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INVESTIGATION OF GROUND-WATER CONTAMINATION IN THE JULIANA AND WEST JUD OIL FIELDS HASKELL AND STONEWALL COUNTIES, TEXAS

By

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
Statement of Problem	1
Method of Investigation	1
LOCATION AND ECONOMY	1
GEOLOGY	1
GROUND WATER	3
Occurrence	3
Quality	3
BRINE PRODUCTION AND DISPOSAL	3
Production	3
Disposal	3
SUMMARY OF CURRENT INVESTIGATION	4
CONCLUSIONS	7
RECOMMENDATIONS	8
REFERENCES	9

TABLES

1. Geologic formations and their water-bearing characteristics, northwestern Haskell County, Texas	10
2. Surface-casing data, Juliana field, Haskell County, Texas	11
3. Surface-casing data, West Jud fields, Haskell County, Texas	12
4. Records of wells in Haskell County	13

TABLE OF CONTENTS (Cont'd.)

Page

5. Selected chemical analyses of produced oil-field brine in Haskell County.. 16

6. Chemical analyses of water samples in northwestern Haskell County.. 17

ILLUSTRATIONS

Figures

1. Map Showing Location of Juliana and West Jud Oil Fields, Haskell County.. 2

2. Pattern Diagrams Illustrating the Effects of Brine Contamination on the Chemical Character of Natural Ground Water in the Seymour Formation (Juliana Strawn, West Jud Strawn and West Jud Bend Conglomerate Fields, Haskell and Stonewall Counties.............. 5

3. Analyses Represented by Three Points Plotted in Trilinear Diagram.. 6

Plates

Follows

1. Juliana and West Jud Oil Fields Showing Location of Water Wells, Oil Wells, Disposal and Collection Systems.................... Page 18

2. Generalized Cross Section of West Jud and Juliana Oil Fields..... Plate 1

INVESTIGATION OF GROUND-WATER CONTAMINATION IN THE
JULIANA AND WEST JUD OIL FIELDS
HASKELL AND STONEWALL COUNTIES, TEXAS

INTRODUCTION

Statement of Problem

On March 6, 1963, the Texas Water Commission received a request from Mr. O. B. Ratliff for assistance in determining the source of salt-water contamination of an irrigation well on Mr. Ratliff's property in northwestern Haskell County. Judge O. F. Dent, a Commissioner of the Texas Water Commission, transmitted the request to the Ground Water Division for field study.

Method of Investigation

During the course of this investigation which was conducted April 15 through April 19, 1963, completion data was obtained, and water levels were measured in water wells located in or adjacent to the area of contamination (table 4); water samples were obtained from 35 water wells for chemical analysis (table 6); and water wells, oil wells, and salt-water disposal systems were located on a map of the area (plate 1).

LOCATION AND ECONOMY

The area of investigation lies in the northwest corner of Haskell County and eastern Stonewall County. The Juliana and West Jud oil fields are included in the area of investigation which is approximately eight miles west of the city of O'Brien in Haskell County (see figure 1).

Irrigated agriculture, oil production and stock farming are the principal contributors to the economy of the area.

GEOLOGY

Rocks of the Wichita Group of the Permian System are the oldest rocks which crop out in Haskell County. Rocks of the Clear Fork Group of the Permian System immediately overlie the Wichita Group in most of the county and underlie the Seymour Formation in the area of investigation. The Wichita and Clear Fork Groups consist mainly of shale, thin beds of limestone, dolomite, gypsum, sandstone and marl as shown in Table 1.

Unconsolidated sediments of the Seymour Formation of Pleistocene age occur at the surface in the area of investigation. The Seymour Formation in northwestern Haskell County attains a maximum thickness of about 60 feet and consists of coarse-grained sand and gravel, fine-grained sand and silt, red and gray clay, caliche, and some volcanic ash. The upper part of the formation usually consists of fine-grained sand and silt underlain by thin beds of unconsolidated caliche.

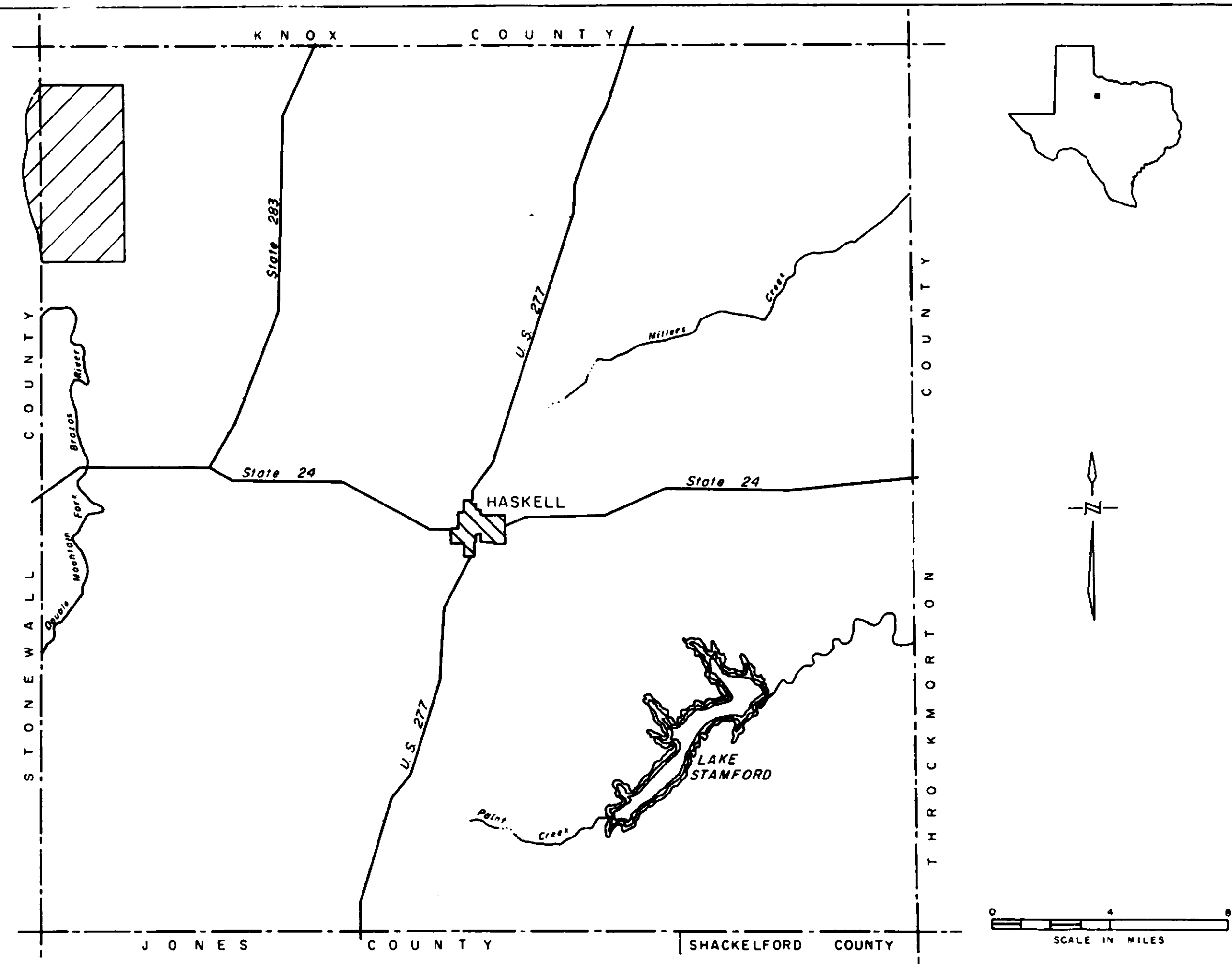

Figure 1

MAP SHOWING LOCATION OF JULIANA AND WEST JUD OIL FIELDS, HASKELL COUNTY

Texas Water Commission

154

The lower part of the formation consists of coarse-grained material, grading into a very coarse gravel which is interbedded with lenses of clay. The gravel is comprised chiefly of rounded pebbles of chert, quartz, igneous rocks and limestone (Ogilbee & Osborne, 1962).

GROUND WATER

Occurrence

The Seymour Formation is practically the only source of ground water of usable quality in the area of investigation. Wells producing from Permian rocks yield only small quantities of water which is generally too highly mineralized for domestic or irrigation use. Recharge to the Seymour is through precipitation on its outcrop which extends over the northwest and north-central part of Haskell County. Water occurring in the Seymour Formation is under water-table conditions; however, because of the presence of lenticular clay zones, it may be locally under sufficient pressure to rise in wells a short distance above the top of the water-bearing bed.

Regionally the direction of ground-water movement in the Seymour Formation in Haskell County is to the north-northeast. Locally, however, in the area of investigation, the direction of ground-water movement is to the north-northwest.

Quality

The native quality of water in the Seymour Formation in northwest Haskell County is generally good, although the water is hard and sometimes high in nitrate (see table 6). The water from the formation has been reportedly suitable for domestic and irrigation uses throughout the period during which it has been developed by wells.

BRINE PRODUCTION AND DISPOSAL

Production

An inventory, made by the Texas Railroad Commission in 1962, of salt-water production and disposal for the calendar year 1961 indicates that a total of 180,250 barrels of salt water was produced in the West Jud (Bend Conglomerate) and West Jud (Strawn) fields, and 272,375 barrels of salt water was produced in the Juliana field.

Disposal

The 1961 salt-water inventory indicates that 100% of the total salt water produced in the West Jud fields was disposed of by injection into the subsurface interval of 4,967 to 4,977 feet below land surface. Of the total salt water produced in the Juliana field, the inventory indicates that 98.4%, or 267,995 barrels, was disposed of by injection into subsurface intervals ranging from 2,087 to 5,163 feet, and 1.6%, or 4,380 barrels, was disposed of into unlined surface pits. However, no evidence of surface-pit disposal was observed during the current investigation.

In July, 1955, a "no-pit" order was issued by the Texas Railroad Commission for both of the fields involved in this study. This was followed in 1960 by a Railroad Commission order which cancelled permits previously issued for annular injection in these fields.

No samples of the produced brines were obtained during this investigation. However, chemical analyses were obtained from the publication "Resistivities and Chemical Analyses of Formation Waters from the West Central Texas Area," which was prepared by the West Central Texas Section of the Society of Petroleum Engineers of A.I.M.E. These chemical analyses are shown in Table 5.

SUMMARY OF CURRENT INVESTIGATION

The field study, which was conducted in response to Mr. Ratliff's complaint of ground-water contamination, was directed toward two primary objectives: (1) to determine if evidence of water-quality deterioration was present and (2) if such chemical quality deterioration had occurred, to determine the source of the contaminant.

The native quality of ground water in the area of investigation is a calcium-magnesium-bicarbonate variety. Figure 2 shows a comparison, through pattern diagrams, of the produced brines, the native quality of the ground water, and the chemical quality of the contaminated water in each field. Figure 3, which is a representation of the analyses represented by three points plotted in trilinear diagrams, also shows the native quality of ground water and quality of contaminated water in each field.

The area of investigation can be broken down into two smaller areas; the Juliana and West Jud oil fields (see plate 1).

Concerning the West Jud oil field area, the position of the points on figure 3 indicates that water from wells 17, 18, 19, 28, 31, 34, and 35 is of native quality and that the water in wells 20, 21, 22, 25, 26, 27, 29, and 30 has been contaminated. A study of the analyses from the contaminated wells in the West Jud oil field area suggests that base exchange is taking place as the contaminant moves through the formation. That is, calcium and magnesium in the formation are replacing sodium in the contaminant, thus resulting in a calcium-magnesium-chloride water rather than a sodium-chloride water. However, studies of the analyses of water samples from wells 20 and 30 indicate an absence of the degree of base exchange found in the other contaminated wells.

In the Juliana oil field area, evaluation of chemical analyses of water from wells 1, 2, 3, 5, 6, 7, 10, 16, 23, 24, 32, and 33 suggests that these wells produce water of native quality. On the other hand, the native quality of water in wells 4, 9, 11, 13, 14, and 15 apparently has been altered. (see figure 3). Quality of water from wells 4, 13, and 14 is of a sodium-chloride type, whereas the water from wells 9, 11, and 15 is of the calcium-magnesium-chloride type, suggesting that the contaminant or contaminants affecting the latter three wells has been altered by base exchange.

Possible sources of the contaminants in the two oil-field areas include past use of unlined surface pits, movement of salt water from the Coleman Junction Limestone, and use of faulty injection wells.

In July, 1955, the Railroad Commission of Texas issued a no-pit order covering both the Juliana and West Jud oil fields. However, one large pit was reportedly used from 1951 until 1959 for salt-water disposal for the Hutchinson lease in the West Jud field, and some surface pits were reportedly used during the same period of time in the Juliana field (see plate 1). Although small pits, commonly called "basic-sediment pits," are still being used intermittently for flushing tanks and back-flushing wells or for emergency disposal of brine, no evidence of surface-pit disposal was observed during the current investigation.

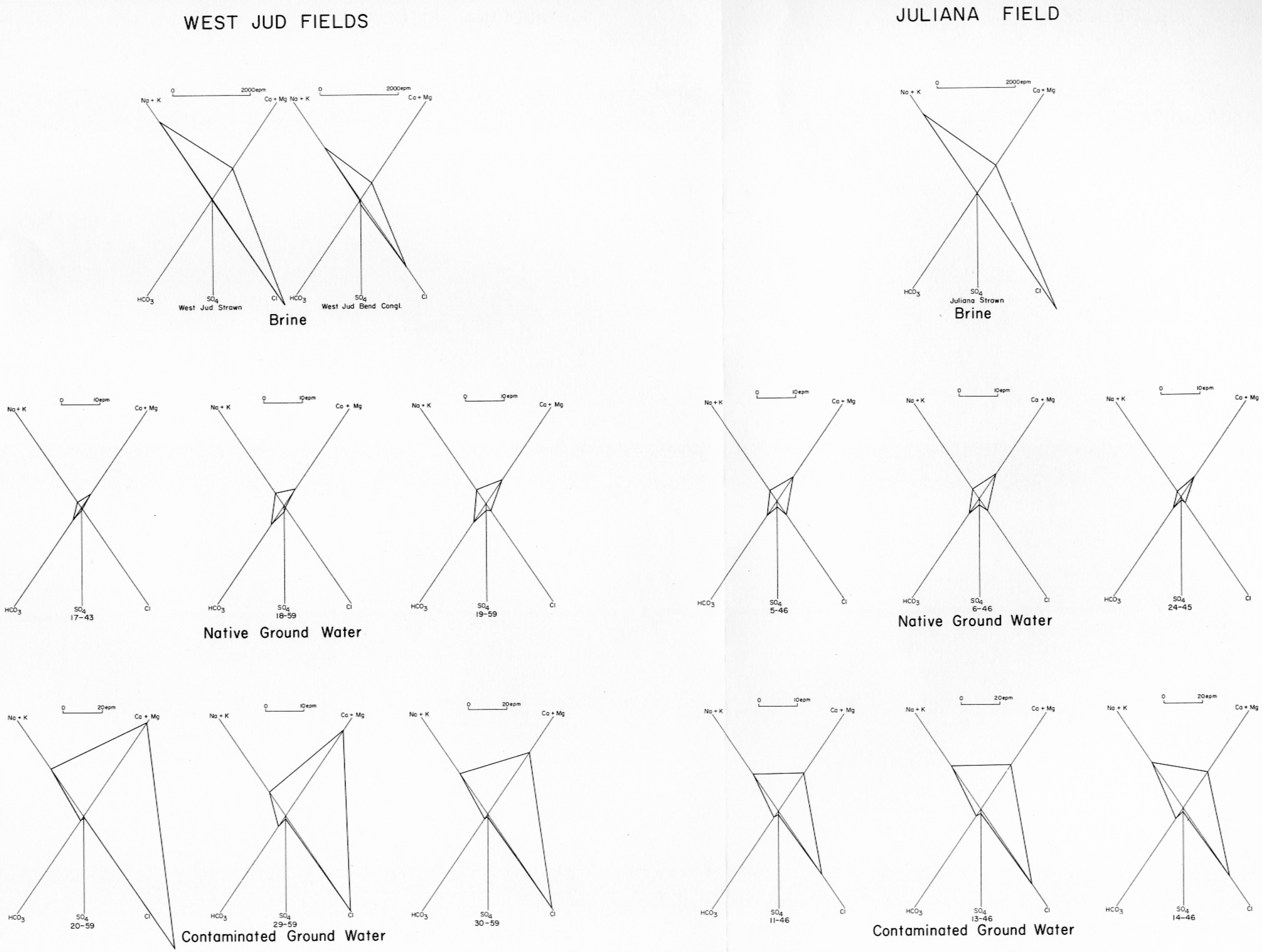

Figure 2

PATTERN DIAGRAMS ILLUSTRATING THE EFFECTS OF BRINE CONTAMINATION ON THE CHEMICAL CHARACTER OF NATURAL GROUND WATER IN THE SEYMOUR FORMATION (JULIANA STRAWN, WEST JUD STRAWN AND WEST JUD BEND CONGLOMERATE FIELDS, HASKELL AND STONEWALL COUNTIES)

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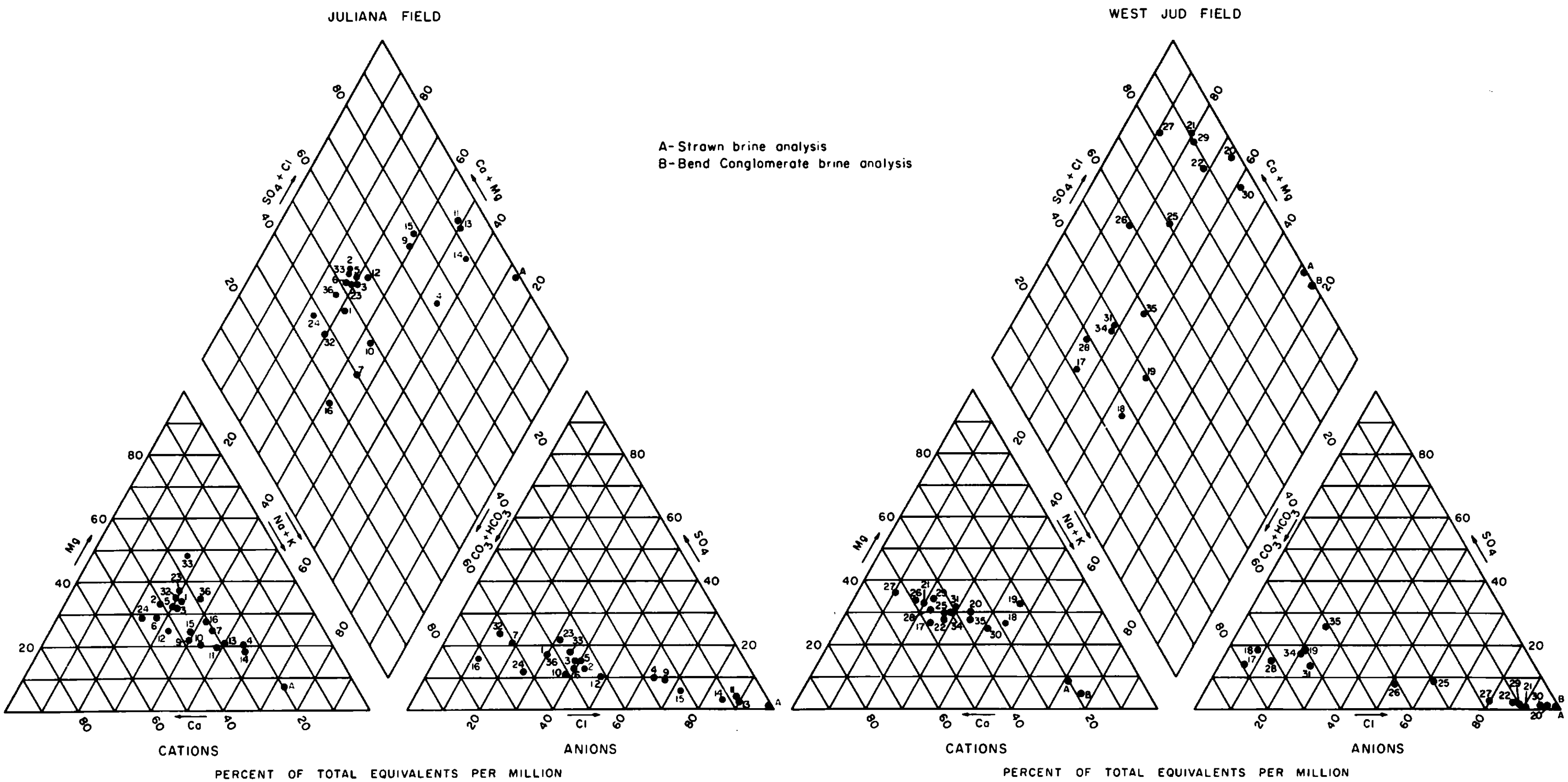

Figure 3

ANALYSES REPRESENTED BY THREE POINTS PLOTTED IN TRILINEAR DIAGRAM

(after A. M. Piper)

Texas Water Commission

Salt water, flowing upward from the Coleman Junction Limestone, could definitely be affecting the water quality in this area. Water in the Coleman Junction Limestone will flow at the surface through wells that penetrate the formation. A check of the files of the Railroad Commission indicates that abandoned wells in the area contain sufficient surface casing for protection of the Seymour Formation, and cement plugs were used in the base of the surface casing when the wells were abandoned (see tables 2 and 3). However, the records do not indicate that cement plugs were used to confine the water to the Coleman Junction. Thus, brine under pressure from the Coleman Junction could rise in the annular space between the long string and the bore hole and move into zones immediately below the surface casing. It was noted during the field investigation that surface injection pressures up to 1,200 psi (pounds per square inch) were necessary to inject salt water into the Coleman Junction Limestone. One operator in the area reported instances of casing failure which were suspected to be caused by high pressures in the Coleman Junction Limestone. Sohio Oil Company reported that because of excessively high pressures necessary for injection into the Coleman Junction and incidences of long string casing failure opposite that zone, they plan to abandon their Coleman Junction injection systems.

Shallow annular or bradenhead disposal of salt water has been used by several companies throughout the area. Surface-casing records on salt-water injection wells permitted by the Railroad Commission are shown in Tables 2 and 3. Most of the bradenhead injections were accomplished at depths ranging from 160 to 250 feet below land surface and with pressures ranging up to 400 psi. However, in 1960 the Railroad Commission cancelled several permits that had been issued for bradenhead injection. This action was taken as a result of a report, dated February 17, 1960, by James E. Smith, Railroad Commission Engineer.

The Anna Mae Hutchinson et al.well No. 4 was reportedly an annular disposal well in the West Jud field from 1959 until 1961. This well was completed with 198 feet of surface casing and reportedly required operating pressures up to 700 psi.

The only injection well in operation in the West Jud field during this field investigation was the Alvin C. Hope-Mayes No. 1-A. This well is equipped to confine the injected salt water in the subsurface interval 4,967 to 4,977 feet. Several pilot waterflood systems are in operation in the area but the Railroad Commission records indicate that no large-scale operations are now in existence.

CONCLUSIONS

1. The native quality of ground water in the area of investigation is of a calcium-magnesium-bicarbonate type. The water is generally hard, and in some instances high in nitrates, but is within the ranges of usable quality for municipal uses as established by the State Department of Health.

2. Some deterioration in ground-water quality has occurred in the area of investigation. Evaluation of the chemical analyses of the ground water by means of radial and trilinear coordinates indicates modification of the chemical character of the native ground water by salt water. This investigation does not indicate a single source of the contaminant, however, the following possible sources of the contaminant are indicated: (1) past use of unlined surface pits for disposal of oil-field brine, (2) movement of brine from the Coleman Junction Limestone into the Seymour Formation, and (3) leakage from faulty injection wells.

(1) Although there was no disposal of oil-field brines into unlined surface pits at the time of the investigation, surface pits have been used in the past for brine disposal. Because of the loose permeable nature of the Seymour Formation, a portion of the salt water that was placed in the pits undoubtedly seeped downward to the water table. Brines which have thus entered the Seymour Formation will move with the ground water to points of natural discharge or to producing water wells.

(2) The Coleman Junction Limestone, occurring at depths between 1900 and 2050 feet below the land surface, is an artestian brine aquifer which is under sufficient head to cause brine flows at the surface through wells penetrating the formation in the area. Plugging records of all oil or gas wells indicate that plugs were not set above the Coleman Junction to isolate the salt water to that interval. Therefore, an avenue is open for movement of brine from the Coleman Junction up the hole.

(3) Injection of oil-field brines at shallow depths, ranging from 150 to 300 feet, may have resulted in some contamination of ground water in the area because of the excessively high injection pressures necessary to put the fluid into the shallow zone; however, the Railroad Commission began cancelling permits for such shallow disposal in some wells in the two fields in 1960. High injection pressures necessary to inject salt water into the Coleman Junction may also present a hazard to ground water in the area.

RECOMMENDATIONS

1. Disposal of produced salt water into unlined surface pits should not be allowed on the Seymour Formation.

2. Disposal of produced salt water should not be attempted into or above the Coleman Junction and associated zones. This interval includes the base of the Valera Shale to the base of the Sedwick (see plate 2).

3. In plugging producing wells or dry holes, all precautionary measures should be utilized to confine fluids to the Coleman Junction and associated zones.

4. All new oil and gas wells should be completed in a manner which would assure that brine from the Coleman Junction and associated zones is sealed off from overlying strata.

REFERENCES

Ogilbee, William, and Osborne, F. L., Jr., 1962, Ground Water Resources of Haskell and Knox Counties, Texas: Texas Water Commission Bull. 6209, 174 p.

Texas Water Commission and Texas Water Pollution Control Board, 1963, A statistical analysis of data on oil-field brine production and disposal in Texas for the year 1961, from an inventory conducted by the Texas Railroad Commission: Unpublished rept., 17 vols.

Table 1.--Geologic formations and their water-bearing characteristics, Northwestern Haskell County, Texas

ERA	SYSTEM	SERIES	GROUP	STRATIGRAPHIC UNIT	LITHOLOGIC CHARACTER	WATER-BEARING CHARACTERISTICS
Cenozoic	Quaternary	Pleistocene		Seymour Formation Unconformity	Stratified, sandy clay, and lentils of gravel. Basal layers in most places are sand and gravel, containing well rounded chert and quartz pebbles and some limestone cobbles.	Principal fresh-water aquifer in Haskell County. Well yields range from 50 to 1300 gpm. The water is of suitable chemical quality for most purposes.
Paleozoic	Permian	Leonard	Clear Fork	Vale Formation	Shale, sandstone, and dolomite.	Yields small quantities of poor-quality water which is used chiefly for livestock.
				Bullwagon Dolomite Member	The Bullwagon Dolomite Member - two thin strata separated by a shale parting-represents the top of the Vale Formation.	
				Arroyo Formation	Shale, limestone, marl, sandstone, and gypsum.	Not known to yield water to wells in Haskell County.
				Rainy Limestone Member	The Rainy Limestone Member consists of dark fossiliferous limestone much of which is weathered.	
			Wichita	Lueders Limestone	Fossiliferous Limestone and shale.	Not a source of water.
				Clyde Formation	Limestone and shale	Not a source of water.
				Belle Plains Formation	Consists of alternating limestone, shale, and small stringers of sandstone.	
				Admiral Formation	The Admiral Formation consists mainly of shale with small stringers of limestone and sandstone.	Undetermined-interpretation of electrical log indicates probable presence of brine. Could be as result of recharge from Coleman Junction.
				Putnam Formation	The Putnam Formation consists of shale and limestone members. Coleman Junction is main limestone member.	The Coleman Junction in this area is known to contain brine under sufficient pressure to flow to surface. When used for brine disposal - excessive pressures result.
				Sedwick Member	Limestone and thin shale beds.	

Table 2.--Surface-casing data, Julianna field,
Haskell County, Texas

OPERATOR	LEASE	BLK. NO.	WELL	FEET OF SURFACE CASING	TOTAL DEPTH PROTECTED BY CEMENTED CASING
Texaco, Inc.	First National Bank of Ft. Worth, Williams Unit (02085)	2	1	198	--
		2	2-SWD	163 at 173'	--
Texaco, Inc.	Beulah Branch (02084)	43	1-Brad.	166 at 179'	--
	do	43	2	163	--
	do	43	3	163	--
Texaco, Inc.	S. B. Williams "A" (02086)	44	1	166	--
		44	2	154	--
		44	3	153	--
		44	4	158	--
Katz Oil Company	Hunley, C.K. (02083)	45	1	120.95	--
		45	2	125.67	--
Texas Pacific Coal & Oil Company	Campbell (02087)	1	1	134.51	--
		1	2	136.71	--
		1	3	135.69	--
		1	4	133.25	--
		1	5	138.57	--
		1	6	134.20	--
		1	7	304.48	--
Texas Pacific Coal & Oil Company	Clyde Grissom (02088)	46	1	271.22	--
		46	2	266.31	--
		46	3	133.42	--
		45	4	136.89	--
Texas Pacific Coal & Oil Company	Hunley, Claudia K., AC. # 1 (02089)	45	1	131.46	--
		45	2	136.15	--
		45	3	139.69	--
Texas Pacific Coal & Oil Company	L. E. Hughes	46	1*	325.21	--
	do	45	2*	137.61	--
Texas Pacific Coal & Oil Company	Juliana McGregor (02090)	46	1	314.61	--
		47	2†	263	999
		46	3*	170	--
		46	4‡	167.83	--
		47	5*	122	--
		47	6†	122.77	722
Katz Oil Company	C G. Wright	43	1	105	1161
	S. W. Neely	44	1	132	--
Great Lakes Carbon Corp'n.	H. M. Rike	43	1	184	--
White Wall Oil Co. Inc.	E. L. Hughes	44	1	132	--
C. B. Drilling Co. Imes & Hickey	L. E. Hughes	46	1	160	--

* Dry hole
† Plugged producer
‡ Plugged producer now SWD Well

Table 3.--Surface-casing data, West Jud fields,
Haskell County, Texas

OPERATOR	LEASE	BLK. NO.	WELL	FEET OF SURFACE CASING	TOTAL DEPTH PROTECTED BY CEMENTED CASING
Rowan & Hope	A. M. Hutchinson	58	1	179	--
Do.	do	58	2	202	--
Do.	do	58	*3	223	--
Do.	do	58	3-A	190	--
Do.	do	58	†4	198	--
Do.	do	58	5	225	--
Do.	do	58	6	349	--
Do.	C. L. Mayes	4	1	240	--
Do.	do	4	†1-A SWD	200	4998
Do.	do	4	2	218	--
Rowan & Hope	L. A. Jones	58	*1	250	980
Alvin C. Hope	Mrs. Winnie B. Kay	58	1	265	--
Do.	do	58	2	229	--
Fletcher Oil and Gas Drlg. Corp'n.	A. B. Kempton	57	*1	111	--
Alvin C. Hope	L. A. Jones	58	1	225	--
Sid Katz	Dollie Helton	58	*1	204	--
Do.	Webb-Short Unit	59	*1	129	--
Hack Drilling Co. & Wayne Pet. Corp'n.	Walter L. Nanny	59	*1	120	--
Alvin C. Hope	Bell & Speck	57	*1	219	2754
Sinclair Oil & Gas Company	Clarence Webb	59	*1	129	--

* Dry hole
† Plugged producer now SWD Well

Table 4.--Records of wells in Haskell County

All wells are drilled unless otherwise noted in remarks.
Method of lift and type of power: B, bucket; CW, cylinder wind; N, none; T-B, turbine butane; T-E, turbine electrical.
Use of Water: D, domestic; Irr, N, none; S, stock.

Well No.	Owner	Driller	Date completed	Depth of well (ft.)	Casing		Water Bearing unit	Water Level		Method of lift	Use of Water	Remarks
					Diameter (in.)	Depth (ft.)		Below land surface datum (ft.)	Date of Measurement			
1-47	O. B. Ratliff	--	--	Spring	--	--	Seymour	--	--	--	S	During irrigation season flow is small.
2-47	Do.	J. M. Rea	--	--	--	--	Do.	--	--	--	Irr.	*
3-47	Do.	Do.	--	--	16	--	Do.	18.0	4-16-63	T,B	Irr.	Hand bailed water sample.
4-47	Do.	Do.	--	--	14	--	Do.	16.4	Do.	T,B	Irr.	*
5-46	L. E. Hughes	Do.	--	--	14	--	Do.	--	--	T,B	Irr.	*
6-47	O. B. Ratliff	Do.	--	--	12	--	Do.	22.6	4-16-63	T,B	Irr.	*
7-47	Do.	Do.	--	--	14	--	Do.	24.2	Do.	N	N	*Hand bailed water sample.
8-48	Do.	Do.	--	--	14	--	Do.	25.7	Do.	N	N	
9-46	L. E. Hughes	Do.	--	--	14	--	Do.	25.4	4-16-63	T,E	Irr.	
10-45	Do.	--	--	--	--	--	Do.	--	--	T,E	D	*
11-46	Do.	--	--	45	--	--	Do.	26.0	4-17-63	N	N	*Hand bailed water sample.
12-46	Do.	--	--	--	--	--	Do.	26.0	4-17-63	T,E	Irr.	*
13-46	Do.	--	--	--	--	--	Do.	28.4	4-17-63	N	N	*Hand bailed water sample.
14-46	Do.	--	--	--	--	--	Do.	30.5	4-17-63	N	N	* Do.
15-46	Do.	--	--	--	--	--	Do.	29.8	4-17-63	N	N	* Do.

*See footnote at end of Table.

Table 4.--Records of wells in Haskell County-Continued

Well No.	Owner	Driller	Date completed	Depth of well (ft.)	Casing Diameter (in.)	Casing Depth (ft.)	Water Bearing unit	Water Level Below land surface datum (ft.)	Water Level Date of Measurement	Method of lift	Use of Water	Remarks
16-48	Karl McGregor	--	--	--	--	--	Seymour	21.8	4-17-63	T,B	Irr.	*
17-43	R. H. Johnson	--	--	57	12	--	Do.	40.8	4-17-63	T,E	Irr.	*
18-59	L. M. Petters	--	1954	30	16	--	Do.	25.4	4-17-63	T,E	Irr.	*
19-59	Do.	J. M. Rea	--	--	14	--	Do.	24.8	4-17-63	T,E	Irr.	*
20-59	M. C. Webb	--	--	--	14	--	Do.	25.0	4-18-63	T,E	N	*
21-59	Louis Nanny	--	--	30	--	--	Do.	--	--	T,E	S	*Dug
22-58	Pete Helton	J. M Rea	1959	40	12	--	Do.	--	--	T,E	S	*
23-46	Texas Pacific Coal and Oil Corp.	--	--	--	--	--	Do.	--	--	T,E	D	*
24-45	C B. Keller	J. M. Rea	1962	42	14	--	Do.	--	--	T,B	Irr.	*
25-58	L. A. Jones	--	--	--	--	--	Do.	--	--	C,W	S	*
26-43	E. L. Ray	--	1956	48	--	--	Do.	--	--	T,E	D	*
27-43	W. D. Edge	--	--	--	--	--	Do.	25.0	--	B	N	*Dug well-Hand bailed water sample.
28-58	L. A. Jones	--	1955	40	--	--	Do.	--	--	T,B	Irr.	*
29-59	Elmo Stephens	--	--	--	--	--	Do.	--	--	T,E	N	*
30-59	Lewis	--	--	--	--	--	Do.	--	--	T,E	N	*
31-44	E. L. Hughes	--	--	--	--	--	Do.	--	--	T,E	D	*
32-45	S. P. Keller	--	--	--	--	--	Do.	--	--	C,W	D	*Dug
33-47	O. B. Ratliff	--	--	--	--	--	Do.	--	--	T,E	D	*

*See footnote at end of Table.

Table 4.--Records of wells in Haskell County-Continued

Well No.	Owner	Driller	Date completed	Depth of well (ft.)	Casing Diameter (in.)	Casing Depth (ft.)	Water Bearing unit	Water Level Below land surface datum (ft.)	Water Level Date of Measurement	Method of lift	Use of Water	Remarks
34-57	Ira Short	--	--	--	--	--	Seymour	--	--	N	N	*Hand bailed water sample.
35-57	Do.	--	1956	--	--	--	Do.	24.6	4-19-63	T,E	D	*
36-47	O. B. Ratliff	J. M. Rea	1963	30	--	--	Do.	--	--	T,E	D	*

* See table 6 for analysis of water.

Table 5.--Selected chemical analyses of produced oil-field brine in Haskell County*

(Analyses given are in parts per million)

Producing zone	Field	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids	pH
Strawn	Juliana	13,205	2,619	56,430	77	139	128,150	--	5.0
Do.	West Jud	15,500	2,170	54,900	165	225	118,000	214,000	6.2
Bend Congl.	do	8,200	1,300	36,900	305	600	74,500	139,100	6.8
Swastika	do	7,810	1,940	44,500	100	935	87,500	161,300	7.5

* Obtained from publication "Resistivities and Chemical Analyses of Formation Waters from the West Central Texas Area", prepared by West Central Texas Section of the Society of Petroleum Engineers of A.I.M.E.

Table 6.--Chemical analyses of water samples in northwestern Haskell County

1-47 (Well No.-Blk. Number)

(Analyses given are in parts per million except specific conductance and pH)

Well	Owner	Depth of Well (ft.)	Date of Collection	Silica (SiO_2)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluor-ide (F)	Ni-trate (NO_3)	Dis-solved Solids	Total Hard-ness as $CaCO_3$	Specific Conductance Micromhos at 25°C.)	pH
1-47	O. B. Ratliff	Spring	4-16-63	30	83	50	90	336	84	112	1.1	84	870	413	1147	7.6
2-47	Do.	--	4-16-63	27	85	35	66	265	60	141	0.7	48	730	387	1027	7.3
3-47	Do.	--	4-16-63	28	79	43	75	267	67	133	0.7	50	740	373	1047	7.2
4-47	Do.	--	4-16-63	27	116	61	319	393	116	530	0.6	44	1610	540	2450	7.3
5-46	L. E. Hughes	--	4-16-63	29	80	45	76	285	60	146	0.9	39	760	385	1070	7.4
6-46	O. B. Ratliff	--	4-16-63	29	93	38	69	290	62	137	0.6	40	760	390	1030	7.3
7-47	Do.	--	4-16-63	22	57	28	96	314	92	58	1.1	38	710	258	833	7.4
9-46	L. E. Hughes	--	4-16-63	27	133	48	162	271	69	409	0.5	34	1150	530	1830	7.4
10-45	Do.	--	4-17-63	28	69	26	100	293	53	124	0.7	31	730	279	983	7.4
11-46	Do.	--	4-17-63	22	287	111	530	238	79	1410	0.5	29	2710	1170	4600	7.1
12-46	Do.	--	4-17-63	28	95	35	86	274	49	181	0.7	30	780	383	1132	7.4
13-46	Do.	--	4-17-63	30	320	139	620	279	77	1690	0.7	27	3180	1370	5300	7.2
14-46	Do.	--	4-17-63	26	252	123	660	378	73	1520	0.6	11	3040	1130	5000	7.2
15-46	Do.	--	4-17-63	25	152	65	190	287	63	520	0.7	20	1320	650	2180	7.3
16-48	Karl McGregor	--	4-17-63	27	54	31	89	359	65	35	1.0	51	710	262	838	7.4
17-43	R. H. Johnson	57	4-17-63	29	51	18	31	237	34	12	0.9	28	441	201	508	7.5
18-59	Loyd Petters	30	4-17-63	22	51	30	92	337	70	23	1.4	84	710	249	845	7.6
19-59	Do.	--	4-17-63	23	69	46	95	356	87	74	1.2	84	840	362	1080	7.4
20-59	M. C. Webb	--	4-18-63	25	620	323	680	168	32	2950	0.7	40	4840	2880	8350	7.1

Table 6.--Chemical analyses of water samples in northwestern Haskell County--Continued

Well	Owner	Depth of Well (ft.)	Date of Collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total Hardness as $CaCO_3$	Specific Conductance (Micromhos at 25°C.)	pH
21-59	Louis Nanny	--	4-18-63	30	393	168	188	207	29	1300	0.7	48	2360	1670	4110	7.2
22-58	Pete Helton	40	4-18-63	27	241	94	177	196	29	820	0.5	22	1610	990	2780	7.2
23-46	Texas Pacific Camp	--	4-18-63	30	89	61	95	312	113	119	0.7	144	960	472	1320	7.3
24-45	C. B. Keller	42	4-18-63	29	67	25	39	246	36	61	0.8	27	530	273	690	7.2
25-58	L. A. Jones	--	4-18-63	30	151	65	105	312	84	357	0.7	19	1120	640	1720	7.1
26-43	E. L. Ray	48	4-19-63	28	120	51	48	287	46	211	0.5	38	830	510	1200	7.2
27-43	W. D. Edge	--	4-19-63	27	186	77	44	192	21	480	0.4	17	1040	780	1870	7.1
28-58	L. A Jones	40	4-19-63	27	64	27	37	278	46	32	0.9	20	540	272	654	7.1
29-59	Elmo Stephens	--	4-19-63	23	398	143	169	201	36	1040	0.7	26	1940	1330	3500	7.2
30-59	Lewis	--	4-19-63	28	435	194	585	176	27	2060	0.7	23	3530	1880	6050	7.0
31-44	E. L. Hughes	--	4-19-63	30	73	36	61	306	56	71	0.8	48	680	330	896	7.2
32-45	S. P. Keller	--	4-19-63	29	70	43	72	366	110	47	1.0	36	770	351	938	7.4
33-47	O. B. Ratliff	--	4-19-63	29	81	94	99	394	121	181	1.2	90	1090	590	1500	7.4
34-57	Ira Short	--	4-19-63	25	74	33	58	305	70	59	1.1	36	660	320	848	7.2
35-57	Do.	--	4-19-63	20	91	40	99	320	130	82	0.6	110	890	391	1100	7.4
36-47	O. B. Ratliff	30	4-16-63	31	84	63	125	433	111	147	1.0	60	1060	468	1350	7.2

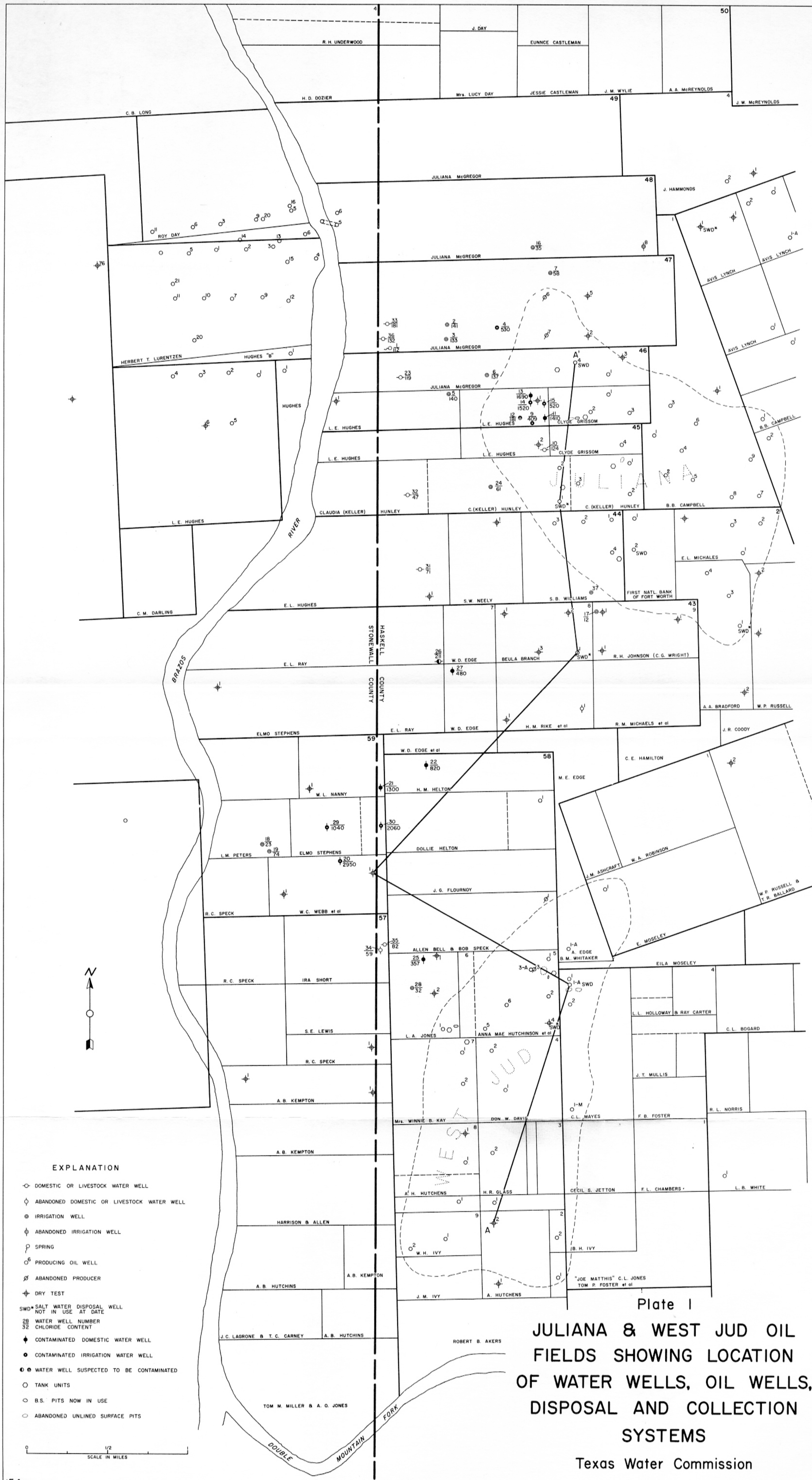

Plate I

JULIANA & WEST JUD OIL FIELDS SHOWING LOCATION OF WATER WELLS, OIL WELLS, DISPOSAL AND COLLECTION SYSTEMS

Texas Water Commission

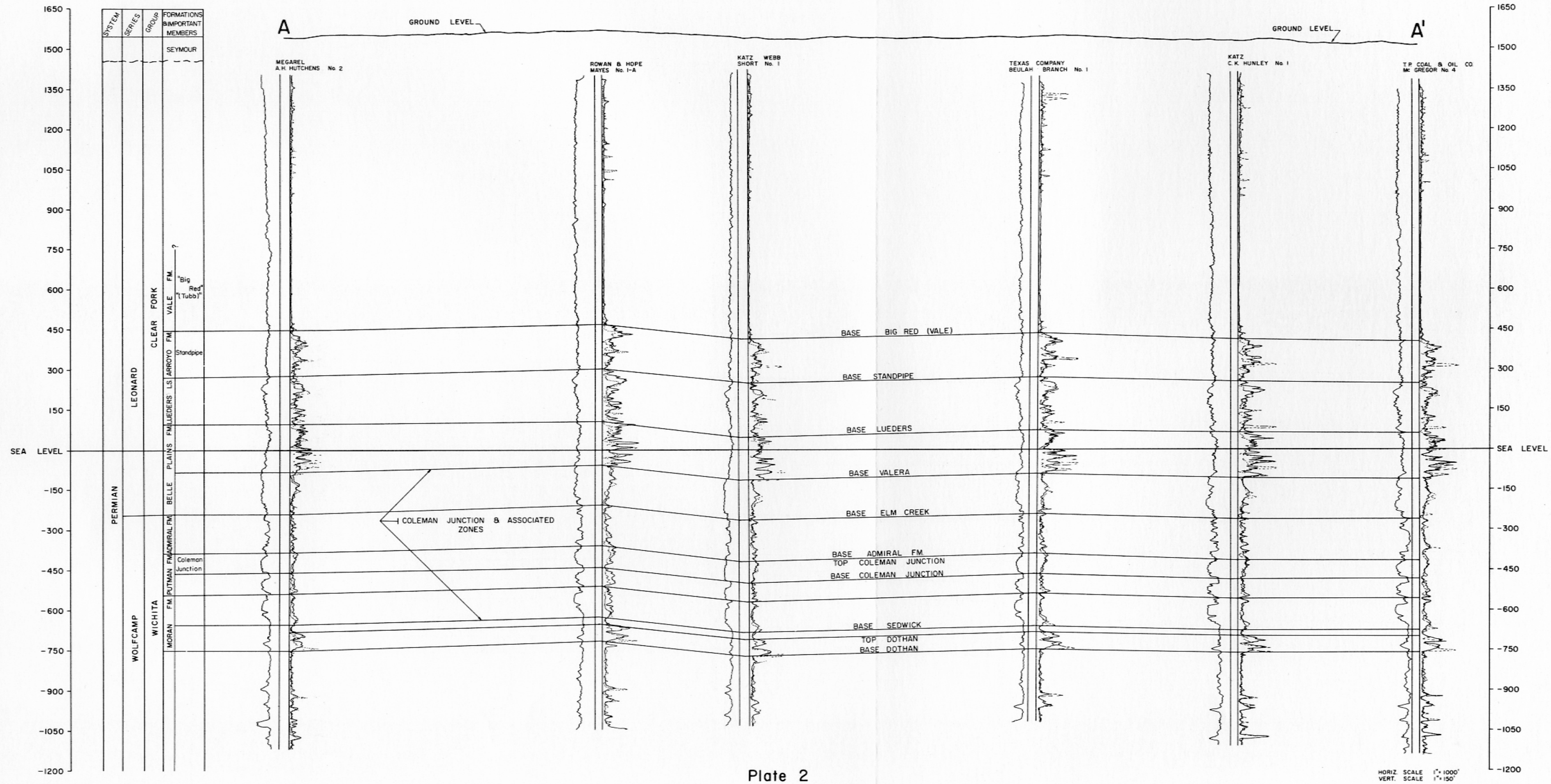

Plate 2

GENERALIZED CROSS SECTION OF WEST JUD AND JULIANA OIL FIELDS

(Section Line A-A', Plate 1)

Texas Water Commission