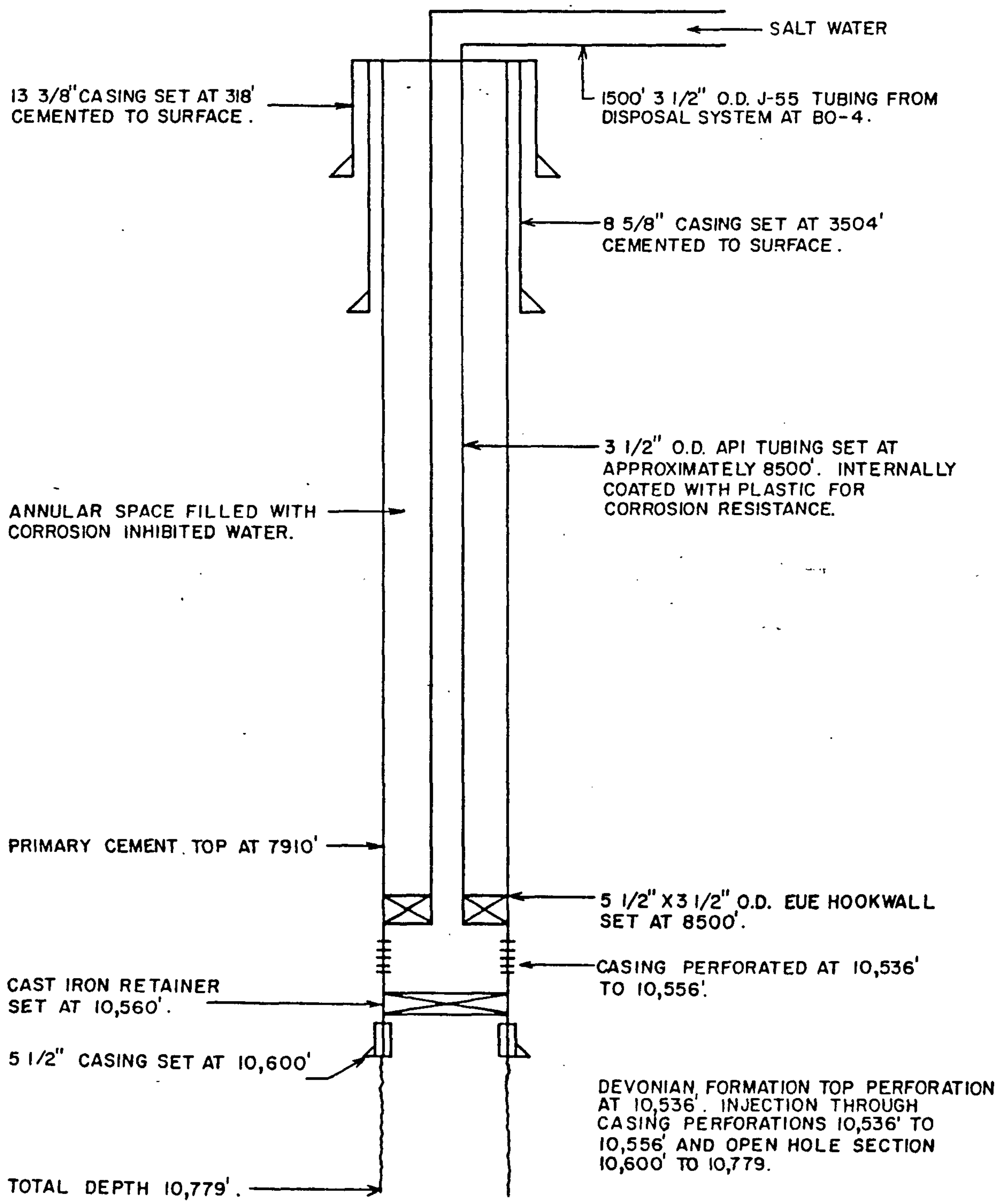


Figure 2. Injection well construction (Modified from Texico, Inc. SWD Well proposal)

Attachment No 14

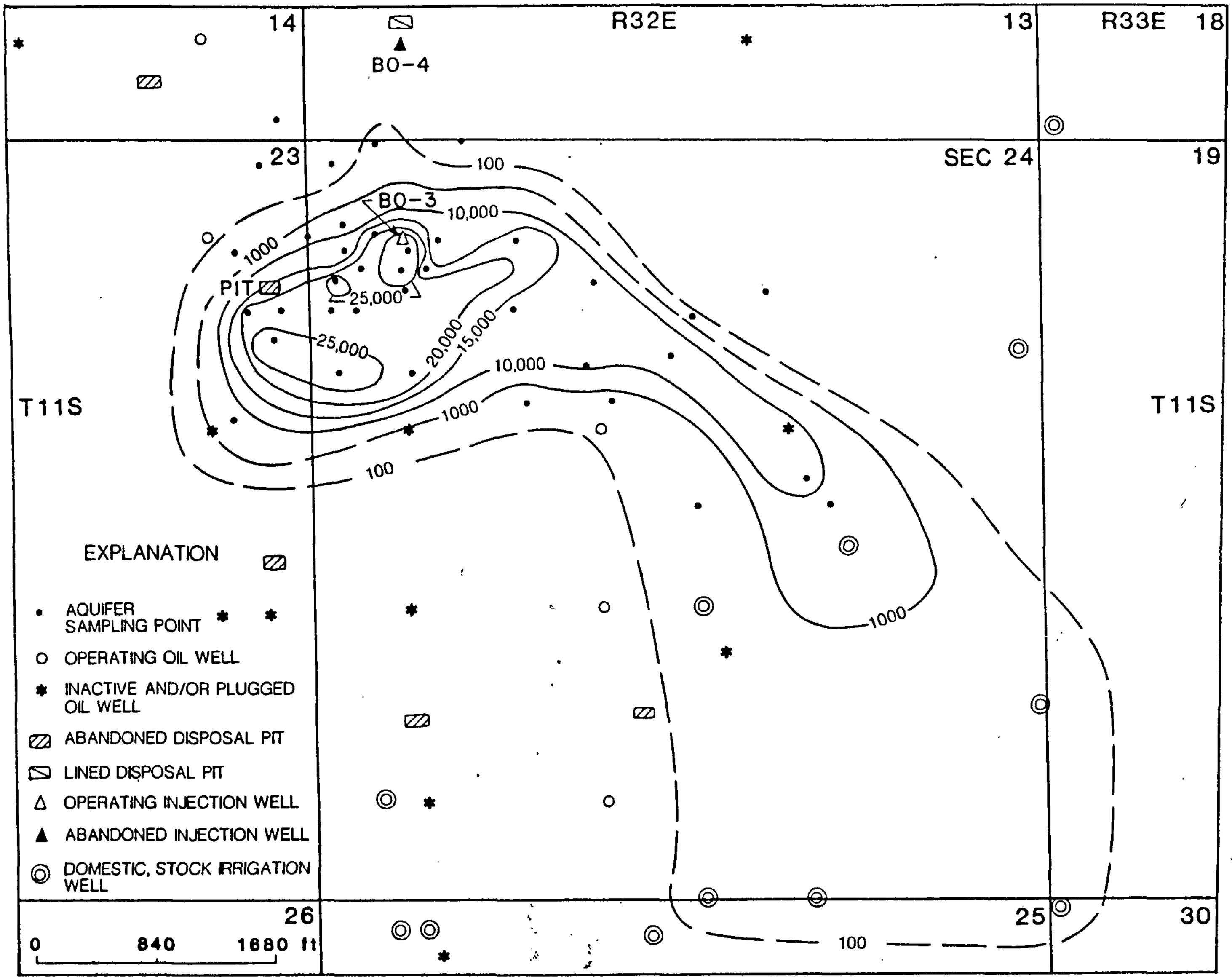


Figure 3. Chloride concentration contour map May 25, 1978 (modified from J. Runyan, NM Oil Conservation Division)

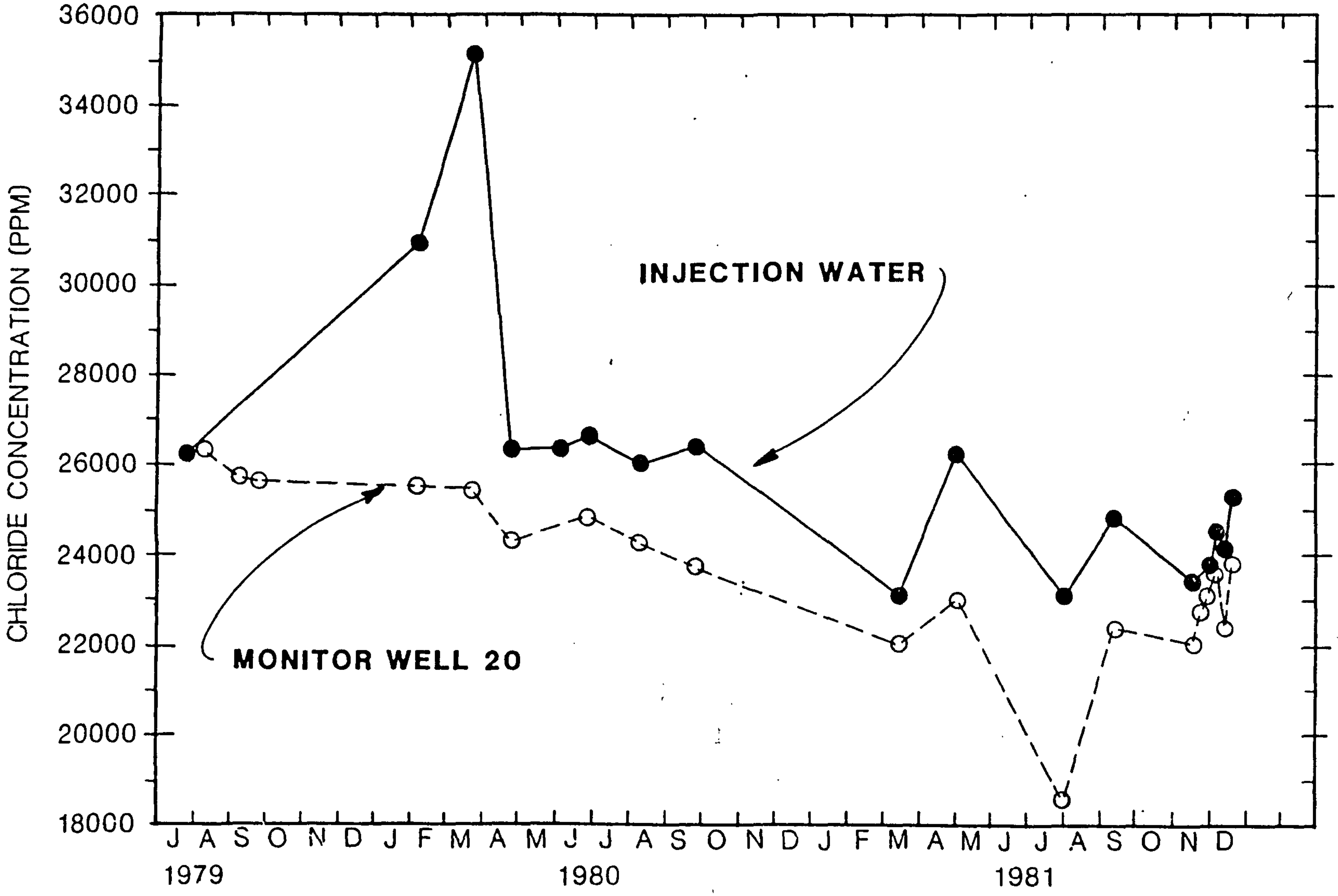


Figure 4. Chloride concentration of injected water and ground water in the Ogallala aquifer. (Analyses by New Mexico Oil Conservation Division)

Attachment No. 14

that BO-3 may not have been leaking. Figure 2 shows that BO-3 was designed to insulate injection fluid from the Ogallala with four steel casings, two of which were cemented to the surface; furthermore, the saline water is being injected nearly two miles below the bottom of the Ogallala. Mechanical integrity tests, which consist of applying and/or monitoring pressure on the casing or injection tubing annuli, were ordered by the N.M. Oil Conservation Division to detect leakage. Radioactive tracer surveys were also conducted. Mr. Richard L. Stamets (OCD, written communication, 1984) indicates that on the basis of "the numerous hearings conducted on this matter before the Oil Conservation Division, the expert witnesses appearing, the expert testimony presented, and the findings of the Commission,... there was no definitive evidence that the salt-water disposal well in question was the source of the contamination."

In 1982, a jury found that both the pit and the injection well contributed to ground-water contamination which reached the irrigation well, on the basis of the above described, and many other, technical issues (Hamilton v. Texaco, US District Court, Santa Fe).

DISCUSSION

In 1981, the OCD assumed responsibility for enforcing the federal Underground Injection Control (UIC) Program which was set forth under the Safe Drinking Water Act (PL 93-523, as amended). According to these regulations, monitoring for Class II injection wells is only required in the injection well unless otherwise stipulated in the permit by the NMOCD. Monitoring essentially consists of a mechanical integrity test at least once every five years; however, since 1978 New Mexico has performed bradenhead tests to check mechanical integrity annually on all salt-water disposal wells in southeast New Mexico (R. L. Stamets, NMOCD, written communication, 1984). According to regulations, the injection well also needs to have facilities available to make measurements of injection and annulus pressure, and monthly injected fluid volume. Other tests may also be required, as ordered by the Director of NMOCD. In reference to the case study of underground injection of saline oil-field water in northern Lea County, no ground-water monitoring in the Ogallala aquifer was required, according to existing regulations. The following discussion will illustrate some of the arguments in favor of ground-water monitoring for the protection of injection well operators and potable ground-water users.

In a typical oil field there are numerous potential sources of saline seepage to shallow aquifers besides injection wells and pits. According to the Petroleum Engineer journal (July, 1967, p. 35) "oil field pollution occurs from ... overflowing waste pits, leakage from broken lines, improperly plugged wells, improperly cased and cemented wells, salt water production from an exploratory core hole, and many other surface and subsurface forms". Many of these potential sources of contamination may be owned and operated by different companies. On the basis of this case study, it might be prudent for the owner of a newly completed salt-water disposal well to install monitor wells to establish baseline conditions before injection begins, as well as a ground-water monitoring-well network surrounding the injection well in order to detect encroaching salt water from other sources. That is, if it is true that the injection well did not ever leak and that all saline water is attributed to the pit, then a few shallow ground water monitor wells drilled prior to converting BO-3 would have shown that the aquifer was already contaminated; this conclusive finding probably would have prevented the costly litigation just described.

Ground-water monitoring of underground injection beneath highly vulnerable and valuable aquifers such as the Ogallala, is crucial to protecting the agricultural economy of the area described in this report. In this case study, 160 acres of farm land was rendered unirrigable, owing to the brine contamination. (However, the present landowner, Mr. Jess Tolton [Caprock NM, personal communication, 1984], reported that he has used an irrigation well located south of the affected irrigation well, apparently just beyond the plume, for small-scale irrigation.) If one assumes, on the basis of hydrologic evidence, that the injection well actually had a leak when the mechanical integrity tests were performed, then the mechanical integrity tests alone may not be a sufficiently reliable means of protecting aquifers. Part of the problem in interpreting mechanical integrity tests may be in detecting leaks which are quite small. A continous, slow rate of leakage comprising only a few percent of the total injection rate could have accounted for contamination near BO-3, for example. Without ground-water monitor wells, extensive aquifer contamination is possible during the five-year period between mechanical integrity tests. At rates of ground-water flow on the order of a few hundred feet per year, typical of high permeability aquifers, the number of contaminated agricultural and domestic wells would soon be appreciable. Annual testing of Class II wells in New Mexico which began in 1978, is a step toward minimizing impacts to ground water, and annual mechanical integrity tests on all injection wells (including Class I and III) completed near fresh-water sources should be encouraged. Depending upon the magnitude of the leak and the time when the leak first develops, even annual mechanical integrity tests may not be adequate to avoid extensive brine contamination. It is reported that annual testing in New Mexico reveals about two percent failures (U.S. EPA, 1983, p. 5).

Injection well BO-3 continues to operate as the salt-water disposal well for the Moore Devonian Pool. There has been no effort to date to clean-up the contamination described in this case study, owing in part to litigation which

Attachment No 14

was pending in 1982. More importantly perhaps, the cost of restoring the Ogallala would be quite substantial, inasmuch as the volume of aquifer contamination is on the order of 50 million cubic feet. Valuable irrigated farm land is located east and southeast of the case study area, in the direction of the contaminant plume described in Figure 3. A few shallow ground-water monitor wells at strategic locations near injection wells, drilled at a cost of approximately $15 per foot of depth, would be a relativiely inexpensive means of monitoring injection wells and protecting ground-water resources.

ACKNOWLEDGEMENTS

The authors would like to thank the reviewers of drafts of this paper for their comments, in particular Mr. R. L. Stamets and staff of the N. M. Oil Conservation Division. The cooperation of Mr. John Gannon of Texaco Inc., Mr. Paul Hamilton, Mr. Jim Wright and Mr. Sherman "Pinky" Galloway of the State Engineer's Office is also acknowledged.

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January 26, 1984

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Dear Mr. Stephens:

Your proposed publication relative to the Moore-Devonian water contamination case forwarded in your letter of January 19, 1984, was received in this office on January 25. The report has been reviewed by Mr. Jerry Sexton, Mr. Joe Ramey, and myself.

Based on this review, there are serious questions with the proposed publication. Some of the problems with the report are as follows:

1) The report fails to note that new owners are now irrigating the property from a well located outside the plume area.

2) The report fails to note that the OCD performs annual mechanical integrity tests on all salt water disposal wells in Southeast New Mexico. This expanded test program began in 1978.

3) The report fails to mention the numerous hearings conducted on this matter before the Oil Conservation Division, the expert witnesses appearing, the expert testimony presented, and the findings of the Commission that there was no definitive evidence that the salt water disposal well in question was the source of the contamination. The order of the Commission was never challenged in court by Mr. Hamilton.

4) In the third paragraph of the discussion you indicate that a slow rate of leakage over a long

Attachment No 15

time could account for the contamination near the BO-3 well. However, I see no calculations of the volume of water necessary to have created the plume and at what rate the "slow leak" would have had to have been in order to have pumped that volume of salt water into the Ogallala and whether or not such a rate could have been detected by the tracer surveys run.

5) There was no discussion of the nature and extent of the tracer surveys run on the well and their results.

6) You indicate that mud pits, producing oil wells, improperly plugged and abandoned oil wells, etc. are sources of saline seepage to shallow aquifers. This implies that contamination is occurring from these sources but you offer no scientific proof. There is a world of difference between being a potential source and an actual source.

Because of the apparent superficial nature of the report, I cannot endorse any part of it. Futher, I am appalled at what appears to be a one-sided unscientific approach to a very complex problem.

Sincerely,

RICHARD L. STAMETS
Technical Support Chief

RLS/dp

Attachment No 15