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DISPOSAL OF OIL-FIELD BRINES IN KANSAS

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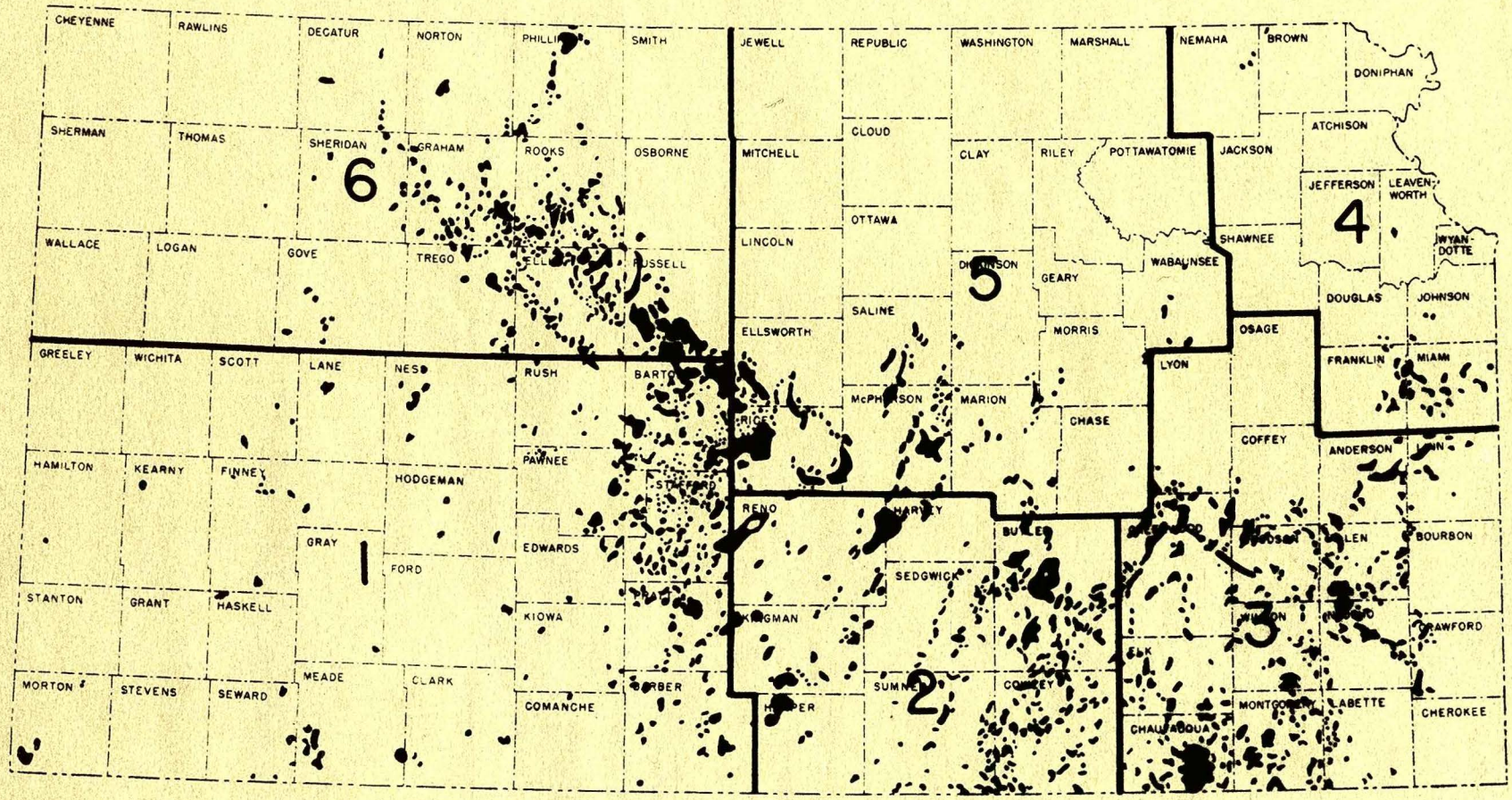
The Brine-Disposal Problem in Kansas

Oil (and the accompanying nuisance, salt water) has been produced in Kansas for nearly a century. In 1956, petroleum production in the state amounted to 124,467,713 barrels (Goebel and others, 1957). Along with this oil, it is estimated that 1,557,198,720 barrels of oil-field brine was produced. This latter figure, however, is misleading unless one understands that water used in the process of secondary recovery of oil is included in this estimate. In secondary-recovery operations large quantities of water, mostly from deeper formations, are injected into the oil-producing formation, and some of this water is again produced along with secondary-recovery oil. Inasmuch as water produced with oil is added to other water and injected, the process is one of recycling. According to the State Board of Health's estimates, 3,160,658 barrels of brine is being placed in disposal ponds and into disposal wells daily in Kansas.



Map of Kansas showing location of oil producing areas, 1956, and Board of Health administrative districts.

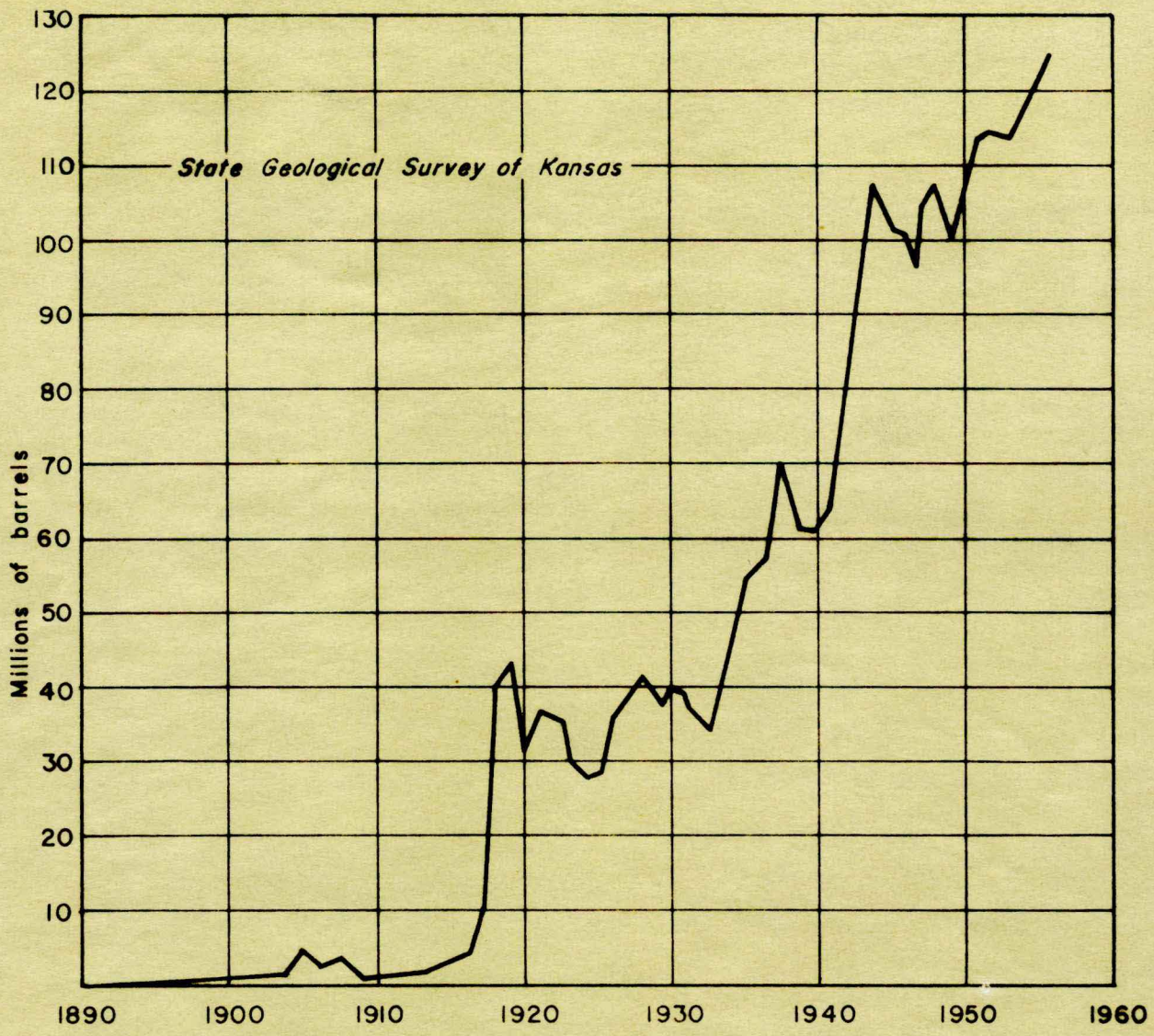
Figure 1 shows location of oil and gas producing areas and administrative districts in Kansas; figure 2 shows, graphically, annual oil production in Kansas from 1890 to 1956 inclusive.

Problems relating to oil-field brines and the hazards of polluting fresh water both in the subsurface and on the surface in areas of secondary recovery (waterflood operations) are somewhat different from problems incurred in areas of primary oil production. Waterflooding is practiced largely in oil fields in the eastern part of the State, whereas primary methods account for most of the oil production in central and western Kansas.

Kansas produced an estimated 15.1 million barrels of oil by means of waterflooding processes (Goebel and others, 1957) during 1956. This oil was produced from about 7,000 oil wells in secondary-recovery projects, in which approximately 1,060 repressuring wells were in operation. An estimated 1,202,040 barrels of water (including large amounts of recycled water) was injected daily in repressuring wells.

From the foregoing discussion, it is seen that great floods of brine are brought daily from the deep rocks to the land's surface in Kansas and that these salty waters may constitute a real hazard to the State's supply of fresh water, the importance of which needs no explanation.

It is, of course, recognized that the bringing of oil-field brines to the land's surface is a necessary part of petroleum production; the overall problem, then, involves the disposal of salty waters with minimum economic and aesthetic damage. The immediate economic hazard involves the danger of pollution of fresh water, and perhaps all attentuating hazards in reality are joined with fresh-water pollution problems.



Annual oil production in Kansas from 1890 to 1956.

Figure 2

If one is to understand the pollution problems that are generated by produced oil-field brines and to formulate procedures that are deemed feasible as disposal practices, it is necessary to review the general water-supply situation in Kansas.

For water for various uses, the people of Kansas must depend on underground water (obtained from wells), on streams, and on supplies artificially impounded. Wells range in capacity from those yielding a gallon water or less per minute to those yielding several hundreds of gallons per minute; streams range in size from small streams to Missouri River; and artificially impounded supplies range from water held in farm cisterns to the largest artifial lakes in the State. Hence, it is necessary to protect both surface and underground water from pollution by oil-field brines. The relative amounts of usable water that comes from the various sources concern us little here.

The total storage in underground fresh-water reservoirs in Kansas probably is some 200 million acre-feet (Foley, Smrha, and Metzler, 1955). The western and south-central parts of the State contain the largest reservoirs, which are mainly in Tertiary and Pleistocene sediments in the High Plains and in some topographically lower regions. In most of eastern Kansas, large yields of fresh ground water can be had only from Pleistocene deposits, chiefly below the flood plains of larger rivers. In the extreme southeastern part of the State, however, bedrock aquifers that lie at a depth of about 1,000 feet yield large amounts of fresh water.

In most parts of eastern Kansas fresh water is not found at depths below 250 to 300 feet. In places the depth to salt water is less than 100 feet. However, there are some exceptions to this general situation. One small city obtains its supply from wells slightly more than 400 feet deep; and in some places in the eastern part of the State usable water has been found at about 500 feet. The occurrence of salt water at shallow depth is due in part to careless handling of oil-field brines.

A sizable amount of brine turned loose on the surface eventually finds its way into natural drainage courses, where it pollutes fresh water. Also salts that are residues from evaporated impounded waters eventually will be redissolved by surface water that finds its way into natural drainage courses or that becomes underground water. During the fiscal year of July 1, 1956, to June 30, 1957, the State Board of Health received 231 complaints in reference to alleged oil-field brine pollution.

Both surface and underground waters may be polluted by oil-field brines other than the "produced waters." That is to say, improperly plugged wells and improper completions, which are not germane to this paper, cause pollution.

It should be noted that surface waters may become polluted with highly mineralized waters in a natural manner. According to Foley, Smrha, and Metzler (1955, Fig. II-13), natural saline ground water is contributed to streams in two major areas in Kansas. One area is a southwest-northeast trending belt about 25 miles wide and 150 miles long extending from northern Barton County and northestern Rush County to the northeastern part of Republic County and the northwestern part of Washington County. The Smoky Hill,

Saline, Solomon, and Republican Rivers cross this area. The other area lies along the lower part of Rattlesnake Creek in the northeastern part of Rice County. Highly mineralized waters also are added naturally to surface waters in some other parts of the State.

Industries other than that of oil production may contribute to stream pollution. According to Foley, Smrha, and Metzler (1955, p. 103 and Fig. IV-6), sources of industrial pollution in Kansas include oil refineries, chemical and fertilizer plants, railroads, salt plants, milk processing plants, meat and poultry packing plants, and aircraft metal fabricating plants.

Regulations

In Kansas the use of surface ponds and the use of injection wells are recognized as legal methods of oil-field brine disposal. Both the State Board of Health and the State Corporation Commission are charged with administrating laws and with issuing rules and regulations pertaining to brine disposal.

"Rules and Regulations," as authorized by General Statutes 65-171 and as amended by the 1957 Legislature, promulgated in 1957 by the Kansas State Board of Health, contain these paragraphs:

> The storage or disposal of salt water, oil, or refuse in surface ponds shall be prohibited unless a permit for such storage or disposal shall first be obtained from the State Board of Health, except that such ponds that are in use on or before July 1, 1957, may be used without a permit until

January 1, 1958, subject to the rules and regulations for the prevention of surface and subsurface water pollution and soil pollution detrimental to public health or to plant, animal or aquatic life of the state.

Applications for permits for storage or disposal of salt water, oil or refuse in surface ponds shall be submitted in duplicate to the Director of the Oil Field Section, Division of Sanitation, Kansas State Board of Health, on forms obtainable from said Director.

1. Operators shall provide satisfactory evidence that surface ponds intended for the storage of salt water, oil or refuse will not cause surface or subsurface water pollution or soil pollution detrimental to public health or to plant, animal, or aquatic life of the state. The State Board of Health may require the installation of observation trenches or holes to determine seepage or leakage.

2. All surface ponds shall be designed for normal operation with a minimum of thirty (30) inches freeboard measured at the lowest point of the top of the dike. Freeboard shall never be less than twelve (12) inches, measured from the lowest point of the top of the dike.

Under date of October 4, 1957, the Director of the Oil Field Section of the State Board of Health made these statements:

> The bill [House Bill #219, 1957 Legislature] and the rules set up to guide its administration provide that permits will be issued only for ponds which do not seep and which do not carry any threat to public health, animal, aquatic or plant life. Permits must be obtained for ponds constructed after July 1, 1957, and all ponds in use after January 1, 1958, must have a permit. In most areas this requires that a pond be sealed, and if it is making much water, the brine will have to be re-injected or hauled to a disposal well.

In Kansas permits for salt water disposal and for water injection for repressuring and pressure maintenance are issued by the Conservation Division of the State Corporation Commission, but applications are reviewed by the Director of the Oil Field Section, State Board of Health. Recent legislation (House Bill 515, 1957 Legislature) has made it mandatory that the State Board of Health, the State Water Resources Board, and the State Geological Survey submit recommendations to the State Corporation Commission for the protection of fresh and usable waters in reference to underground disposal of brines. The State Corporation Commission is authorized to use these recommendations in promulgating rules and regulations.

Under the date of October 14, 1957, the State Corporation Commission Conservation Division, included in its order Docket No. 34,780-C (C-1815):

> The Commission in passing upon applications for the use of nonproducing formations for disposal use, will give consideration to the determinations on file with the Commission (denomination Table II) made by the State Board of Water Resources, the State Board of Health, and the State Geological Survey establishing minimum safe depths for salt brine or other oil field waste disposal wells for all producing areas in the state, in determining whether such formtions may be safely and legally used.

In June, 1957, the State Board of Health, the State Water Resources Board, and the State Geological Survey submitted to the State Corporation Commission a table (Table II, referred to above) in which minimum depths for disposal wells in each of the Kansas counties were recommended. In some counties only depths were specified, and in some, geological horizons (for example "Top of Cheyenne Sandstone") were given as recommended minimum depths for disposal wells.

The Effect of Brine Disposal and Enforcement Procedures on Oil Production

The brine disposal enforcements required by the new statutes, rules, and regulations seem to have little, if any, effect on the State's production of oil, in that Kansas has had an annual increase in the production of oil during the past six years.

The Board of Health enforces its rules and regulations for correct oil-field brine disposal. Whenever the Board receives a complaint of improper disposal from any citizen or from one of the Board's geologists, an investigation is made. If it is found that the brine is polluting fresh water, the operator of the lease where the alleged improper disposal is taking place is asked to cooperate by correcting the situation. If the operator refuses to cooperate, legal action may be taken. Generally the condition is corrected immediately and cooperation is assured. Seemingly most oil producers in Kansas do not object to the disposal regulations. There is little evidence of any adverse effect on oil production in the State.

Penalties for Improper Disposal

Laws that cover various disposal procedures and the drilling of all wells that penetrate salt-water-bearing formations provide for fines ranging from $25.00 to $1,000.00.

Resume of Brine Production and Methods of Disposal

Although oil was discovered in Kansas in 1860 and commercial production followed soon (Jewett, 1954, p. 26), little attempt was made to prevent damage from salt water for many years. This statement can be made in spite of the fact that nearly all known oil-producing formations in the State contain some brine and in spite of the fact that damage to land and to water must have been taking place. Undoubtedly in the early days of Kansas oil production irreparable damage was done. Nevertheless, few complaints were made. As pointed out by the State Board of Health (1956, p. 2), "Land was cheap and the royalty checks were eagerly sought." Early Kansas oil and gas reports made no mention of brine-disposal problems, but references were made to salt waters as a

menace to the successful operation of oil wells (Fath, 1921, p. 172).

The time arrived, however, when landowners, city officials, and oil operators began to give serious consideration to the problems of brine disposal.

The first attempt to curtail and prevent damage to land and water by Kansas oil-field brines was through the use of surface ponds planned to hold brine. Seemingly it was assumed that evaporation would take care of the salt water. It was evident that the evaporation does not remove the dissolved minerals in the water, and furthermore it was soon found that ponds filled and overflowed unless they leaked substantially into the subsurface. Many streams were polluted and probably many fresh-water aquifers were contaminated from these ponds.

In eastern Kansas, evaporation from exposed water surfaces generally is nearly equalled by rainfall. Where such is the case it is inevitable that ponds into which quantities of brine are placed will overflow. It is said that operators purposely breached pond levies in times of high water stages in nearby streams. Such practice, obviously, was well taken under the circumstances, as it allowed brines to enter surface waters when the least amount of pollution would take place. In all probability this practical method of brine disposal is still taking place in some parts of Kansas.

For some time previous to 1935, the problem of oil-field brine disposal was building to a climax. Litigation pertaining to pollution of fresh water was costly to oil operators and courts were granting heavy damage penalties. Three things were done by the State Legislature in 1934 to safeguard water supplies from oil-field pollution: (1) The Oil Field Section of the Division of Sanitation, Kansas State Board of Health, was established, (2) the Legislature passed an act that allowed the return of brine to subsurface formations

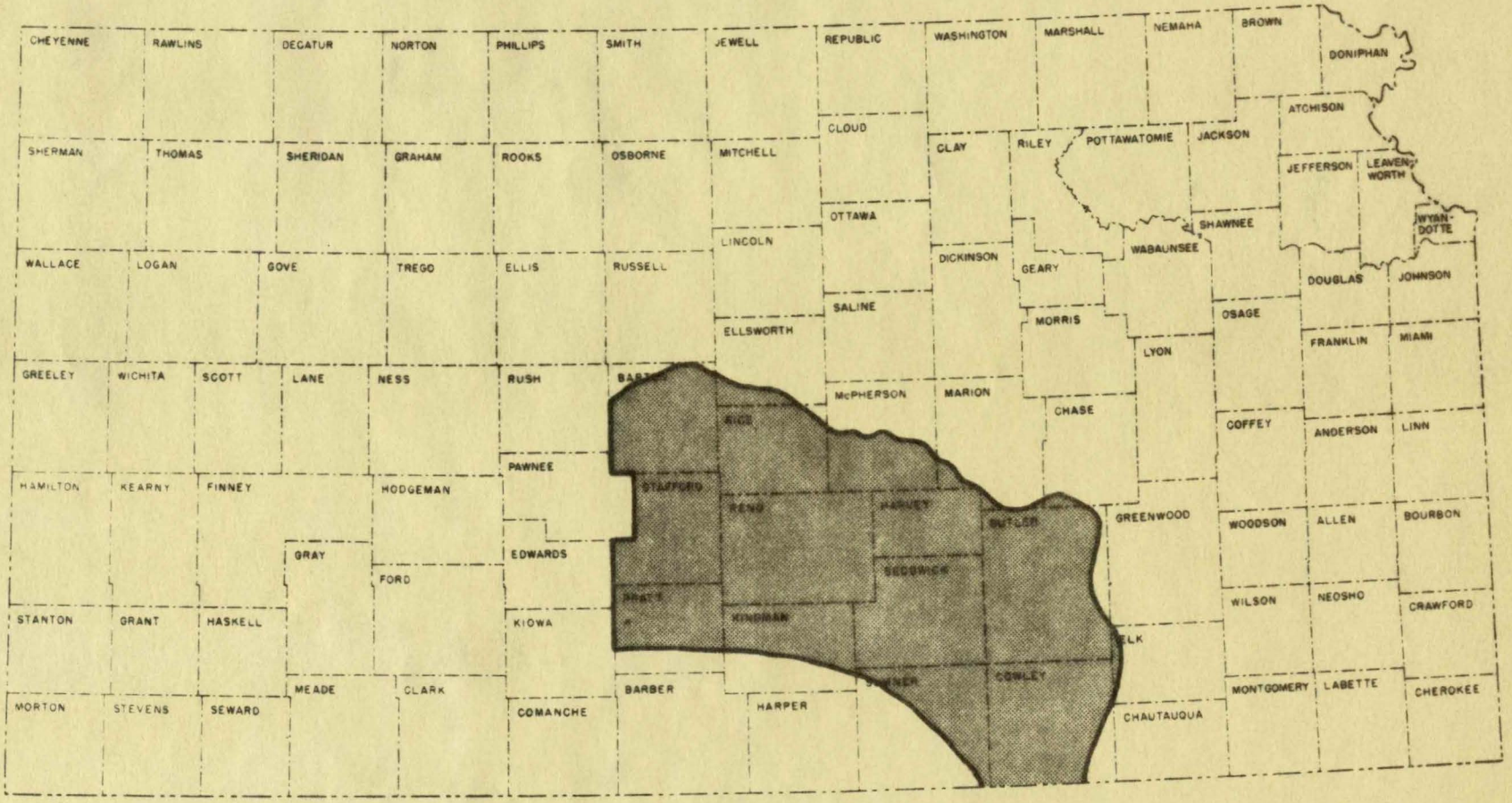
carrying mineralized waters but not producing oil, and (3) the Legislature passed an act that allowed waterflooding of oil-producing formations.

At the present time there are about 1,353 surface ponds in use in Kansas. These ponds receive an estimated 41,697 barrels of brine per day. There are also a large number of "treatment ponds" that are parts of waterflood operations, and these treatment ponds may be sources of pollution.

About 2,843 brine injection systems in Kansas are receiving an estimated 4,321,001 barrels of brine per day. This includes secondary-recovery operations.

In 1953, the Oil Field Section of the State Board of Health made a detailed study of brine disposals in an area in Arkansas River Basin comprising about one-fifth of the oil-producing area in Kansas. The area covered by the study includes some of the largest and smallest oil fields, both old and new producing areas and some areas in which repressuring is being done. All or major parts of Butler, Cowley, McPherson, Harvey, Sedgwick, Sumner, Rice, Reno, Kingman, Barton, Stafford, and Pratt Counties, and small parts of Ellsworth, Marion, and Chase Counties are included in the area studied (Fig. 3). According to the Board of Health (1956, p. 6-7), "the study revealed 652 surface ponds in use; these received 27,617 barrels of brine per day. In comparison 618,349 barrels of brine per day were returned to the subsurface through injection systems."

The Oil Field Section of the State Board of Health (1956, p. 5, 9, and 13) recognizes that severity of the pollution problem at the present time "is dependent upon (1) the amount of brine entering surface ponds; (2) the concentration of the brines; (3) the



Map of Kansas showing location of area covered by the Arkansas River Basin study, 1953.
Figure 3

geology of the area where ponds are located; (4) the amount and proximity of fresh water supplies in relation to the ponds in a given area; and (5) the nature of the material between the base of the pond and the fresh water aquifer." Also it is recognized that "proper casing and cementing of...disposal wells is...essential if pollution of fresh water is to be prevented" and "oil field brines are...corrosive to steel" and "that holes develop in the tubing set in input wells through which brine is constantly flowing under high pressure."

In Kansas, surface ponds used for brine disposal are constructed in areas of widely varying geologic conditions. In the State, brine is placed, through disposal wells, into geologic formations ranging in age from early Cretaceous to Cambrian. Requisite conditions for disposal wells comprise porous rocks that lie below the zone of fresh water and the depth to these rocks ranges from less than 100 feet to more than 1,000 feet below the land surface. It is noteworthy, however, that the disposal of brine into shallow formations is not generally recommended.

In 1954-1956 biennium, 201 ponds were eliminated by "pond orders" from the Board of Health, and in the same beinnium, 1,542 ponds were eliminated by the installation of injection systems (State Board of Health, 1956, Tables 3 and 4). In the twelve-month period of July 1, 1956, to June 30, 1957, 123 ponds were eliminated by pond orders.

The Board of Health's report (1956, p. 15) states:

> This method (subsurface disposal) is now recognized as the best method of disposal yet evolved. However, it is seldom the least expensive nor is it always applicable, nor have all the physical and chemical problems surrounding it been solved.....

Statistics on Brine Disposal

Table I contains data on amount of oil-field brine that at present is being handled in Kansas. Districts, as divided by the Oil Field Section of the State Board of Health, are shown in Figure 1.

Table 1. - Statistics on oil-field brine production and disposal in Kansas

District	Disposal wells		Repressuring wells		Surface ponds	
	No. of disposal wells	Barrels of brine received daily	No. of repressuring wells	Barrels of brine received daily	Surface ponds	Barrels of brine rec'd daily
1	393	546,663	94	106,596	357	5,660
2	356	466,716	265	300,510	225	6,975
3	89	41,296	445	504,630	587	10,596
4	2	415	52	58,068	170	3,150
5	296	474,192	110	124,440	268	10,765
6	647	1,589,679	94	106,596	246	4,551
Total	1,783	3,118,961	1,060	1,202,040	1,853	41,697

Total wells (including repressuring wells) ---------- 2,843

Total barrels of brine into all wells ---------- 4,321,001

Total barrels of brine disposed daily
(into wells and ponds) ---------- ~~4,325,552~~ 4,362,698

Subsurface Reservoirs

Geologic (stratigraphic) units used for subsurface brine disposal reservoirs in Kansas are shown in tabular form below (Table II)

Table II - Stratigraphic units used as brine disposal reservoirs in Kansas

Geologic system	Unit used as a brine disposal reservoir	Remarks
Quaternary	(None)	
Tertiary	(None)	
Cretaceous	Cheyenne ss	
Jurassic	(None)	
Triassic	(None)	
Permian	Wellington sh	A zone formerly occupied by salt, but from which salt is now absent, and called the "Lost circulation zone" is used to some extent; depths from 250 to 1,325 feet. Disposal wells in Barton, McPherson, Reno, Saline, and Sedgwick Counties. Districts 1, 2, and 5. (See Fig. 1.)

Pennsylvanian	Topeka ls	
	Douglas group	Sandstones in this division commonly are known as "Big Salt sand" and as "Stalnaker." Disposal wells are in Elk, Greenwood, Chautauqua, Wilson, and Montgomery Counties. District 3. Depths of disposal wells about 400 feet.
	Lansing and Kansas City groups	Sandstone known locally as "Layton sand" is a disposal reservoir. Porous limestone also is used as a reservoir rock. Wells are in Barber, Barton, Butler, Cowley, Elk, Ellis, Ellsworth, Kingman, Marion, Ness, Pratt, Rice, Rush, Russell, Sedgwick, Stafford, and Sumner Counties. Districts 1, 2, 3, 5, and 6. Depths from 2,106 to 4,100 feet.

	"Granite wash"	Coarse detrital arkosic material resting on and derived from Precambrian rocks in several parts of Kansas is called "Granite wash". Probably mostly where used as a disposal reservoir, the deposit is of Pennsylvanian age. Wells are in Barton, Butler, Ellis, Ellsworth, Graham, Marion, Rice, Rooks, Russell, and Trego Counties. Depths from 2,447 to 4,310 feet.
Mississippian		
Devonian	(None)	
Silurian	(None)	
Ordovician	Arbuckle group	Rocks assigned to this group are in part of late Cambrian age. Disposal wells are in many parts of the State. Depths are from 2,117 to 5,500 feet.

Cambrian	Lamotte ss	Reagan ss and Lamotte ss are used as names of the same rocks. Wells are in Barton, Ellsworth, Rice, Rush, and Russell Counties. Depths from 3,330 to 3,938 feet.

It is believed that the list of geologic formations that are being used as disposal reservoirs cannot be increased with safety; and it may be that it will become advisable to curtail disposal in some formations now being used as reservoirs.

Technical Problems Relative to Brine Disposal

The overall technical problem in reference to disposal of oil-field brines is of geological-hydrological nature. Obviously the overall objective is to dispose of oil-field wastes with a minimum amount of damage. As stated elsewhere in this report damage that is likely to result from the bringing to the surface large amounts of salt water almost entirely involve pollution of fresh water, either surface or subsurface.

All or most of the reservoirs that are being used for disposal are in places fresh-water reservoirs. Hence, the complexity of problems is evident.

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