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OIL-FIELD FLOODING STREAMLINED FOR WAR—  
A SUGGESTION

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# OIL-FIELD FLOODING STREAMLINED FOR WAR—

## A SUGGESTION

By Frederick Squires

**W**AR needs more oil and needs it now. Increasing the supply by flooding under the usual method is too slow for this emergency. It is to suggest a way by which production from flooding may be speeded up that this paper is presented.

The usual flooding technique requires plugging of all existing wells and re-drilling an entire new pattern. Since depth to the producing sands determines the cost of drilling, operations are begun in the shallowest horizons and, if financially successful, are later extended into deeper pools. In the southeastern Illinois oil field the deeper sands are generally richer.

There is going on in Illinois at the present time a flooding project, the well spacing for which is shown diagrammatically in Fig. 2. This work is being done by men skilled in the art of flooding in Pennsylvania, Kansas and Oklahoma. It will be noted that the spacing which they follow in their Illinois project is 660 ft., water well to water well. Many other Illinois sands are more permeable than the sand on which this flood is operating. The unusually high permeability of many Illinois oil sands is the key to this proposed method. Sands of low permeability would, of course, require closer spacing.

Territory for the project shown in Fig. 2 was selected because it was the shallowest available in which past production history gave promise of successful recovery by water flooding. Since all old wells were plugged and the property was re-drilled on a different pattern, depth to the sand determined the cost.

### A Wartime Suggestion

Because time is of critical importance, war justifies an attempt to

streamline the technique of exploratory and development work in water flooding. The following method is therefore suggested. This would consist of using only old wells by: (1) Inclined coring in input wells; (2) using alternate staggered wells for water-input and oil-producing wells; and (3) flooding with upper salt water in a closed system. Because depth would not determine costs, the rich deep southern pools could be flooded almost as cheaply as the light shallow northern pools.

The standard spacing in the old fields of Illinois is shown in Fig. 3. Note that if alternate staggered wells were converted into water-input wells, the maximum distance from water well to water well would be 650 ft., or 10 ft. less than that of the flooding patterns shown in Fig. 2. A diagram of the resulting pattern is shown in Fig. 4. The repeating unit is shown in Fig. 5, and the distances involved appear in Fig. 6. Fig. 7 shows the application of the method to an Illinois oil field in which accidental flooding of nearby areas in the same sand resulted in production of an average of 6,000 bbl. per pumping well for nine cases of accidental flooding. It is believed that many Illinois oil sands are as permeable as that in the pool shown in Fig. 7.\* If this is the case, water under a 1,000-ft. head will travel through many Illinois sands at a speed of one location in about 6 months.

### Acquisition of Subsurface Information

The advantages gained by drilling and coring new wells before flooding fall into two general classes: (1)

\*Squires, F., and Bell, A. H., Water Flooding of Oil Sands in Illinois: Illinois Geol. Survey Rept. Inv. No. 89, 1943.

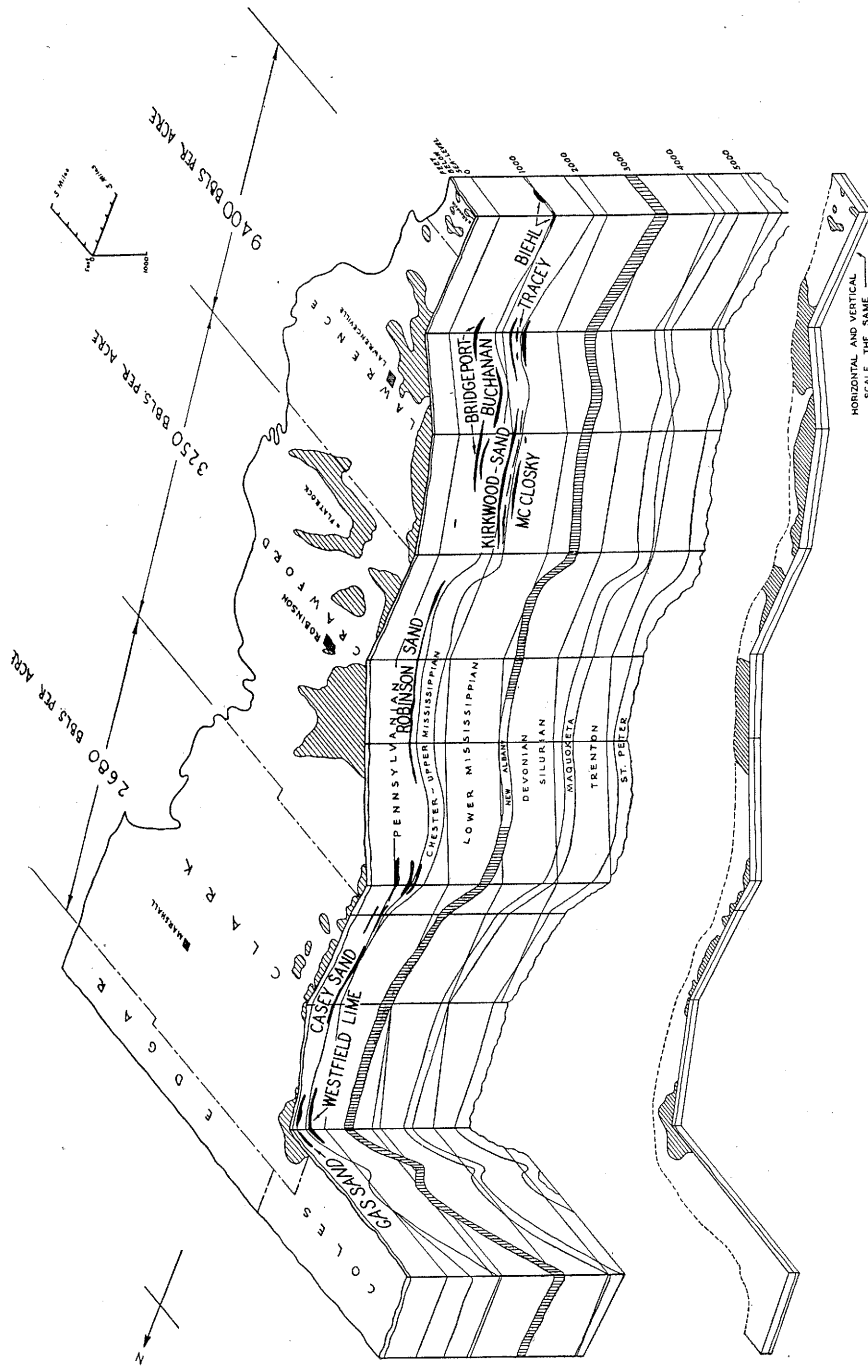
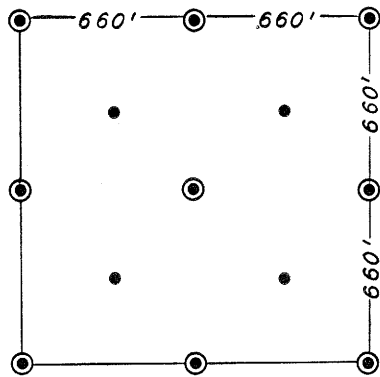


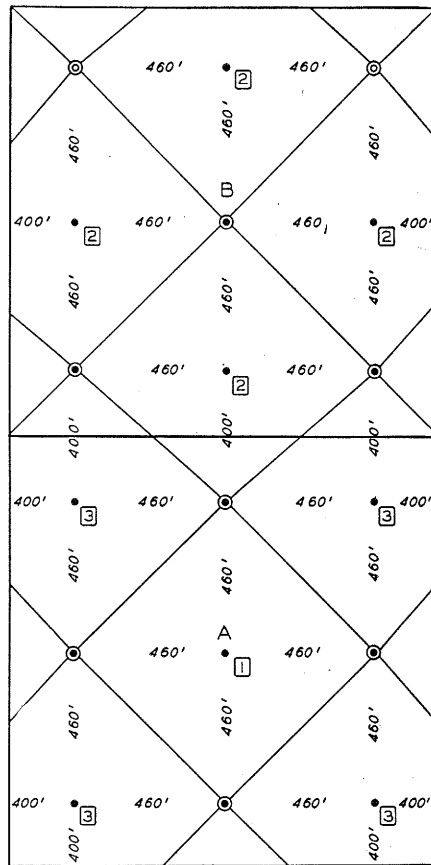
Fig. 1: Block drawing showing the relative depth and average oil production per acre up to end of 1942 of Clark, Crawford, and Lawrence County sands. It illustrates the advantage of flooding the deeper sands



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● OIL WELL    ⊙ WATER INPUT WELL

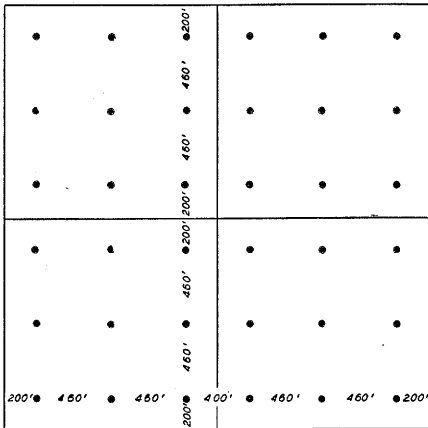
Fig. 2: The flooding pattern for an operation now under way in Illinois. The territory was selected because the oil sand is found at a shallow depth. It is located in a part of the old Illinois fields where the average oil recovery was low. In spite of a lower oil recovery, a greater profit may be realized in comparison to deeper, richer territory because of the lower cost of well drilling which is the major expense in a redrilled flooding operation. The water-input wells are 660 ft. apart



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● OIL WELL    ⊙ WATER INPUT WELL

Fig. 4: Proposed well pattern for water flooding without new drilling by conversion of alternate producing wells into input wells. Tract A will have a single square at its center (marked 1), the corners of which are formed by water-input wells, each 460 ft. from the center oil well; this will be surrounded by eight asymmetrical tracts. Tract B will have a water-input well at the center which forms the common corner for four asymmetrical areas each of which has three distances of 460 ft. to the included oil well and one distance of 400 ft. Note that the oil well is always at the crossing of lines joining opposite water-input wells



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● OIL WELL

Fig. 3: The standard well pattern for practically the entire oil-producing territory in the old Illinois oil fields, regardless of depth. Comparison with Fig. 2 shows that the wells are more closely spaced in the old field than in the redrilled pattern for the flooding operation

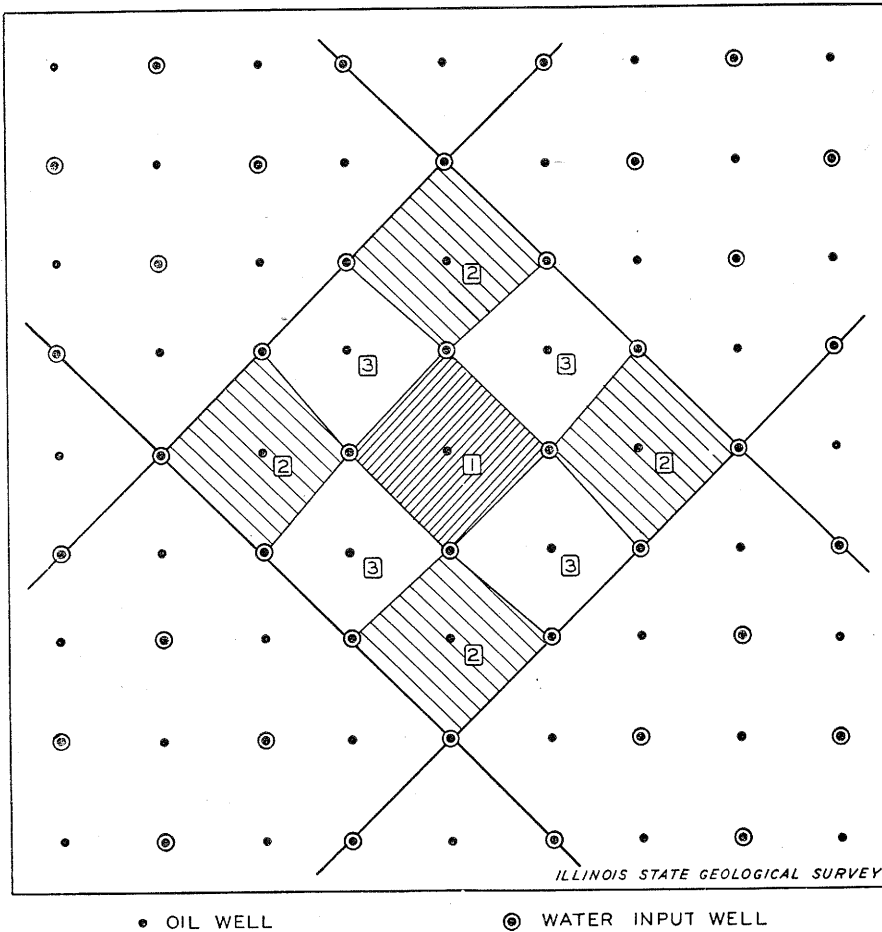


Fig. 5: The same well pattern as that shown in Fig. 4 on a smaller scale to show how the pattern repeats. The square pattern in the center of this drawing and marked 1, 2 and 3 covers 80 acres and is repeated without change all over the field. It consists of one symmetrical and eight slightly asymmetrical tracts

Information as to porosity and permeability of the sand, its oil and water content, and the probable oil recovery, and (2) information as to presence of streaks of such excessive permeability as to require cementing off and information as to the best location for the packer to shut off upper gas sands. At least one such new well should be drilled and cored on every operation and could be placed to occupy an undrilled location in the old drilling pattern.

Old wells provide little subsurface information because neither cores nor good well records are usually available. In order to obtain the most im-

portant part of the information which would normally be given by the core from a new well, the following three methods are suggested: (1) Drill below the casing seat with a deflected hole, directed far enough from the vertical to miss the shot hole and so obtain a full core of the sand as illustrated in Fig. 8; (2) if coring is not undertaken, relative permeability may be determined as follows: after cleaning run a well caliper to determine the shape of the shot hole, then subject each vertical foot of the sand to air or water under pressure using the pressure and volume readings to determine relative permeabil-

ity as the hole is filled up from the bottom in 12-in. increments with some sealing compound such as jelly seal, the seal would be removed after the test; (3) permeability may also be tested by using the Dow "electric pilot" to locate the interface between oil and salt water introduced through casing and tubing separately. Then by raising the oil and salt-water interface, in the hole through the entire sand section, the relative volumes and pressures on the fluids forced into the sand above and below the interface will show foot by foot the relative permeability of the sand.

Oil and connate water content of the sand body as a whole cannot be

estimated from cores taken so near old producing wells. However, as a guide to remaining oil content a careful study of initial, yearly, and total oil production can be made from production records of the leases involved. Every oil man knows that, other conditions being the same, a lease which has made 14,775 bbl. to the acre will probably still contain more recoverable oil than one which has produced only 1,639 bbl. (Fig. 9). Present water-oil ratios would be known and their past history could be approximated. A lease with high present or past water-oil ratio will contain less recoverable oil than an equally productive one which has produced and

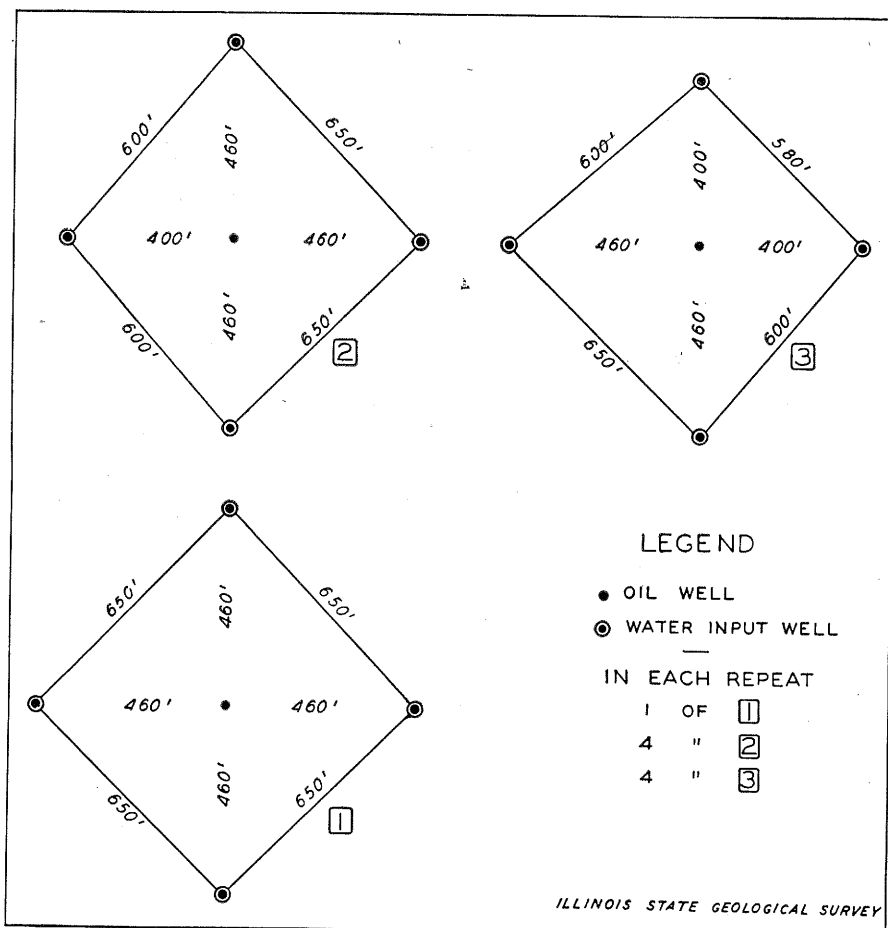


Fig. 6: This diagram shows the distances from water well to water well, and oil well to water well in the pattern shown in Figs. 4 and 5. Note that each repeating pattern gives nine areas, one like (1) and four each like (2) and (3)

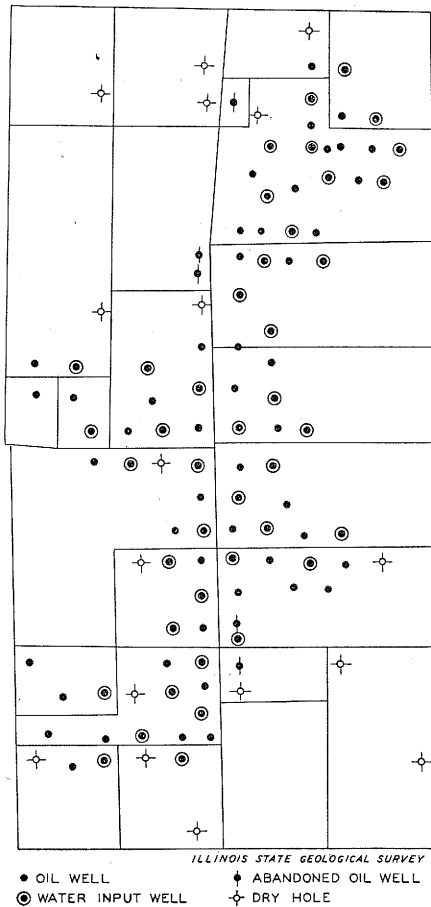


Fig. 7: A possible flooding development in a pool in the old Illinois oil fields. Its probable success is indicated by the facts that (1) the territory has been unusually rich, (2) the producing sand has no gas and very little water, (3) in other nearby areas in the same sand, repressuring has shown that the sand is unusually permeable, (4) there has been a large number of accidental floods on this sand in nearby areas that have produced large amounts of oil, and (5) the distance between wells in the nearby areas has been traversed by water which has increased production within 6 months of the start of flooding

sand. When found in the same well the Kirkwood, Tracey, and McClosky are produced together in an open hole below the cased-off Buchanan water sand. The method is also applicable to the Tracey and McClosky. It is to be understood that the horizontal dimensions are greatly exaggerated and that the deflection shown from the vertical is much greater than can be obtained in the 100 ft. of open hole above the Kirkwood sand

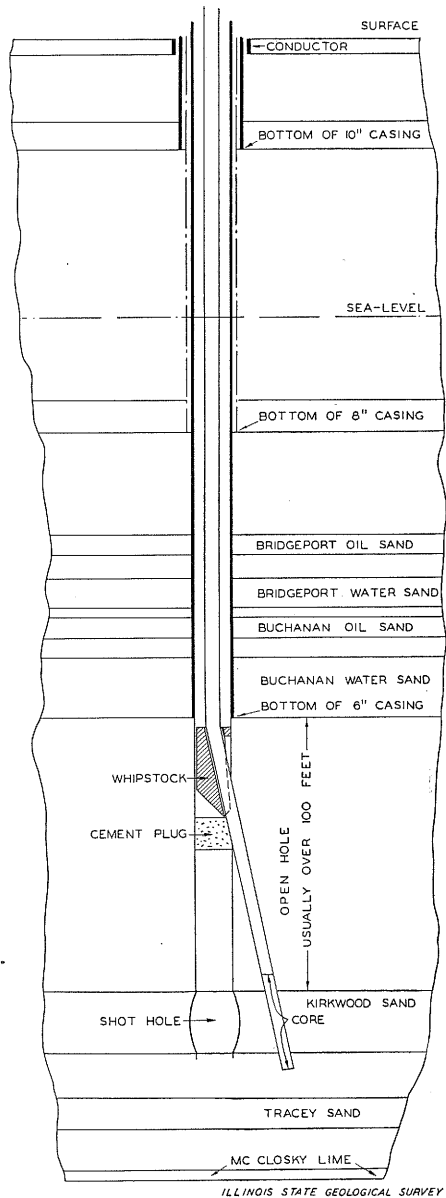


Fig. 8 (right): A proposed method of coring the oil sand by directional drilling in an old Lawrence County well cased in the usual manner. There is considerable amount of open hole above the Kirkwood (Cypress)

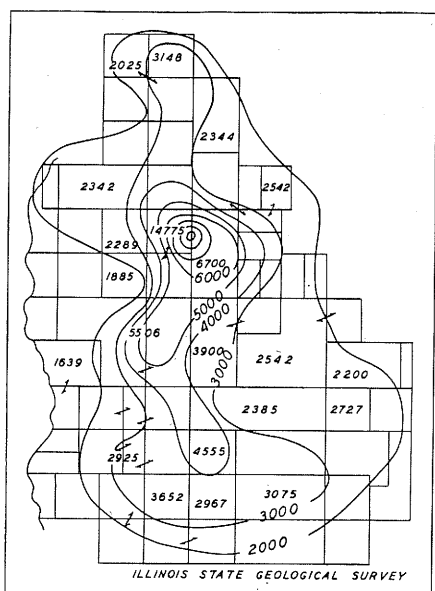


Fig. 9: This map of part of an oil-producing area in the old Illinois fields shows by figures the total oil production per acre by leases to the end of 1942 and by lines surrounding areas of equal production the variation in richness in the pool. It is generally believed that areas which have produced high yields by primary methods will recover high yields by flooding, so that even in the absence of cores favorable territory may be selected

is producing but little water with its oil.

#### The Suggested Flooding Pattern

The use in the old fields of staggered alternate wells for water input and oil production would give a five-spot pattern. A repeat pattern would occur on each 80 acres, divided into nine units, one symmetrical and the remaining eight slightly asymmetrical as shown in Figs. 4 and 5.

#### Flooding With Salt Water

In most of Illinois' producing territory in the old fields, at least one sand above the oil stratum is charged with great quantities of salt water which would rise in an open hole to a high static head. This is true of the sands in the Robinson area—the Buchanan oil sand underlies the Bridgeport water sand, the Kirkwood and Tracey oil sands underlie the

Bridgeport and Buchanan water sands, and the Biehl oil sand underlies a sand full of water under high pressure. All these oil sands have been the subjects of accidental floods when the upper water has invaded the lower sand through defective casing.

It is proposed to gun-perforate the casing opposite the water sand in wells chosen for water input and to measure and regulate the rate of water inflow into the oil sand by means of a meter and valve on rods in the tubing. The meter and valve would be raised to the surface, readings taken, the valve adjusted and then lowered into position. The packer would be set and cemented just above the sand. In the case of a gas sand or other too permeable top streak, the packer would be omitted and the tubing would have a perforated section in the lower part of the shot hole, which would be filled with gravel to a point just above the perforations. Cement would be added in quantity sufficient to fill up several feet of the open hole. This whole assembly would result in a closed system protecting the inflowing water from any contact with air and so would prevent the oxidation of its iron content (Fig. 10). The flooding wells in accidental floods have never been plugged by iron compounds from upper waters because the accidental method results in a similar closed system.

If it were desired to raise the brine to the surface in order to increase the input pressure on the oil sand by means of pumps, it could be air-jetted, chemically treated, filtered and pumped back through unperforated tubing under any desired pressure in the ordinary flooding technique.

#### Conclusions

By following the method described and illustrated above, flooding costs would be largely independent of depth, with the result that installations could be made in the rich deep southern areas as quickly and far more profitably than in the light shallow northern parts of the old fields. Flooding would be comparable in cost to gas repressuring.

The five-spot patterns would be nearly symmetrical, and the distances



from water well to water well would be shorter than they are in the Parker and Patoka floods of the Bradford type now in operation in Illinois. Permeability information which was formerly obtained from cores taken from newly drilled wells would be provided by cores taken by directional drilling below the casing of

old wells or by the measurement of fluids forced into the old wells themselves—which is really a full-sized application of the laboratory method. Selection of property favorable for flooding on the basis of oil content would be determined by actual past oil production, the water content of the sand would be indicated by the past and present water-oil ratios. Little financial risk would be involved because much of the production is now in the submarginal class, and relatively little new expense would be involved. The time required to start the actual flooding operation would be reduced to that required to caliper, directional core, gun-perforate the casing opposite the water sand, run and cement the packer, and set the meter and valve, well by well. All of this would be but a small fraction of the time required to plug all the old wells, drill the entire new pattern, find and drill a fresh water supply, and erect and put into operation a water preparation and pumping system. Application of a faster method is of wartime importance.

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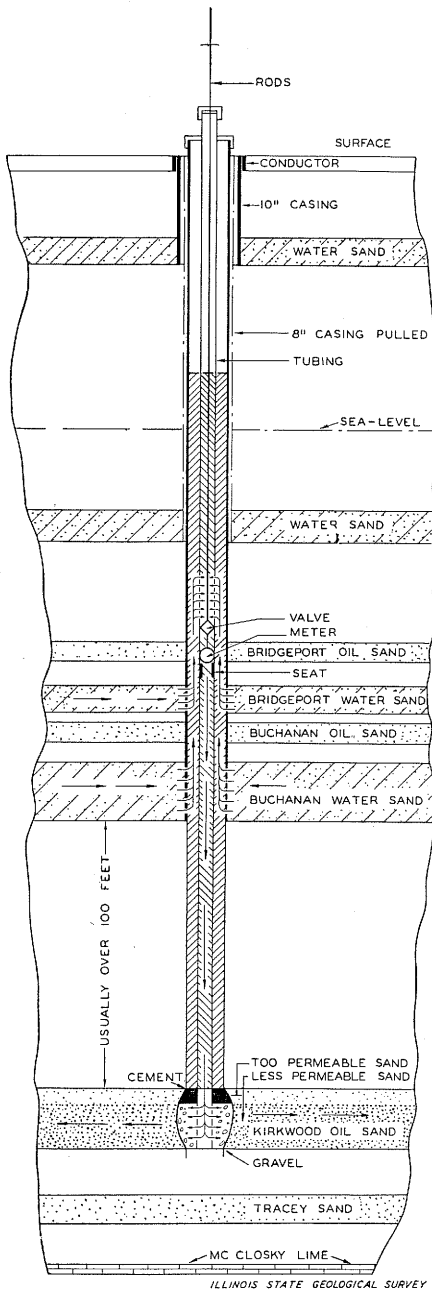


Fig. 10: Diagram showing a proposed method of flooding a Kirkwood well from the Buchanan and Bridgeport water sand. The proposed method applies also to the Tracey and McClosky which occur below the Kirkwood. The casing is gun-perforated opposite the water sands. A packer is run on tubing and cemented just above the sand to be flooded. Where a too-porous streak in the top of the sand in the shot hole is encountered, the bottom of the tubing is perforated below the porous streak and gravel is filled in the shot hole to cover the perforations. On this gravel, the well is cemented. A perforated joint of tubing occurs above the water sands which allows any solid matter such as floating sand to settle out before the water enters the tubing. A meter and valve is run on rods and landed on a seat in the tubing. Periodically the meter and valve is withdrawn on the rods and if the input is found to be too great, the valve is adjusted