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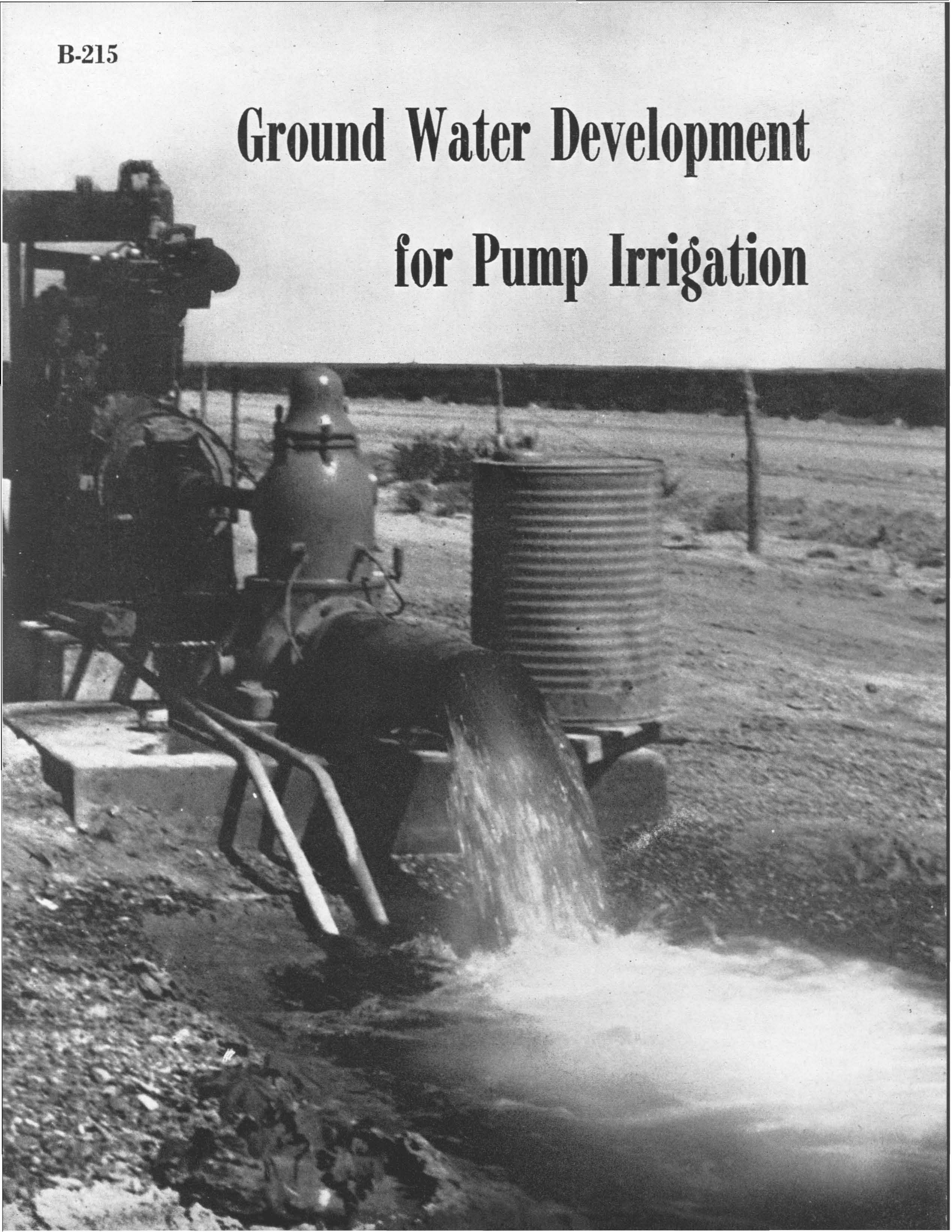
Ground Water Development for Pump Irrigation



Ground Water Development for Pump Irrigation

By

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Pumping ground water from wells may provide a substantial and economical supply of irrigation water. The farmer planning development of ground water for irrigation should consider the following points:

1. Availability, quality, and depth of water. Availability of an adequate supply of ground water will depend primarily on the thickness and character of the waterbearing formation. Information pertaining to the availability, quality and depth of water for specific areas in Texas may be obtained from the Texas Board of Water Engineers. A test hole will provide information relative to the thickness and character of the water bearing formation, depth to water table, and quality of water. An abundance of water, chemically unfit for production of crops, will be of no value. The maximum depth from which water can be pumped economically for irrigation depends entirely on the increased net returns derived from the individual farm unit.

2. Trend of water table, source of natural recharge, possibilities of artificial recharge. Withdrawals of ground water in excess of natural recharge may cause rapid declines in the water table. Heavy investments in an area where overdevelopment has occurred may be unwise unless artificial recharge is possible. The Texas Board of Water Engineers has records for many areas of Texas of water table trends along with information concerning sources of natural recharge and possibilities of artificial recharge.

3. Ground Water Laws. In Texas present laws declare percolating ground water to be property of the land owner, and its use for irrigation is not limited except to beneficial use and prevention of waste. The law provides for the forming of Underground Water Conservation Districts within a designated ground water reservoir or sub-division thereof. Such a district is formed by a majority vote of the people within the area of the reservoir. If the farm is located in an Underground Water Conservation District, land owners may be required to comply with established regulations as set up by the board of directors prior to construction of wells which will deliver water in excess of 100,000 gallons per day (24 hours.)

4. Amount and suitability of land for irrigation. The amount of land suitable for irrigation on a farm may be a deciding factor in ground water development for irrigation. Farms with only a few acres that could be successfully irrigated might not justify the large cost for irrigation water development. Some factors influencing suitability of land for irrigation are soil depth, texture, structure, available water storage capacity, rate that water will move into and through the soil profile, chemical characteristics, drainage, slope, and soil productivity. The topography, type of crops to be grown, and amount of water will influence methods of irrigation.

5. Operating cost and returns. If irrigation is to be profitable, the additional income from such must more than offset expenditures for pumping cost, land preparation, extra farming equipment, increased labor, and other items connected with irrigation.

THE WELL AND HOW IT FUNCTIONS

Wells provide a means by which ground water can be brought to the surface by pumping. The ability of the well to produce water depends on the character and thickness of the water bearing formation and on the construction of the well. Little can be done regarding the formations encountered, but much is known about the construction of wells that will yield the most water the formation is capable of producing. Good irrigation water wells are more than mere holes drilled into underground formations. They can be compared more nearly with a house in that both require good materials, much skill to build, and should be constructed with the idea of long life and dependable service. Farmers should realize that a higher initial cost paid a competent driller to construct a well that will produce the greatest amount of water for the least amount of drawdown over long periods of time will usually be more economical in the long run.

As pumping begins, the flow of water into the well is brought about by a lowering of the water level in the well. As pumping continues, the water level in the well is continually lowered until the flow from the saturated material surrounding the well will keep up with the discharge. When this condition exists, the water level in the well will become steady. During pumping, the rate of water movement through the saturated sand and gravel toward the well, will increase the closer the water gets to the well. If fine grained sand surrounds the perforated casing, the rate of movement of water may be sufficient to carry the fine sand in suspension, resulting in pumping of sand. If the formation contains sufficient amounts of particles larger than the openings in the casing, these large particles will collect around the casing as the small particles are

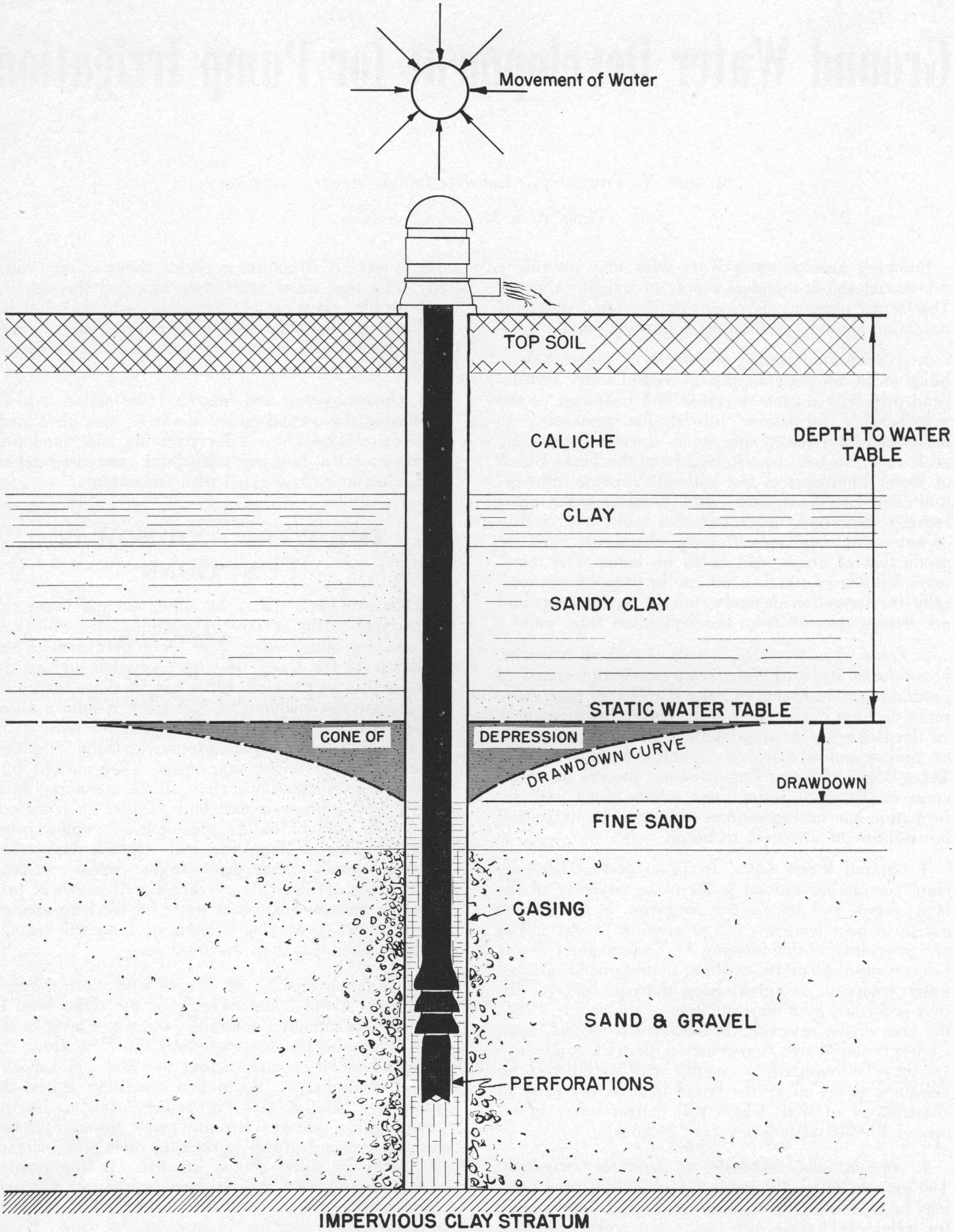

Fig. 1. The irrigation water well.

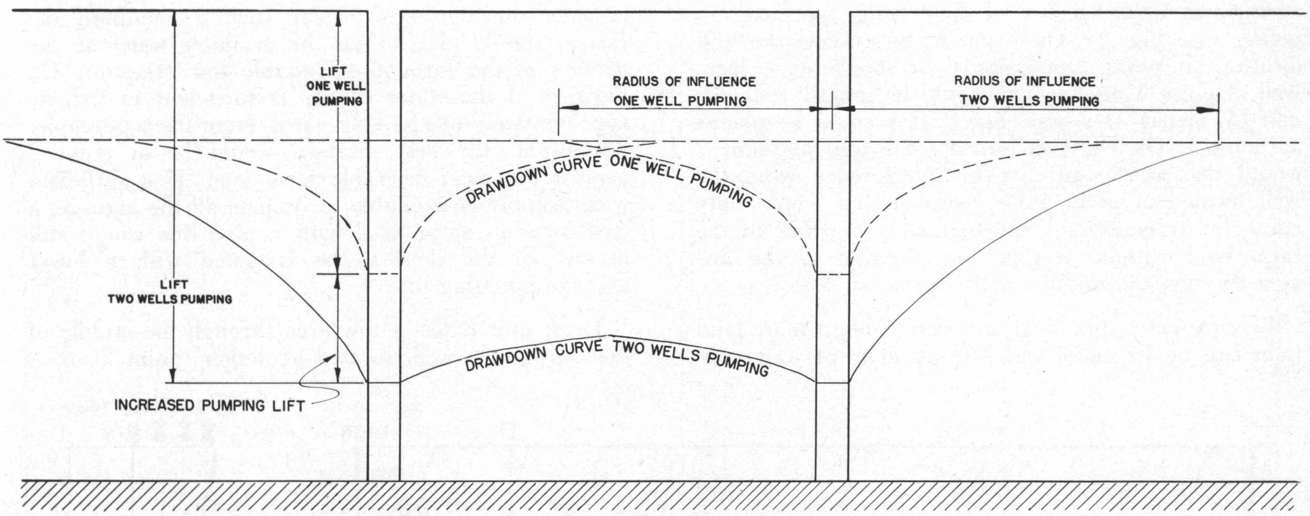

Fig. 2. Typical example of increased pumping lifts resulting from improper well spacing.

carried into the well as shown in Fig. 1. These larger particles around the casing will provide for more rapid movement of water into the well and hold back the fine sand. Some water bearing formations contain only fine sand with no large particles to collect around the casing. When this condition exists, gravel may be placed around the casing to prevent pumping of sand. This is commonly called gravel packing. Often too little consideration is given to the size gravel required to prevent movement of sand into the well.

WELL SPACING AND INTERFERENCE

The possibility of interference from other wells is an important factor in selecting a well location. When two wells are pumping and spaced so as to cause overlapping of their cones of depression, increased pumping lifts along with probable decrease in yield of each well will result. In areas where adequate information is not available relative to the extent of the cone of depression of a pumped well, then wells should be spaced as far apart as practicable. The effect of interference resulting from improper well spacing is illustrated in Fig. 2.

PROSPECTING FOR GROUND WATER

In areas where limited information is available pertaining to ground water it is generally advisable to put down one or more test holes before an irrigation well is drilled. Several test holes drilled at various locations on the farm will indicate where the best possible water bearing formations are located. A test hole is merely a small well, four to six inches in diameter which will furnish information as to the location of the water table and thickness and character of the formations. This information may also suggest the most suitable methods of drilling, and provide valuable information as to the type of casing and size of slot openings that should be used. Water-bearing formations often vary widely in short distances; consequently the location of the irrigation well should be very close to the test hole. Precaution should be used in drilling a well at the exact location of the test hole. If the test hole is crooked or out of plumb, the drilling tools will follow the test hole, thus leaving a crooked well that may not be useable.

WELL LOCATION

The first step is finding the place on the farm where there is enough water bearing material to obtain a satisfactory well. On some farms the chance of obtaining a good well may be equal at any location. Under such a condition, other factors such as topography of the land surface, possible interference from nearby wells, soil type, and method of irrigation, should be considered.

USE OF TOPOGRAPHIC MAP IN LOCATING A WELL

To choose the best site for the well with reference to the irrigation layout, a topographic map is helpful. With the topographic map it is possible to compare elevations at various points on the farm, thus determining grades, high and low points, and acreages involved.

The topographic map in Fig. 3 with profiles AB and CD shows a complete relief picture of the farm. Contour lines represent points of equal elevation. Notice the closer the contour lines are together, the steeper the slope of the land.

With equal chances for obtaining a satisfactory well on any location of the farm, Fig. 4 gives illustrations of typical problems that might arise in locating the well. The high points on Farm A and Farm B are just across the road. Location of wells on both farms placed at point 1 probably would result in interference of the two wells because of their being too close together (see Fig. 2). On Farm A, by moving the well location to point 2, possiblity of interference from well at point 1 on Farm B would be greatly reduced, and by means of a pipe line, water could be placed at point 1. On Farm B locating the well at point 2 would decrease possibility of interference from the well located at point 1 on Farm A, but would only allow for irrigation of approximately one-half of the farm land without a pipe line because of the low area through the middle of the farm.

In some cases, the farm unit may contain more land than can be irrigated with the quantity of water obtained from the well. Under such a condition the farmer should plan to use the available water on the portion of the farm most suitable for irrigation. On Farm A if the water supply is sufficient to irrigate approximately one-half the farm, from the topography standpoint, the best location would be at point 2 nearest the most desirable farm land. If a sufficient water supply is available to irrigate all the acreage, a well location at point 2 with a pipe line would still permit all the land to be irrigated with a lower average pumping lift.

Farm unit B has a low area through the middle of the farm. A well located at either point 2 or 4

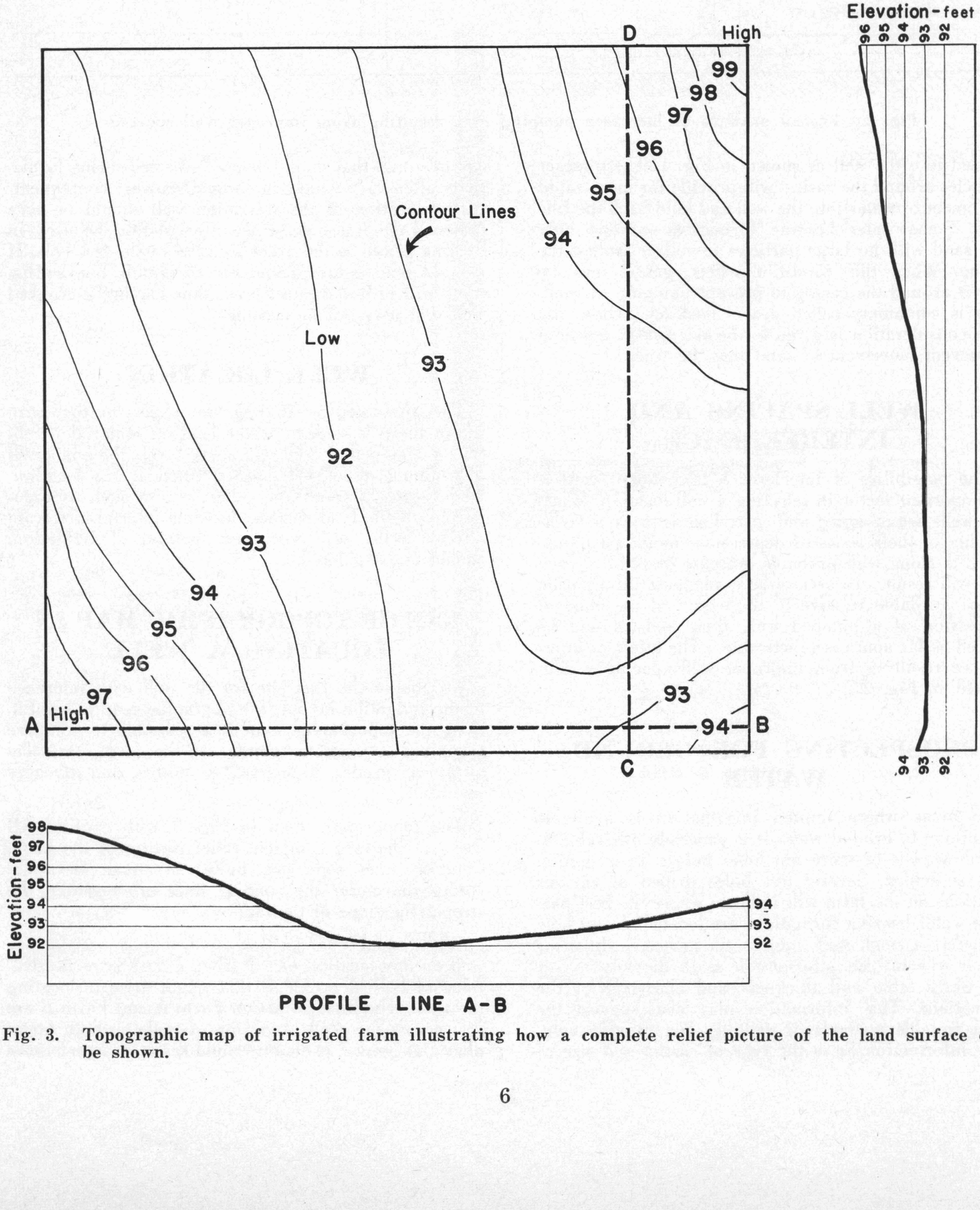

Fig. 3. Topographic map of irrigated farm illustrating how a complete relief picture of the land surface can be shown.

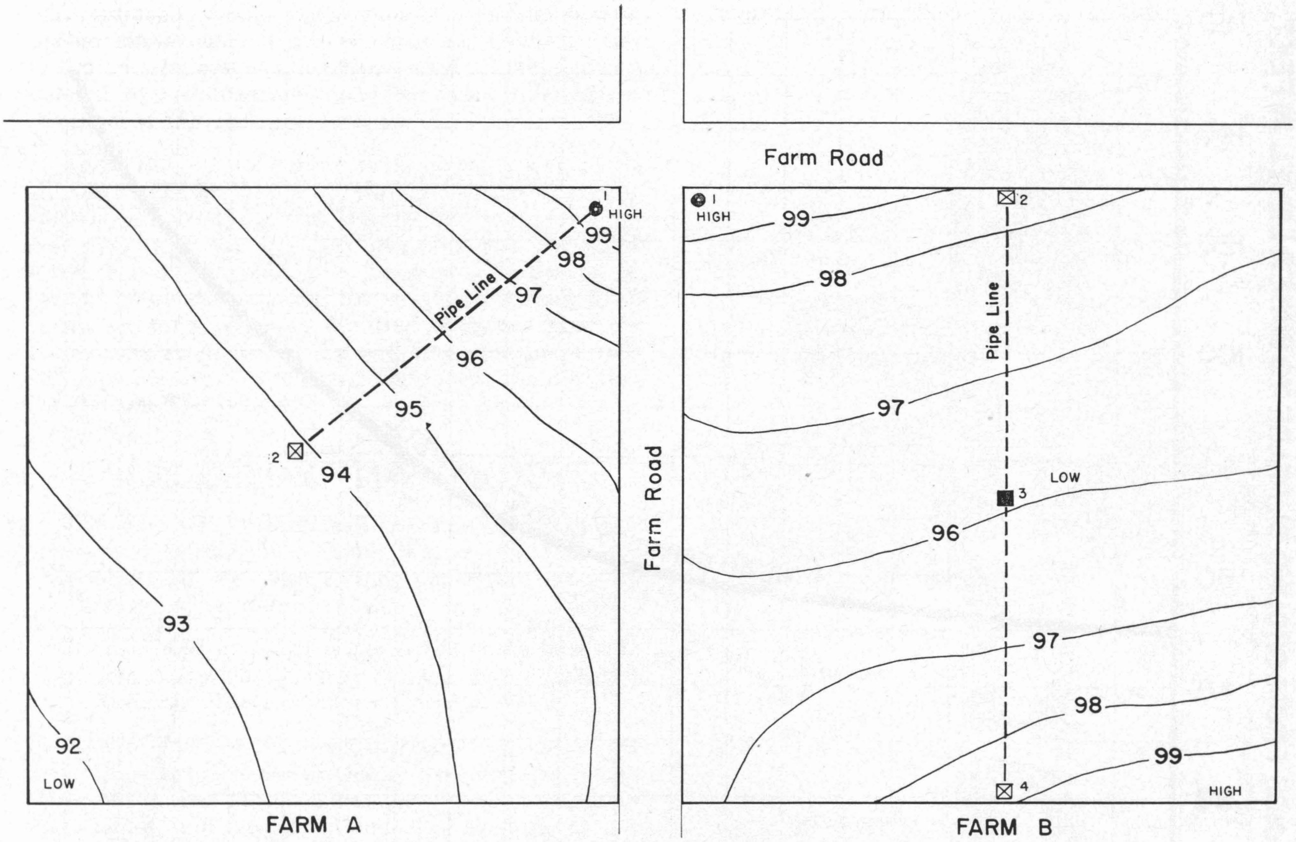

Fig. 4. Possible irrigation well locations.

without a pipe line would provide for irrigation of approximately half the farm. Well location at point 3 with a pipe line extending to points 2 and 4 would permit water delivery to these points. Many pump irrigation farmers are replacing all farm ditches with permanent or portable pipe lines. With this in mind, well location at point 3 with a pipe line extending to points 2 and 4 would permit irrigation of almost all the farm land. A well located in the center of the area to be irrigated would also require less pipe if the sprinkler method of irrigation were used.

TESTING THE WELL

After the well is completed, the well should be tested to determine its characteristics. To install a pumping plant in a well that has not been tested may lead to an unsatisfactory pumping installation. If the capacity of the pump and power unit are too large or too small for the well, lower operating efficiency and increased pumping cost will result.

Many farmers may be inclined to purchase pumping plants based on the characteristics of near-by wells. Although the characteristics of the near-by well are definitely known, the particular well involved still should be tested because wide variations in water bearing formations may exist over short distances.

If the well has been developed with an old pump, this may be used to make the test. The primary purpose of testing a well is to find out the yield of water per foot of drawdown. The yield of water may be measured with any standard water measuring device such as an orfice, wier, or Parshall flume. The depth to the water surface is generally measured with an electrical apparatus or airline. Fig. 5 illustrates how results of a pumping test are shown in graphic form, showing the distance to the water level in the well for various pumping rates. This example illustrates the conditions often found in shallow wells, that the greater the rate of pumping the less the yield per foot of drawdown. From the illustration, it is seen that while pumping 600 G. P. M. the drawdown would be 20 feet (70′ − 50′). Then $\frac{\text{600 G. P. M.}}{\text{20 Ft.}} = \text{30 G. P. M.}$ per foot of drawdown. If the well is pumped at 1000 G. P. M., then the drawdown is approximately 100 feet (150′ − 50′.) Then $\frac{\text{1000 G. P. M.}}{\text{100 Ft.}} = \text{10 G. P. M.}$ per foot of drawdown.

Determination of the head capacity curve for the well not only provides for selection of the most economical pumping *rate* for the well, but will give the information needed for selecting the proper size pump and power unit for efficient operation.

At the beginning of the test, the well should be pumped at a slow rate and measurements taken when the water level and discharge become practi-

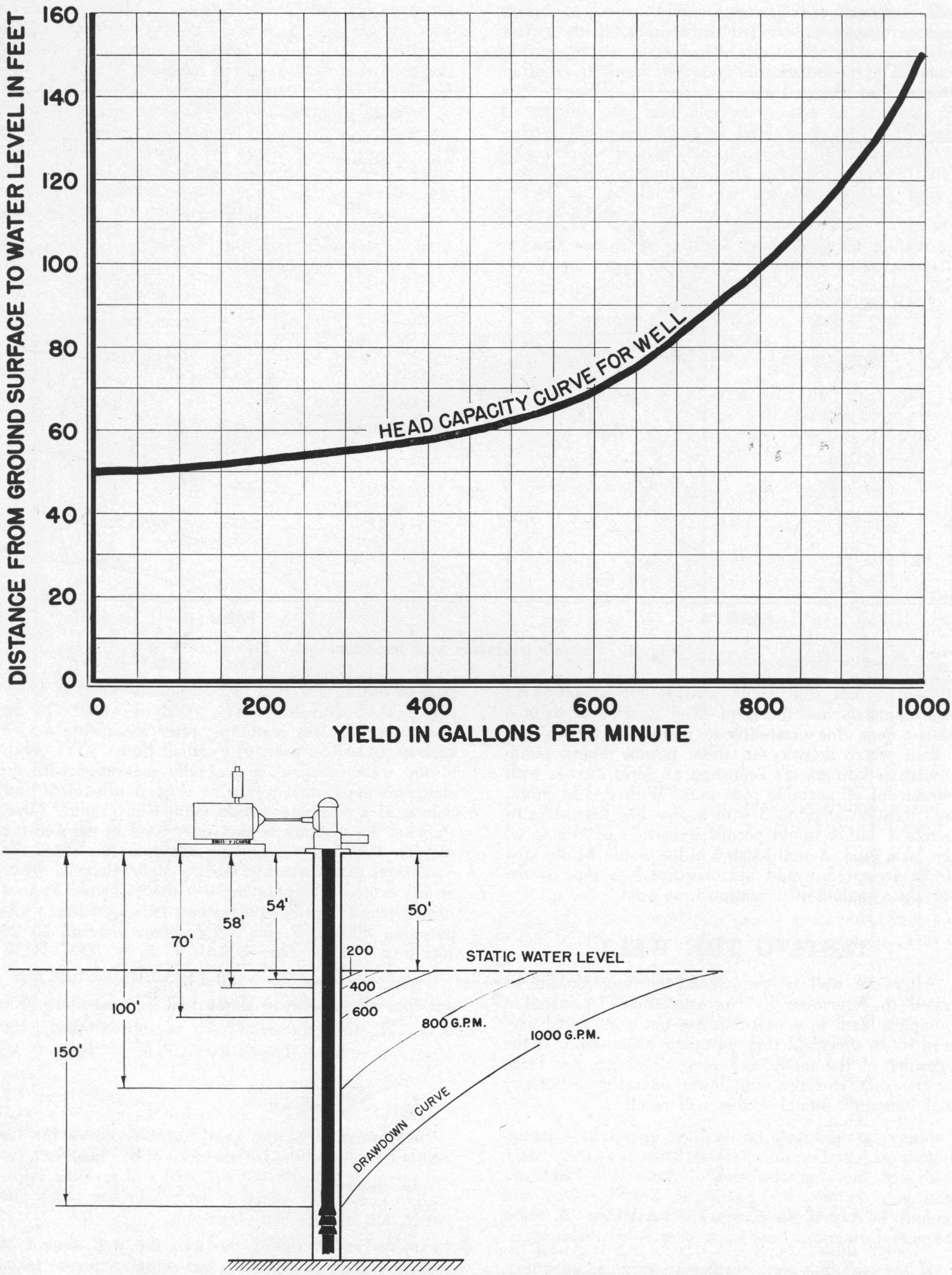

Fig. 5. Typical performance curve for shallow water well.

cally constant. The pump speed is increased and measurements are taken again when the discharge and water level become practically constant. This procedure should be continued until complete data of the characteristics of the well are obtained.

Tests run on irrigation wells where water levels fluxuate during the year, may be misleading. For instance, a pumping test during the year when no other wells in the area are operating and the water level is high may not give the same information as would be obtained during the irrigation season. Also, pumping tests of short duration may not give the actual characteristics of the well when longer periods of pumping are encountered. The longer the duration of the test, the better.

SELECTING THE PUMP

The deep well turbine, as illustrated in Fig. 6, has been used extensively to pump water from wells for irrigation. All deep well turbine pumps are made up of three principal parts.

1. *The head assembly* includes the pump base and the type of drive unit—right angle, V belt, flat belt, or direct connected motor.
2. *The column and shaft assembly* consists of the pipe between the discharge base and the pumping unit. This includes the column pipe, drive shaft and bearings, and the oil tube if the pump is oil lubricated. Shafting in deep well turbine pumps may either be water or oil lubricated.
3. *The pump bowl assembly* is located at the lower end of the discharge column, which includes the pump diffuser bowls, impellers, suction pipe and strainer.

The pump bowls should be located below the water level, thus eliminating priming.

In selecting a deep well turbine pump be sure that it fits the characteristics of the well and operates at its maximum efficiency under these conditions. With a given operating speed, most turbine pumps have a wide selection of impellers and bowls, each having different operating characteristics. If the well has been thoroughly tested and the characteristics of the well plotted, a pump can be selected that will operate efficiently. For example, in Fig. 7, it is seen from the field head capacity curve, for the pump with an operating speed of 1750 R. P. M., that the pump will deliver 600 G. P. M. against a total pumping head of 70 feet (follow lines AB and BC.) The efficiency at which this particular pump will operate under these conditions is at its maximum at 70% (follow line BD and DE.)

SELECTING THE POWER UNIT

Power units used to supply power for deep well turbine pumps may be either an internal combustion engine or an electric motor. Internal combustion

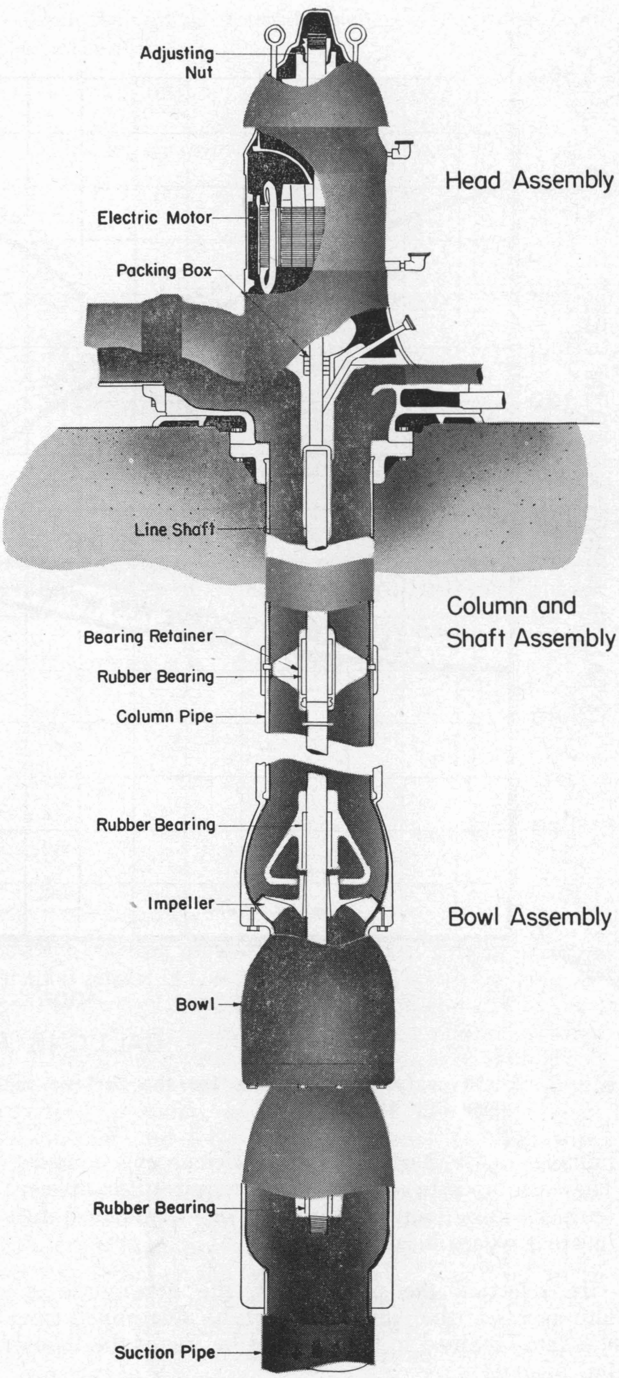

Fig. 6. Deep well turbine pump.

engines include the diesel, burning commercial diesel fuels, and those having electrical spark ignition system equipped to burn various types of hydrocarbon fuels such as gasoline, butane, natural gas and kerosene.

In choosing the type of power unit, consider carefully the initial cost, horse power requirements of the pump, number of hours of operation per season, availability of fuels or electric power, cost of operation per hour over the expected life, and availability of service in case of breakdown. Electric motors are

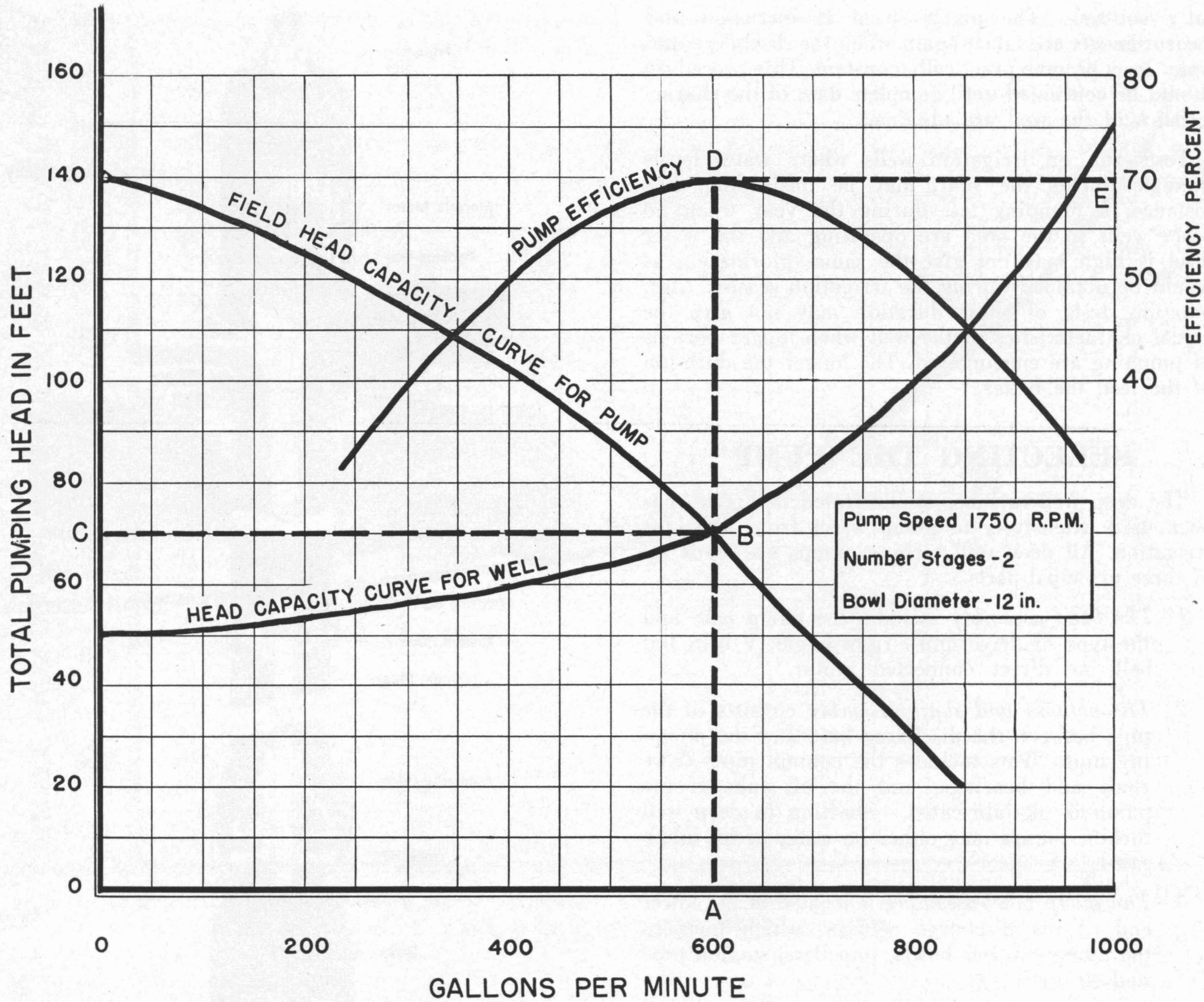

Fig. 7. Field performance curves for the turbine pump matched to head capacity curve for well for maximum operating efficiency.

reliable, easily started, highly efficient and compact. They also operate smoothly, and require little upkeep. Farmers have found natural gas an economical fuel in areas where it is available.

In selecting the power unit, the horsepower requirements at the pump shaft can be determined from the data obtained in the well test by use of the following formula:

$$\text{Hp. required at pump shaft} = \frac{\text{gallone per minute} \times \text{total pumping head in feet.}}{3960 \times \text{efficiency of pump}}$$

The total pumping head in the formula not only includes the pumping lift, but friction losses and other losses expressed in feet of lift.

After determining the horsepower required to operate the pumping plant, the power unit may be chosen. For internal combustion engines, inspection of the manufacturers curves will aid in selecting an engine that will operate efficiently under the required load. Internal combustion engines should operate at about 80 percent of their maximum rated horsepower.

By obtaining the operating speed of the engine from the manufacturers curves, a drive can be selected to operate the pump at the recommended speed. Directly connected drives generally are more efficient and give less trouble than belt drives.

Electric motors operate most efficiently when fully loaded. Electric motors are available in speeds of 870, 1160, and 1760 revolutions per minute.

In selecting power units to operate turbine pumps in areas of declining water levels, some reserve power may be desirable to prevent overloading as the water level declines.

PUMPING COST

Irrigation pumping costs over a period of years generally exceed the initial installation cost. Consequently, it is important that farmers who plan to put down irrigation wells estimate pumping costs as accurately as possible. This pumping cost along with other costs involved in irrigation, must be offset by increased farm income if irrigation is to be profitable. Many farmers with irrigation wells often underestimate pumping costs because consideration is given only to fuel costs, and so-called fixed costs are disregarded. Total pumping costs are primarily dependent upon prices paid locally for the pumping plant and fuel, total pumping head, pumping plant efficiency, amount of land irrigated, and total quantity of water pumped. Also included are depreciation, interest, taxes, and repairs. The following is a theoretical example of some items to be considered in figuring pumping costs:

EXAMPLE

Initial Pumping Plant Cost*

Well drilling, 200 feet @ \$3.00 per foot	\$ 600.00
200 feet of well casing 16″ × ¼″ @ \$4.50 per foot with 100 feet perforated at \$.75 per foot	975.00
Well testing	300.00
8″ deep well turbine pump, 3 stage bowl assembly, set 180′ with 10′ suction and strainer installed with concrete base and spillway	2750.00
50 Hp. electric V. H. S. Dripproof motor with across line starter, installed	1500.00
Pump house	250.00
TOTAL	\$6375.00

Total pumping cost involves *fixed* and *operating* cost.

Fixed Cost

1. *Interest on investment and taxes*
   Interest on investment of \$6375.00 @ 5% per annum.
   Average over a period of years due to plant depreciation 2½% \$159.38
   Taxes and insurance 2% per annum, average over a period of years 1% 63.75
2. *Depreciation*
   Well, \$600.00 @ 5% 30.00
   Casing, \$975.00 @ 5% 48.75
   Pump, \$2750.00 @ 7% 192.50
   Electric Motor and Control equipment, \$1500 @ 5% 75.00
   Pump house, \$250.00 @ 5% 12.50

TOTAL ANNUAL FIXED COST \$581.88

Operating Cost

Assume electrical energy 1½ cents per kilowatt hour

Assume total pumping head of 140 feet

Assume pump efficiency of 70% and electric motor efficiency 88%

Over-all efficiency = 70% × 88% = 61.6%

*Prices used for illustrative purposes only

Then the cost of electrical energy to pump one acre-foot of water

= 1.024 × total pumping head in feet × the energy cost per kwh divided by over-all pumping plant efficiency

$$= \frac{1.024 \times 140 \times \$.015}{.616} = \$3.50$$

Assume repairs (cost per acre foot	0.25
Assume Lubricant (cost per acre foot)	0.15
Assume plant attendance (cost per acre foot)	0.15
TOTAL OPERATING COST PER ACRE FOOT	\$4.05

From the example it is seen that the total fixed costs remain the same each year, however it is apparent that fixed cost per acre-foot of water decreases as the quantity of water pumped per season increases.

TOTAL PUMPING COST

Acre-feet pumped per season	Fixed cost per acre-foot	Operating cost per acre-foot	Total cost per acre-foot
25	\$23.28	\$4.05	\$27.33
50	11.64	4.05	15.69
100	5.82	4.05	9.87
200	2.91	4.05	6.96

Farmers who do not consider fixed cost in arriving at total pumping cost may be misled when figuring net profits derived from irrigation at the end of the year. The overall pumping plant operating efficiency often is disregarded in relation to operating cost. The graph shown in Fig. 8 will give the number of kilowatt hours required to pump an acre-foot of water at various efficiencies and total pumping heads. The following example explains use of the graph in Fig. 8. To determine how many kilowatt hours will be required to pump an acre foot of water against a total head of 130 feet with an overall pumping plant efficiency of 60 percent, locate on the left margin 130 (point A); move to the right until the line representing 60% is intersected at point B; then follow downward until the lower margin is intersected at point D and read approximately 222. This represents the number of kilowatt hours required to pump an acre foot of water against a 130 foot head with an overall pumping plant efficiency of 60%. Using the same procedure, it is seen that if the pumping plant were 40% efficient, approximately 333 kilowatt hours would be required. This means that by lowering the overall pumping plant efficiency from 60% to 40% or 20% net loss, then 111 kw-hr. would be wasted. At 1½¢ per kw-hr., with 200 acre feet of water pumped per season,

$$\$.015 \times 111 \times 200 = \$333.00$$

has been lost through low operating efficiency. Over a ten year period \$3330.00 would be lost, which bears

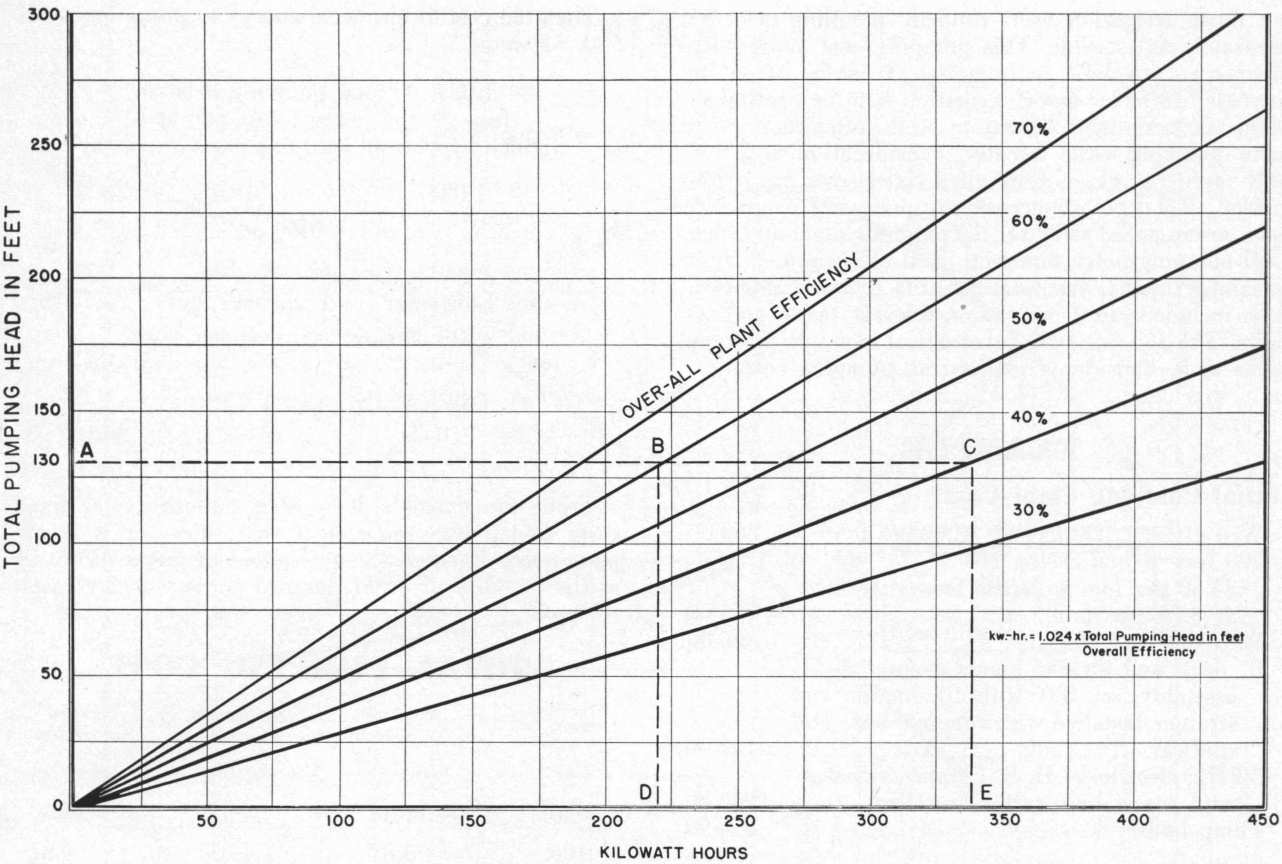

Fig. 8. Kilowatt hours required to pump one acre-foot of water at various heads and various over-all efficiencies.

out the importance of overall pumping plant efficiency in relation to pumping cost.

Periodic efficiency tests of the pumping plant will indicate to the farmer the overall operating efficiency of his irrigation pumping plant. To keep pumping cost at a minimum, pumping plants having low operating efficiencies should undergo necessary repairs to regain high operating efficiencies.

USEFUL INFORMATION

Units and Equivalents

Volume and Weight

1 U. S. gallon	= 231 cubic inches
	= 0.1337 cubic feet
	= 8.33 pounds
1 cubic foot	= 7.48 U. S. gallons
	= 62.4 pounds
1 acre-foot	= 43,560 cubic feet
	= 325,829 U. S. gallons
1 acre-inch	= 3,630 cubic feet
	= 27,152 U. S. gallons

Units of Pressure or Head

1 pound per square inch = 2.31 feet of water
= 2.04 inches of mercury
= 144 pounds per square foot
1 foot of water = 0.433 pounds per square inch

Length and Area

1 mile = 5,280 feet
1 acre = 43,560 square feet

Rate of Flow

1 cubic foot per second	= 449 gallons per minute
	= 26,928 gallons per hour
	= 2 acre-feet per day, 24 hours, (approx.)
	= 1 acre-inch per hour (approx.)

Units of Power

1 Horsepower	= 33,000 foot-lbs. per minute
	= 550 foot-lbs. per second
	= 0.746 kilowatts
1 kilowatt	= 1000 watts
	= 1.341 horsepower

Formulae

$$\text{Water horsepower} = \frac{\text{gallons per minute} \times \text{total pumping head in feet}}{3960}$$

$$\text{Horsepower required at pump shaft} = \frac{\text{gallous per minute} \times \text{total pumping head in feet}}{3960 \times \text{pump efficiency}}$$

Energy cost per hour of operation for electrical pumping =

$$\frac{0.189 \times \text{gallons per minute} \times \text{total pumping head in feet} \times \text{rate per kilowatt hour}}{1000 \times \text{overall pumping plant efficiency}}$$

$$\frac{\text{Gallons per minute}}{450} = \text{acre inches per hour pumped}$$

$$\frac{\text{Gallons per minute} \times \text{hours per irrigation set}}{450 \times \text{acres irrigated per set}} = \text{average depth of water applied in inches}$$

G.P.M.—Gallons Per Minute
R.P.M.—Revolutions Per Minute
kwh—Killowatt Hour
Hp.—Horsepower

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