# GROUND WATER SUPPLY OF BRYAN, TEXAS

By

B. A. Barnes, C. R. Follett, and R. W. Sundstrom

PREPARED IN COOPERATION BETWEEN THE GEOLOGICAL SURVEY, U. S. DEPARTMENT OF THE INTERIOR, AND THE TEXAS STATE BOARD OF WATER ENGINEERS

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## Introduction and purpose of investigation

The City of Bryan is contemplating the drilling of additional water wells to the Sparta sand to meet a slightly increasing demand and to provide the additional water needed due to the decline in yield of the present wells.

Concern had been expressed as to the advisability of further development of the Sparta sand in the vicinity of the Bryan well field. As a result an investigation was made by the Texas Board of Water Engineers and the United States Geological Survey to determine whether additional development of the Sparta sand would be economically feasible in the vicinity of the present well field. Pumping tests on five wells were conducted between June 15 and July 4, 1944. This report contains the results and conclusions based on these tests.

The investigation was conducted by the Texas Board of Water Engineers in cooperation with the U. S. Geological Survey under the general direction of W. N. White, Principal Engineer, of the Geological Survey, who is in charge of the ground-water work in Texas.

## Acknowledgments

The Texas Board of Water Engineers and the Geological Survey with to express their appreciation to G. O. Summers, City Manager, C. M. Ramsey, Superintendent, and all other members of the Bryan water department for their pleasant and helpful cooperation.

## History of development of present well field

In January 1938, S. F. Turner 1/, of the Geological Survey submitted a report to the City of Bryan discussing ground water conditions and existing water supplies, and among other recommendations for improvement suggested the exploration of the water-bearing characteristics of the sands in the vicinity of an oil test on the Conitella property (well 50 on plate 1) about 3½ miles northwest of the city. In response to this recommendation the city in May and June 1938 drilled a test well several hundred feet from well 50 to a total depth of 1,768 feet. Water samples were obtained from sands at 1,665 to 1,687 feet; 648 to 688 feet and 462 to 542 feet below the surface. The water in the sands at 462 to 542 feet belonging to the Sparta sand formation of the Claiborne group was by far the most suitable in chemical quality for municipal use (see table 10 page 26), and therefore, the city decided to develop these sands in the vicinity of this test well. Between May and August 1939 well 2, 3 and 4 were drilled and in August 1943 the fifth well was finished, completing the development of the well field as of August 1944.

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1/ See page 17 for table of references

## Geology

The geological information contained in this report is based chiefly on Turner's report 1/ and on information obtained during the development of the city well field. No field studies of the geology or geologic mapping was done during the recent investigation.

The table below gives the paleontological correlation of the sediments penetrated by the test well as made by the Humble Oil and Refining Company for the Layne-Texas Company. The sediments from the surface to about 1,120 feet belong to the Claiborne group, which is underlain by the Wilcox group all of Eocene age.

Table 1

Paleontological correlation of cuttings and cores from Bryan test well 1 and well 5 by Humble Oil and Refining Company

| Age | Formation | | Depth from which samples were obtained: Well 1 | Well 5 |
|---|---|---|---|---|
| Eocene | Cook Mountain | (Crockett) | 41-282 (cuttings) | 0-275 (cuttings) |
| | Sparta sand | | 282-543 (cuttings and cores) | 275-588 (cuttings) Note: Samples from 583-588 feet may be Weches, no diagnostic fossils were present) |
| | | Weches green-sand | 572-648 (cuttings) | |
| | Mount Selman | Queen City sand | 648-978 (cuttings and cores) | |
| | | Reklaw | 978-1052 (cuttings) | |
| | Carrizo sand | | 1052-1120 (cuttings) | |
| | Wilcox group | | 1120-1582 (cuttings and cores) | |

The above correlation places the top of the Sparta in well 1 and 5 at about 282 feet and 275 feet below the surface, respectively.

As shown by the drillers' logs of all five wells and the electrical log of well 5 the Sparta sand contains two and possibly three sands. The upper sand varies in thickness from about 23 feet in well 1 to about 40 feet in well 5, and the middle sand from about 68 feet in well 4 to 85 feet in well 2. The log of well 1 shows a 5-foot sand 24 feet below the base of the middle sand and the log of well 4 a 10-foot sand, the top of which is 26 feet below the middle sand. In well 5 this basal zone occurs about 42 feet below the bottom of the middle sand according to the electrical log. The basal zone was not reached in wells 2 and 3. Plummer 2/ in describing the Sparta states the following:

> "The sediments of the Sparta are thought to be mostly continental in origin. The basal sands were laid down on a beach and coastal plain in conjunction with the withdrawal of the Weches sea. The middle sands are mainly fluviatile deposits spread broadly over a flat plain. The upper sediments were deposited along a transgressing shoreline laid down in advance of the Crockett sea and were worked over later by marine waters. (Strata of such origin wedge out seaward and expand landward). The basal and upper layers show shore conditions with beach sands, dune deposits, and interfingering shallow deltaic strata. Cross-bedding formed by streams and ripple marks are noteworthy in the middle beds."

He also describes the Sparta formation as containing about 70 per cent sand, 25 per cent sandy shale or clay, 3 per cent glauconitic sand, 1 per cent limonite and 1 per cent lignite. The sand is gray or buff-colored consisting of round and subangular quartz grains about 0.5 mm. in diameter mixed with a small percentage of exceedingly fine grains.

## Recharge to reservoir in Sparta sand

Recharge to the reservoir in the Sparta sand occurs from penetration of rainfall and seepage from streams on the outcrop of the sand from four to five miles northwest of the well field (see plate 1). This outcrop is 3½ to 6 miles in width and has a southwest-northeast trend. The outcrop area has a sandy soil, is sparsely wooded in places and has comparatively low relief. These conditions are favorable for ground-water recharge. A 54 year record at College Station shows an average annual rainfall of 38.77 inches.

## Present city wells

The present well field consists of five wells (nos. 1 to 5) and is about 3½ miles northwest of the city of Bryan and about 4½ miles down dip from the outcrop of the top of the Sparta formation. Wells 1 to 4 were completed between July 1938 and July 1939. The deep test after the sampling of the lower sands had been completed was plugged back to 569 feet, screened in the Sparta sand, and finished as well 1. The last well (No. 5) was drilled in 1943. Plate 2 shows the approximate position of the wells, and a description of them is given in table 11, page 27.

According to the logs, wells 1 to 3 are screened in the middle sand section only, well 4 is screened in both the middle and upper sands, and well 5 is screened in the middle and lowermost zones (see table 2).

## Decline of water levels in wells

Table 2, page 18 gives the available water level measurements from the drilling and development of the well field to date. The measurements that are believed to represent the original static levels in wells 1, 2 and 4 adjusted for altitude agree within a few feet. The first measurement of the water level in well 2 is about 17-18 feet lower than those in the first three names, apparently due to the fact that it was taken only a few minutes after the pump stopped. The approximate net loss between the original 1938-39 static levels and the highest water level recorded during the pumping tests of June 14 to July 8, 1944 were as follows: Well 1, 71 feet: well 2, 61 feet (allowing 17 to 18 feet correction the decline amounts to 78 or 79 feet); well 3, 68 feet; and well 4, 65 feet. Well 5 had not been used prior to the pumping tests and therefore the water level of 114.57 in it obtained on June 24, 1944 shows the water level at that point under average conditions of pumping from the other four wells.

## Pumpage

Although wells 1 to 4 were drilled and developed in 1938 and 1939 operation of this field was not begun until March 1940 when production from wells 1 and 2 was started. Continuous pumping from well 3 was started a month later in April 1940. Well 4 was not used until June 1942 and then only as a standby well due to the fact that the water is somewhat less desirable chemically than the water from the other wells. Figure 1 shows graphically the estimated pumpage from each well, and the estimated total pumpage since the start of operation.

The estimated figures for the average total pumpage in millions of gallons a day from 1940 to 1944 is approximately as follows: 1940, (10 months) 1.33; 1941, 1.38; 1942, 1.52; 1943, 1.82; 1944, (first six months) 1.63.

The city furnishes water to Texas Agricultural and Mechanical College at College Station about 2½ miles south of Bryan and the increased war training program at the college was the major factor contributing to the increased use of water. The demand for water may decrease with the declining war program at the college.

## Pumping tests

A series of pumping tests consisting of five interference and two recovery tests was made on the Bryan wells between June 14 and July 4, 1944. The recovery tests were made on wells 4 and 5 and were maintained for 24 and 48 hours respectively, while each of the interference tests were carried on for about 48 hours. Water level measurements in the observation wells were made by means of a steel tape to the nearest .01 of a foot. Pumping level measurements, where possible were also made by tape, otherwise airline measurements to the nearest foot were recorded.

The yield of each well was obtained by periodic measurements of the discharge over weirs that the city maintains at each well. Although the stilling basin of each weir is equipped with baffles it is estimated that the error in measurements is between five and ten per cent due to slight wave action.

<u>Results of tests</u> - Table 3 shows the coefficients of transmissibility and storage computed from the observed pumping tests data by the Theis non-equilibrium formula 3/. These coefficients are a measure of the ability of the aquifer to transmit water and in combination with length of time of pumping distance from pumped well and the rate of pumping are the factors that determine the amount and rate of drawdown of the water levels caused by pumping from wells.

The coefficient of transmissibility is defined as the number of gallons of water which will move in one day through a vertical strip of the aquifer one foot wide and having the height of the aquifer with a hydraulic gradient of 100 per cent 4/

The coefficient of storage is defined as the volume of water measured in cubic feet released from storage in each column of the aquifer having a base one foot square and a height equal to the thickness of the aquifer when the artesian head is lowered one foot.

The non-equilibrium formula developed by C V. Theis of the U. S. Geological Survey is

$$S = \frac{114.6\,Q}{T} \qquad \frac{e^{-u}du}{u}$$

$$\frac{1.87\,r^2 S}{Tt}$$

where S is the drawdown in feet at any point in the vicinity of a well discharging at a uniform rate; Q is the discharge of the well in gallons a minute; T is the coefficient of transmissibility of the aquifer in gallons a day; r is the distance of the discharge well to the point of observation in feet; S is the coefficient of storage; and t is the time the well has been pumped in days 5/.

The formula assumes that an ideal aquifer is under investigation in that it is infinite in extent, that it is homogeneous and isotropic and that it is bounded by impermeable beds both above and below.

In these tests the non-equilibrium formula was applied graphically to the amount and rate of drawdown and recovery that occurred in a single observation well at different times during the day.

As seen in table 3 the transmissibility coefficients computed from the tests are in two fairly distinct groups, those in the "high" group being in the order of 14,000 to 15,000 gpd/ft., and averaging about 14,490 gpd/ft., while those in the "low" group very between 9,000 and 12,000 gpd/ft., and averaging about 10,780 gpd/ft. In compiling the curves in figures 2 to 7 the average "high" coefficients of transmissibility and storage used were 14,500 and 0.00024 respectively, and the average "low" coefficients were 10,800 and 0.00015 respectively.

The coefficients of storage computed from the observations on wells 1 and 2 all agree rather well, varying between 0.000221 and 0.000275 and averaging 0.000243 while the storage coefficient computed from the observations on well 3 is 0.000151 or about 37.8 per cent less than the average of the coefficients mentioned above.

The probable range within which the drawdown could be expected to vary in an infinite aquifer at the end of specific periods as a result of known changes in pumpage can be estimated by using average maximum coefficients of transmissibility and storage to obtain the probable minimum effect and by using the average minimum coefficients of transmissibility and storage to obtain the probable maximum effect. Using the average of each of these two groups of coefficients, two sets of curves were constructed to show the theoretical drawdown that would result in an idealized aquifer from pumping a well continuously at the rate of 1,000 gallons a minute, at the end of 3 months, and 1, 5, 10, 15 and 20 years (see figs. 2 to 7). The curves represent the approximate upper and lower limits within which the drawdown, due to a known pumpage will occur at the end of these periods. It is believed that the actual conditions existing in the aquifer are more nearly approached by expressing the computed drawdowns as a range limited by the curves of the average maximum and the average minimum coefficients.

Boundaries - The curves in figures 2 to 7 show the computed drawdown that will occur in an ideal aquifer, that is, one that is infinite in extent, homogeneous and isotropic. Since this condition is seldom found in nature the lateral boundaries of the aquifer and their characteristics must be determined. These boundaries can be structural such as faulting and folding, depositional such as the lensing out of a sand or the cropping out of the aquifer at the surface. As long as boundry intercepts occur at less than infinity they will eventually effect the amount and rate of decline of the water level. Proximity to the boundary decreases the time necessary for it to effect the decline of water levels and increases the amount of its effect. Boundaries such as faults tend to increase the amount and rate of decline while recharge in outcrop areas tends to decrease the amount and rate of decline of the water levels. At this location where it is only 4½ miles from the well field, the effect of the outcrop is to cause the rate of decline to become less and less until at the end of 5 years the drawdown will have practically ceased.

In computing the drawdowns shown in tables 5 to 9 the assumption was made that there has been and that there will be no drawdown in the outcrop and that recharge has maintained and will maintain a constant water level at the contact of the artesian and water-table areas. Whether or not this condition is achieved is not known, but it appears probable that if drawdown occurs the amount is small. In this connection it is believed advisable that at least two wells should be drilled and the water levels in them measured periodically, one well in the water table zone in the outcrop of the sand, and the other in the artesian zone down the dip where the sand is under cover, but close to the outcrop. By observing and correlating the changes in the water levels in these wells proper adjustment of estimates of drawdown in the water levels in the field can be made.

## Effect of pumping

Specific capacity - The non-equilibrium formula is likely to give results that are in error when used to determine the drawdown in a well caused by its own pumping. For this reason the specific capacity of a well is used to compute the drawdown caused by its own pumping 6/. (The specific capacity of a well is defined as the quantity of water that a well will yield in gallons a minute for each foot of drawdown in the well). The specific capacity of the Bryan wells computed from the drawdown at the end of 24 hours of pumping is given in table 4, page 20. A specific capacity of 6.5 gallons a minute per foot of drawdown has been used in all the computations to estimate the drawdown in proposed wells caused by their own pumping.

Drawdown of water levels - Computations show that the water levels in the Bryan well field are essential equilibrium, that the decline in water levels has practically ceased and that practically all of the water is coming from the outcrop. This condition will continue as long as pumping continues at the present rate if recharge is sufficient to maintain the water table in the outcrop at approximately the present level. However each increment of additional pumping will cause additional decline in the water levels. The principal limiting factor restricting the permissible amount of drawdown is the position of the top of the sand. Dewatering with the attending reduction in transmissibility should not be allowed to occur. In the compilation of tables 5 to 9 pages 21 to 25 it has been assumed that the drawdown produced by the pumping of the present wells 1, 2, 3, and 4 has practically ceased, and that in the future these wells will be pumped at the same average rate as in the past. Well 5 is considered as a new well, and table 5 page 21 gives the estimated drawdown of water levels that will be caused in the different wells by pumping well 5 continuously at the average rate of 600 gallons a minute. Computations show that the drawdown will be very little greater in the wells at the end of 5 years than it is at the end of 3 months, being in well 1 for example, between 27 and 37 at the end of 5 years as compared with 24 to 33 feet at the end of 3 months. The estimated pumping levels in the different wells at the end of the different periods given in the table are the pumping levels recorded during the pumping tests of June 14 to July 8 plus the computed drawdown caused by pumping well 5. The figures show that the pumping level at the end of three months would be very close to the top of the pump bowls in wells 2 and 3, (for depth to top of pump bowls see table 11, page 28), but that there would remain a large margin of safety in the well before dewatering of the aquifer begins. The margin of safety in the other wells would be considerably greater.

Tables 6 to 9, pages 22 to 25, give compilations of the estimated drawdowns that will occur at the end of the periods shown assuming an additional well pumping at the rate of 600 gallons a minute, at any one of four different locations, "A", "B", "C", and "D", as described in the heading of each table and shown in figure 8. The pumpage from this additional well in combination with that from well 5 would amount to about 1.73 million gallons a day or slightly over the total average amount pumped daily for the first six months of 1944. The total pumpage from all six wells would amount to about 3.36 million gallons a day which probably represents the maximum demand expected by the city for some time. By comparing tables 6 and 7 it can be seen that the total computed drawdown in the existing wells caused by proposed well 6 at site "A", 2,000 feet north of center well 2 is from 16 to 25 feet more than the computed drawdown caused by the well at location B, 6,100 feet southwest of well 2. In each case the assumed site is about 2,000 feet beyond the existing pipe line.

By comparing the drawdown given in tables 8 and 9 with those in table 7, it can be seen that by placing the proposed well 6 at sites C and D, 7,100 and 8,100 feet from well 2, the total saving in head at the end of five years is approximately 10 feet, and 15 to 20 feet, respectively.

## Quality of water

In the test well drilled to determine the quality of water contained in the Sparta, Queen City and Carrizo formations the samples were obtained by setting screens opposite the sands to be tested and pumping until there was obtained a representative sample of the water contained in the sand.

Comparison of the analyses (table 10, page 26) of the samples obtained between 462 and 543 feet (Sparta); 648 and 688 feet (Queen City) and between 1,665 and 1,687 feet (Wilcox) indicates that the water from the Sparta formation is of the most acceptable quality and is the only water tested that meets the U. S. Public Health Standards.

According to the analyses the water from wells 1, 2, 3 and 5 is of similar chemical character while that from well 4 is more highly mineralized containing total dissolved solids-approximately 2½ times the total solids in any of the other wells. Since number 4 is the only well screened in the upper sand member of the Sparta formation and because there is no data available that indicates a changing quality of water in the middle sand member in the direction of well 4, it is assumed that the water of higher mineralization is derived from the upper sand. The analysis of a sample of water from well 5 is very similar to analyses of these from wells 1, 2 and 3, although well 5 is screened in a lower zone, from 538 to 576 feet, in addition to the middle sand. It is believed the transmission capacity of this lower zone is small and it would appear that either very little water is obtained from this lower section or that it contains water very similar to that contained in the middle sand.

## Summary and conclusions

In the vicinity of the present well field the Sparta sand is the only sand that contains water of suitable quality for municipal use, and it is believed that to obtain water of comparable quality from either the Queen City sand or Carrizo sand development must take place several miles up the dip to the northwest of the present well field.

Computations indicate that essential equilibrium is attained and that the drawdown resulting from the pumping practically ceases at the end of 5 years. Therefore, it is believed that the decline in the water levels in the well field due to the pumping that has been done thus far has practically stopped. New increments of withdrawals will cause additional decline. Extension of the well field at either end of the line through well 2 to 4, however, will result in less drawdown than if the wells are placed an equal distance northwest or southeast of the center of the present field.

It is computed (table 5) that the pumping levels in wells 2 and 3 will be near the top of the pump bowls after three months continuous pumping of well 5 at the rate of 600 gallons a minute in addition to withdrawals from wells 1 to 4 at the present rate. If a new well (6) is added at side A (table 6) and pumped continuously at the rate of 600 gallons a minute, making the over all pumpage of 3.36 million gallons a day, the pumping levels will be lower than the pump bowls in wells 1, 2, and 3 at the end of 3 months. The relation of the pumping levels in tables 7, 8 and 9 to the pump settings can be obtained by comparing the above tables with the pump settings in table 2.

It is estimated (see tables 5 to 9) that well 5 and a sixth well at any one of the sites A, B, C, or D, can be pumped continuously at the rate of 600 gallons a minute each and there will still remain a large margin of safety at the end of 5 years, approximately 100 feet before dewatering of the aquifer begins. (If trouble with sand results from pumping the new well at the rate of 600 gallons a minute, the rate of pumping must be reduced). This additional 1.73 million gallons a day together with the present yield of about 1.63 million gallons a day from wells 1, 2, 3, and 4 will probably be sufficient to meet the expected increased demand for several years. It is recommended that the new well be spaced not less than 1,000 feet from the nearest existing well.

From the data available it appears possible that the decline in yield of the present wells may be due to inadequate pumping equipment and it is believed this should be checked. More pump bowls or more power may be needed.

It is recommended that the policy of electrical logging in all new wells be continued and in addition that the basal section of the Sparta be cored in well 6, (the equivalent of the section penetrated from 542 to 576 feet in well 5), and the permeability of the core determined. This will indicate the advisability of screening and developing the basal section, since there is considerable doubt as to the ability of this zone to transmit water.

The Texas Board of Water Engineers and the U. S. Geological Survey will be glad to assist, in any way possible, any future development.

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TABLE 2

Water levels in Bryan City wells, Bryan, Texas

| Date of measurement | Water level (feet below land surface) Well 1 | Well 2 | Well 3 | Well 4 | Well 5 | Remarks |
|---|---|---|---|---|---|---|
| July 30, 1938 | 66 1/ | | | | | |
| May 4, 1939 | | 106 1/ | | | | Shut down 10 minutes. |
| May 15, 1939 | | | 94 1/ | | | |
| July 14, 1939 | | | | 88 1/ | | |
| Dec. 11, 1940 | | 165 1/ | 190 1/ | | | Shut down 10 minutes. |
| Apr. 7, 1941 | 119 1/ | | | | | Shut down. Three wells pumping. |
| Oct. —, 1942 | | | | 128 1/ | | |
| Aug. 21, 1943 | | | | | 125 1/ | Shut down 10 minutes. |
| June 14, 1944 | | | | 152.97 | | Shut down 3 days. Wells 1, 2 and 3 pumping. |
| June 18, 1944 | | | | | 115.73 | Shut down 4 (+) days. Wells 1, 2 and 3 pumping. |
| June 23, 1944 | | 168.56 | | | | Shut down 6 days. Wells 3 and 4 pumping. |
| June 24, 1944 | 137.28 | | | | 114.57 | Well 1 shut down 7 days, well 5 shut down 5 days, wells 2, 3 and 4 pumping. |
| June 30, 1944 | 143.09 | | | | | Shut down 3 days. Wells 4 and 5 pumping. |
| July 2, 1944 | | 166.70 | 162.15 | | | Shut down 5 days. Wells 1, 4 and 5 pumping. |
| July 8, 1944 | | | 173.05 | | | Shut down 19 hours. Wells 1, 2 and 4 pumping. |

1/ Water level reported by Layne-Texas or City of Bryan.

TABLE 3

Coefficients of transmissibility and storage as determined from interference and recovery tests on Bryan City wells at Bryan, Texas

| Date of test | Pumping change | Observation well | Coefficient of transmissibility | Coefficient of storage | Sand thickness | Coefficient of permeability a/ |
|---|---|---|---|---|---|---|
| June 21 to June 23, 1944 | No. 5 off | No. 1 | 10,950 | 0.000275 | 69 | 158 |
| June 23 to June 24, 1944 | No. 2 on | No. 1 | 14,470 | 0.000221 | 69 | 210 |
| June 21 to June 23, 1944 | No. 5 off | No. 2 | 14,690 | 0.000229 | 85 | 173 |
| June 30 to July 2, 1944 | No. 1 on | No. 2 | 14,310 | 0.000246 | 85 | 168 |
| July 2 to July 4, 1944 | No. 2 on | No. 3 | 10,990 | 0.000151 | 72 | 153 |
| June 15 to June 16, 1944 | No. 4 off | No. 4 | 11,340 | | 99 | 196 |
| June 21 to June 24 | No. 5 off | No. 5 | 9,330 | | 116 | 80 |
| Averages | | | 12,370 | 0.000224 | 88 | 163 |
| Average of three highest transmissibility coefficients | | | 14,490 | | | |
| Average of four lower transmissibility coefficients | | | 10,780 | | | |

a/ Not corrected for temperature.

TABLE 4

Specific capacities of the Bryan City wells after 24-hours pumping

| Date | Well | Rate of pumping (g.p.m.) | Pumping level (feet below measuring point) | Drawdown of water level after 24 hours pumping (ft.) | Specific capacity (gallons a minute per foot of draw-down) |
|---|---|---|---|---|---|
| June 27 to June 28, 1944 | 1 | 261 | 219 | 70.5 | 3.7 1/ |
| June 30 to July 1, 1944 | 1 | 261 | 214.8 | 72.9 | 3.6 |
| June 17 to June 18, 1944 | 2 | 315 | 231 | 60.0 | 5.2 1/ |
| June 23 to June 24, 1944 | 2 | 315 | 231.7 | 64.0 | 4.9 |
| June 27 to June 28, 1944 | 2 | 320 | 234.7 | 61.6 | 5.2 |
| July 5, to July 6, 1944 | 3 | 346 | 258.5 | 82.3 | 4.2 |
| June 14 to June 15, 1944 | 4 | 424 | 223.2 | 70.2 | 6.0 |
| June 15 to June 16, 1944 | 4 | 424 | 223 | 68.8 | 6.2 1/ |
| June 18 to June 19, 1944 | 5 | 582 | 205.8 | 90.1 | 6.5 |
| June 21 to June 22, 1944 | 5 | 582 | 208.3 | 88.1 | 6.6 1/ |

1/ Specific capacity determined from 24-hours recovery of water levels.

TABLE 5

Theoretical drawdown at the end of the periods shown caused by pumping well 5 continuously at the rate of 600 gallons a minute

| | Well 1 | | Well 2 | | Well 3 | | Well 4 | | Well 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| **Three months** | | | | | | | | | | |
| Estimated drawdown (ft.) | 24 | 33 | 19 | 26 | 15 | 21 | 12 | 17 | 112 | 118 |
| Estimated pumping levels below pump base (ft.) | 239 | 248 | 249 | 256 | 275 | 281 | 235 | 240 | 227 | 233 |
| Height of water level above top of sand (ft.) | 219 | 210 | 189 | 182 | 142 | 136 | 159 | 154 | 191 | 185 |
| **One Year** | | | | | | | | | | |
| Estimated drawdown (ft.) | 26 | 36 | 21 | 28 | 17 | 23 | 14 | 19 | 114 | 121 |
| Estimated pumping levels below pump base (ft.) | 241 | 251 | 251 | 258 | 277 | 283 | 237 | 242 | 229 | 236 |
| Height of water level above top of sand (ft.) | 217 | 207 | 187 | 180 | 140 | 134 | 157 | 152 | 189 | 182 |
| **Five Years** | | | | | | | | | | |
| Estimated drawdown (ft.) | 27 | 37 | 22 | 29 | 18 | 24 | 15 | 20 | 115 | 122 |
| Estimated pumping levels below pump base (ft.) | 242 | 252 | 252 | 259 | 278 | 284 | 238 | 243 | 230 | 237 |
| Height of water level above top of sand (ft.) | 216 | 206 | 186 | 179 | 139 | 133 | 156 | 151 | 188 | 181 |

TABLE 6

Estimated drawdown at end of periods shown caused by pumping well 5 and proposed well 6 continuously at the rate of 600 gallons a minute each. Well 6 assumed to be at site A (see fig. 8), 2,000 feet northwest of well 2 and normal to a line through 2, 3 and 4.

| | Well 1 | | Well 2 | | Well 3 | | Well 4 | | Well 5 | | Proposed Well 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| **Three Months** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 23 | 31 | 27 | 36 | 22 | 30 | 18 | 24 | 17 | 23 | 112 | 118 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 262 | 279 | 276 | 292 | 297 | 311 | 253 | 264 | 244 | 256 | 129 1/ | 141 1/ |
| Height of pumping levels above top of sand (ft.) | 196 | 179 | 162 | 146 | 120 | 106 | 141 | 130 | 174 | 162 | | |
| **One Year** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 25 | 34 | 29 | 39 | 25 | 33 | 20 | 26 | 19 | 26 | 114 | 121 |
| Estimated pumping levels below pump base all wells and Well 6 (ft.) | 266 | 285 | 280 | 297 | 302 | 316 | 257 | 268 | 248 | 262 | 133 1/ | 147 1/ |
| Height of pumping levels above top of sand (ft.) | 192 | 173 | 158 | 141 | 115 | 101 | 137 | 126 | 170 | 156 | | |
| **Five Years** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 26 | 35 | 29 | 40 | 25 | 34 | 20 | 27 | 20 | 27 | 115 | 122 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 268 | 287 | 281 | 299 | 303 | 318 | 258 | 270 | 250 | 264 | 135 1/ | 149 1/ |
| Height of pumping levels above top of sand (ft.) | 190 | 171 | 157 | 139 | 114 | 99 | 136 | 124 | 168 | 154 | | |

1/ Drawdown only.

## TABLE 7

Estimated drawdown at end of periods shown caused by pumping well 5 and proposed well 6 continuously at the rate of 600 gallons a minute each. Well 6 assumed to be at site B (see fig. 8), 6,100 feet southwest of well 2, and in line with 2, 3 and 4.

| | Well 1 | | Well 2 | | Well 3 | | Well 4 | | Well 5 | | Proposed Well 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| **Three Months** | | | | | | | | | | | | |
| Estimated drawdown due to well 6 (ft.) | 21 | 28 | 17 | 22 | 13 | 18 | 11 | 15 | 27 | 36 | 112 | 118 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 260 | 276 | 266 | 278 | 288 | 299 | 246 | 255 | 254 | 269 | 139 1/ | 154 1/ |
| Height of pumping levels above top of sand (ft.) | 198 | 182 | 172 | 180 | 129 | 118 | 148 | 139 | 164 | 149 | | |
| **One Year** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 23 | 32 | 19 | 25 | 15 | 21 | 13 | 18 | 29 | 39 | 114 | 121 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 264 | 283 | 270 | 283 | 292 | 304 | 250 | 260 | 258 | 275 | 143 1/ | 160 1/ |
| Height of pumping levels above top of sand (ft.) | 194 | 175 | 168 | 155 | 125 | 113 | 144 | 134 | 160 | 143 | | |
| **Five Years** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 24 | 33 | 19 | 26 | 16 | 22 | 14 | 19 | 29 | 40 | 115 | 122 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 266 | 285 | 271 | 285 | 294 | 306 | 252 | 262 | 259 | 277 | 144 1/ | 162 1/ |
| Height of pumping levels above top of sand (ft.) | 192 | 173 | 167 | 153 | 123 | 111 | 142 | 132 | 159 | 141 | | |

1/ Drawdown only.

## TABLE 8

Estimated drawdown at end of periods shown caused by pumping well 5 and proposed well 6 continuously at the rate of 600 gallons a minute each. Well 6 assumed to be at site C (see fig. 8), 7,100 feet southwest of well 2 and in line with 2, 3 and 4.

| | Well 1 | | Well 2 | | Well 3 | | Well 4 | | Well 5 | | Proposed Well 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| **Three Months** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 19 | 26 | 15 | 21 | 12 | 17 | 10 | 14 | 23 | 31 | 112 | 113 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 258 | 274 | 264 | 277 | 287 | 298 | 245 | 254 | 250 | 264 | 135 1/ | 149 1/ |
| Height of pumping levels above top of sand (ft.) | 200 | 184 | 174 | 161 | 130 | 119 | 149 | 140 | 168 | 154 | | |
| **One Year** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 21 | 29 | 17 | 23 | 14 | 20 | 12 | 17 | 25 | 34 | 114 | 121 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 262 | 280 | 268 | 281 | 291 | 303 | 249 | 259 | 254 | 270 | 139 1/ | 154 1/ |
| Height of pumping levels above top of sand (ft.) | 196 | 178 | 170 | 157 | 126 | 114 | 145 | 135 | 164 | 148 | | |
| **Five Years** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 22 | 30 | 18 | 24 | 15 | 21 | 13 | 18 | 26 | 35 | 115 | 122 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 264 | 282 | 270 | 283 | 293 | 305 | 251 | 261 | 256 | 272 | 141 1/ | 157 1/ |
| Height of pumping levels above top of sand (ft.) | 194 | 176 | 168 | 155 | 124 | 112 | 143 | 133 | 162 | 146 | | |

1/ Drawdown only.

TABLE 9

Estimated drawdown at the end of periods shown caused by pumping well 5 and proposed well 6 continuously at the rate of 600 gallons a minute each. Well 6 assumed to be at site D (see fig. 8), 8,100 feet southwest of well 2 and in line with 2, 3 and 4.

| | Well 1 | | Well 2 | | Well 3 | | Well 4 | | Well 5 | | Proposed Well 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| **Three Months** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 17 | 23 | 14 | 19 | 11 | 16 | 10 | 13 | 20 | 23 | 112 | 118 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 256 | 271 | 263 | 275 | 286 | 297 | 245 | 253 | 247 | 255 | 132 1/ | 146 1/ |
| Height of pumping levels above top of sand (ft.) | 202 | 187 | 175 | 163 | 131 | 120 | 150 | 141 | 171 | 163 | | |
| **One Year** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 19 | 26 | 16 | 22 | 13 | 18 | 11 | 16 | 22 | 31 | 114 | 121 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 260 | 277 | 265 | 277 | 290 | 301 | 248 | 258 | 251 | 267 | 136 1/ | 152 1/ |
| Height of pumping levels above top of sand (ft.) | 198 | 181 | 173 | 161 | 127 | 116 | 146 | 136 | 167 | 151 | | |
| **Five Years** | | | | | | | | | | | | |
| Estimated drawdown due to Well 6 (ft.) | 20 | 27 | 17 | 22 | 14 | 19 | 12 | 16 | 23 | 32 | 115 | 122 |
| Estimated pumping levels below pump base due to all wells and Well 6 (ft.) | 262 | 279 | 269 | 281 | 292 | 303 | 250 | 259 | 253 | 269 | 138 1/ | 153 1/ |
| Height of pumping levels above top of sand (ft.) | 196 | 179 | 169 | 157 | 125 | 114 | 144 | 135 | 165 | 149 | | |

1/ Drawdown only

TABLE 10

Partial analyses of water from Bryan City wells in Bryan, Texas

Analyzed at the University of Texas under the direction of E. W. Lohr and W. W. Hastings, chemists, U. S. Department of the Interior, Geological Survey, and Dr. E. P. Schoch, Director of the Bureau of Industrial Chemistry. Results are in parts per million. Well numbers correspond to numbers in table of well records.

| Well | Owner | Depth of well (ft.) | Date of collection | Total dissolved solids | Silica ($SiO_2$) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium and Potassium (Na+K) (calc.) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Fluoride (F) | Nitrate ($NO_3$) | Total hardness as $CaCO_3$ (calc.) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | City of Bryan | a/462-542 | May 13, 1938 | 180 | | | 5.0 | 1.7 | 67 | 150 | 10 | 18 | 0.3 | 0.1 | 19 | |
| | do. | a/462-543 | b/July 21, 1938 | 153 | | | 4+ | | | 136 | 5+ | 17 | 0.2 | 0 | | |
| | do. | a/462-543 | c/July 30, 1938 | 149 | | | 4+ | | | 134 | 5+ | 16 | | | | |
| | do. | 569 | Nov. 11, 1942 | 177 | 18 | 0.05 | 1.0 | 0.2 | 67 | 148 | 5.3 | 16 | 0.1 | 0 | 3 | 8.2 |
| | do. | 648-688 | May ? 1938 | 1,151 | | | 4.8 | 2.1 | 485 | 1,038 | 6.9 | 72 | 1.6 | 1.0 | 21 | |
| | do. | a/1,665-1,887 | d/July 5, 1938 | 3,093 | | .12 | 5.8 | 1.9 | 1,274 | 1,664 | 1.0 | 885 | 3.2 | | 22 | |
| 2 | do. | 532 | Nov. 10, 1942 | 184 | 18 | 0.04 | 2.0 | 0.3 | 67 | 156 | 5.7 | 12 | 0.2 | 0 | 6 | 8.2 |
| 3 | do. | 498 | do. | 188 | 16 | 0.05 | 1.5 | 0.2 | 71 | 163 | 2.4 | 16 | 0.2 | 0 | 4 | 8.2 |
| 4 | do. | 677 | e/Oct. 10, 1942 | 474 | 15 | 0.25 | 2.1 | 0.5 | 192 | 436 | 1.6 | 45 | 0.3 | 0.2 | 7 | 8.2 |
| 5 | do. | 584 | Aug. 23, 1943 | 184 | 19 | 0.10 | 1.7 | 0.2 | 69 | 159 | 1.5 | 16 | 0 | 0 | 5 | 8.1 |

a/ Sample obtained between depths shown.
b/ Sample collected after 24 to 48 hours pumping.
c/ Sample collected after 245 hours pumping.
d/ Sample collected after $47\frac{1}{2}$ hours pumping.
e/ Sample collected after pumping 15 minutes at 250 gallons per minute.

TABLE 11

Records of the Bryan City wells, Bryan, Texas[1/]

| Owner's No. | Date completed | Approximate altitude (ft.) | Depth of well (ft.) | Diameter of well (in.) | SAND | | Depth to top of screen (ft.) | Length of screen (ft.) | Height of measuring point above ground (ft.) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Depth to top of bed (ft.) | Thickness (ft.) | | | |
| 1 | July 30, 1938 | 310 | 1,768 | 8-5/8 | 458<br>480 | 10<br>59 | 462<br>494 | 13<br>50 | —<br>—<br>2.0 |
| 2 | May —, 1939 | 333 | 523 | 16 | 438 | 85 | 435 | 88 | —<br>—<br>2.3 |
| 3 | May 23, 1939 | 335 | 498 | 16 | 417 | 72 | 422 | 70 | —<br>—<br>1.6 |
| 4 | July 14, 1939 | 331 | 677 | 16 | 394<br>529 | 31<br>68 | 391<br>549 | 31<br>51 | —<br>—<br>1.4 |
| 5 | Aug. 28, 1943 | 301 | 584 | 16 | 418<br>538 | 78<br>38 | 430<br>534 | 55<br>39 | —<br>1.8 |

1/ All wells drilled by Layne-Texas Company

TABLE 11

| WATER LEVEL | | | | PUMP | | | |
|---|---|---|---|---|---|---|---|
| Below measuring point (ft.) | Date of measurement | Length of airline (ft.) | Motor h.p. | Depth to top of pump bowls (ft.) | Bowl size (in.) | Number of stages | Remarks |
| 66 2/<br>119 2/<br>137.28<br>143.09 | July 30, 1938<br>April 7, 1941<br>June 24, 1944<br>June 30, 1944 | 260 | 30 | 260 | — | — | Casing: 459 feet of 8-5/8 inch, 125 feet of 6-5/8 inch with 17-foot lap into 8-5/8 inch. Temperature 80° F. |
| 106 2/<br>165 2/<br>168.56<br>166 70 | May 4, 1939<br>Dec. 11, 1940<br>June 23, 1944<br>July 2, 1944 | 260 | 50 | 260 | 12 | 9 | Casing: 435 feet of 16-inch; 191 feet of 8-5/8 inch with 103-foot lap into 16-inch. Underreamed to 30-inch diameter and gravel from 435 to 523 feet. |
| 94 2/<br>190 2/<br>162.15<br>173.05 | May 15, 1939<br>Dec. 11, 1940<br>July 2, 1944<br>July 8, 1944 | 280 | 50 | 280 | 12 | 10 | Casing: 416 feet of 16-inch, 178 feet of 8-5/8 inch with lap of 102 feet into 16 inch. Underreamed to 36-inch diameter and gravel from 416 to 497 feet. Temperature 80° F. |
| 88 2/<br>128 2/<br>152.97 | July 14, 1939<br>Oct. 15, 1942<br>June 14, 1944 | 290 | 50 | 290 | 12 | 10 | Casing: 581 feet of 16-inch 329 feet of 8-5/8 inch with 110 foot lap into 16 inch. Underreamed to 36 inch diameter and gravel 290 to 605 feet. Temperature 80.5° F. |
| 125 2/<br>115.73<br>114.57 | Aug. 21, 1943<br>June 18, 1944<br>June 24, 1944 | 270 | 60 | 270 | 12 | 11 | Casing: 424 feet of 16-inch 267 feet of 8-5/8 inch with 111-foot lap into 16 inch. Underreamed to 36-inch diameter and gravel from 424 to 582 feet. Temperature 80.5° F. |

2/ Water level reported by driller or city.

Table of drillers' logs, Bryan City wells,
Bryan, Texas

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| **Well 1** | | |
| Clay | 13 | 13 |
| Sand | 10 | 23 |
| Rock | 1 | 24 |
| Gray shale | 27 | 51 |
| Brown shale | 27 | 78 |
| Sand | 3 | 81 |
| Brown shale | 2 | 83 |
| Sand | 5 | 88 |
| Brown shale | 10 | 98 |
| Fine-grained green sand | 13 | 111 |
| Brown shale | 17 | 128 |
| Rock | 1 | 129 |
| Light gray shale and layers of shell | 125 | 254 |
| Rock | 1 | 255 |
| Gray shale, boulders and layers of shell | 26 | 281 |
| Sand and layers of shale | 12 | 293 |
| Gray shale and shell | 27 | 320 |
| Gray shale and layers of sand | 13 | 333 |
| Sandy shale | 20 | 353 |
| Gray shale and streaks of sand | 27 | 380 |
| Hard brown sandy shale with streaks of sand and lignite | 33 | 413 |
| Sand with streaks of brown shale and lignite | 23 | 436 |
| Sandy shale, lignite, shell and layers of sand | 19 | 455 |
| Hard shale | 3 | 458 |
| Hard sand rock | 10 | 468 |
| Sand and layers of shale | 12 | 480 |
| Sand | 59 | 539 |
| Brown shale and shell | 10 | 549 |
| Brown shale, shell and lignite | 14 | 563 |
| Sand | 5 | 568 |
| Brown and green shale, shell and lignite | 52 | 620 |

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| **Well 1 — Continued** | | |
| Rock | 1 | 621 |
| Brown shale, shell, lignite and pyrite | 23 | 644 |
| Sand with shale breaks | 40 | 684 |
| Shale, shell and lignite | 36 | 720 |
| Rock | 1 | 721 |
| Shale and shell | 9 | 730 |
| Sandy shale and lignite | 28 | 758 |
| Shale | 3 | 761 |
| Sandy shale, layers of sand, lignite and glauconite | 23 | 784 |
| Sand, sandy shale and streaks of shale and shell | 42 | 826 |
| Shale, shell and lignite | 21 | 847 |
| Fine-grained sand | 7 | 854 |
| Hard brown shale and lignite | 32 | 886 |
| Brown shale, shell and layers of sand | 28 | 914 |
| Brown shale and shell | 12 | 926 |
| Rock | 1 | 927 |
| Muddy sand and streaks of brown shale | 58 | 985 |
| Rock | 2 | 987 |
| Brown shale, shell and lignite | 41 | 1028 |
| Brown sandy shale, lignite and shell | 22 | 1050 |
| Rock | 1 | 1051 |
| Hard brown shale, shell and lignite | 5 | 1056 |
| Hard brown and gray shale, shell and lignite | 84 | 1140 |
| Hard shale, shell and layers of limerock | 34 | 1174 |
| Rock | 4 | 1178 |
| Shale | 2 | 1180 |
| Rock | 1 | 1181 |
| Hard shale | 39 | 1220 |
| Hard packed sand | 7 | 1227 |
| Shale | 4 | 1231 |
| Hard packed sand, layers of rock, shell and shale | 15 | 1246 |

continued on next page

Table of drillers' logs, Bryan city wells—Continued

**Well 1 — Continued**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Rock, shale, shell and layers of hard rock | 21 | 1267 |
| Shale | 9 | 1276 |
| Rock, shale, shell and layers of hard rock and pyrite | 15 | 1291 |
| Brown shale and lignite | 53 | 1344 |
| Sandy shale | 80 | 1424 |
| Shale and streaks of sandy shale | 10 | 1434 |
| Muddy sand with layers of shale | 32 | 1466 |
| Sand and layers of shale | 14 | 1480 |
| Sandy shale | 5 | 1485 |
| Sand (cored) | 9 | 1494 |
| Sand, shale, lignite and mica | 31 | 1525 |
| Brown and gray shale and lignite | 31 | 1556 |
| Sand rock | 2 | 1558 |
| Hard brown and green shale and lignite | 20 | 1578 |
| Hard brown and green shale, lignite and streaks of sandy shale | 48 | 1626 |
| Sandy shale and lignite | 26 | 1652 |
| Muddy sand | 49 | 1701 |
| Sand rock | 3 | 1704 |
| Hard packsand | 2 | 1706 |
| Rock | 3 | 1709 |
| Fine-grained hard packsand | 42 | 1751 |
| Shale, sandy shale, lignite and shell | 16 | 1767 |
| Rock | 1 | 1768 |

**Well 2**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Red and white clay | 27 | 27 |
| Sandy shale | 23 | 50 |
| Gray shale | 108 | 158 |
| Rock | 2 | 160 |
| Gray shale and shell | 47 | 207 |

**Well 2 — Continued**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Rock | 1 | 208 |
| Gray shale, boulders and shell | 32 | 240 |
| Rock | 1 | 241 |
| Gray shale, boulders and shell | 54 | 295 |
| Rock | 1 | 296 |
| Sand and shale | 11 | 307 |
| Sand and shell | 30 | 337 |
| Sand and shale | 25 | 362 |
| Fine-grained sand | 30 | 392 |
| Shale, lignite and sand | 46 | 438 |
| Sand and shale | 85 | 523 |

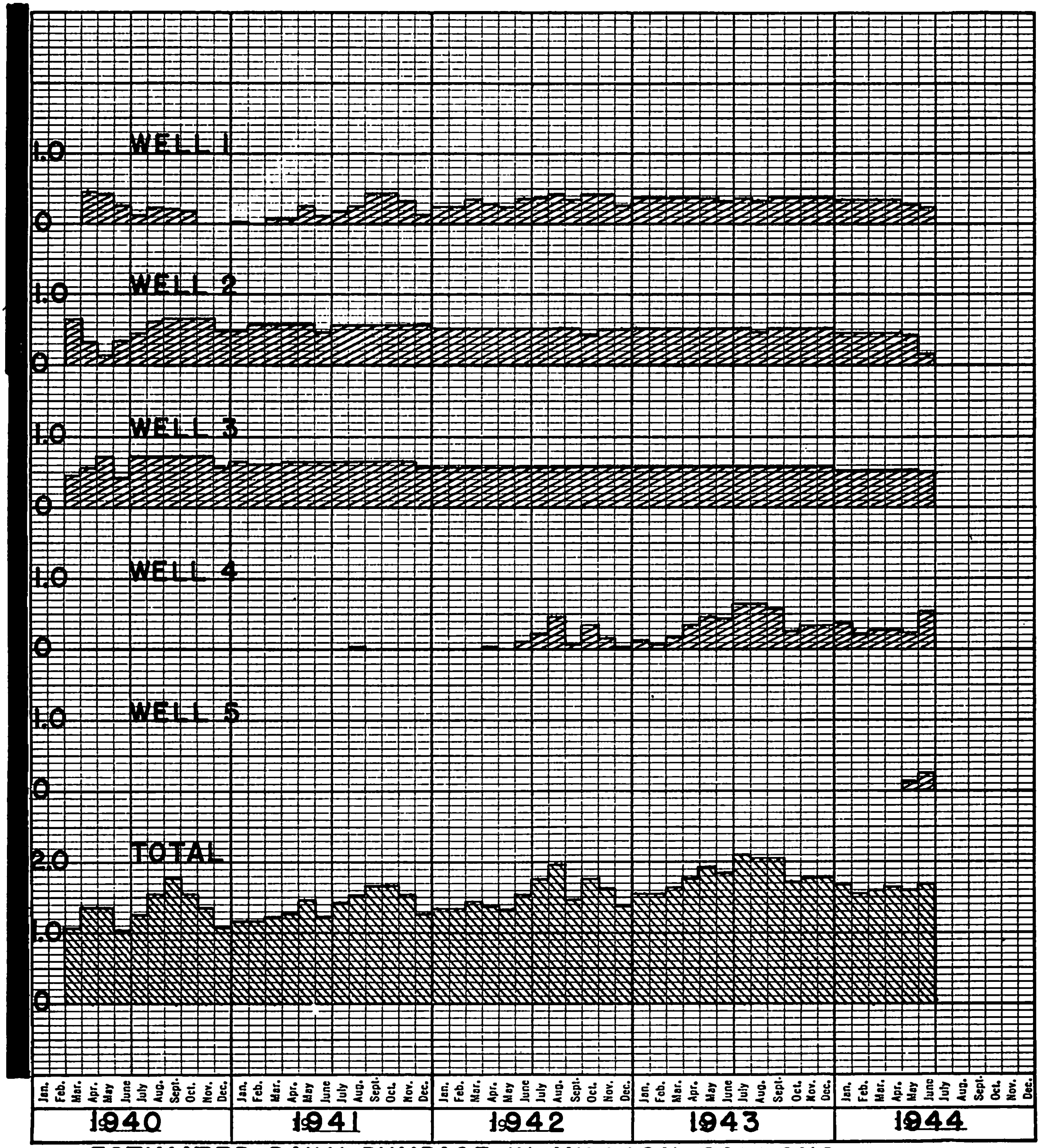
**Well 3**

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| Clay | 28 | 28 |
| Red and white clay | 47 | 75 |
| Rock | 1 | 76 |
| Sandy shale | 28 | 104 |
| Sand | 12 | 116 |
| Rock | 1 | 117 |
| Hard, green sand | 24 | 141 |
| Gray shale | 44 | 185 |
| Rock | 2 | 187 |
| Shale and rock layers | 3 | 190 |
| Rock | 1 | 191 |
| Gray shale | 32 | 223 |
| Gray shale and shell | 24 | 247 |
| Shale, shell and boulders | 23 | 270 |
| Rock | 1 | 271 |
| Shale, shell and boulders | 24 | 295 |
| Sand and shale layers | 19 | 314 |
| Shale and shell | 28 | 342 |
| Shale and sand | 31 | 373 |
| Shale and sand layers | 20 | 393 |
| Shale and sandy shale | 24 | 417 |
| Sand | 72 | 489 |
| Shale | 9 | 498 |

Table of drillers' logs, Bryan city wells — Continued

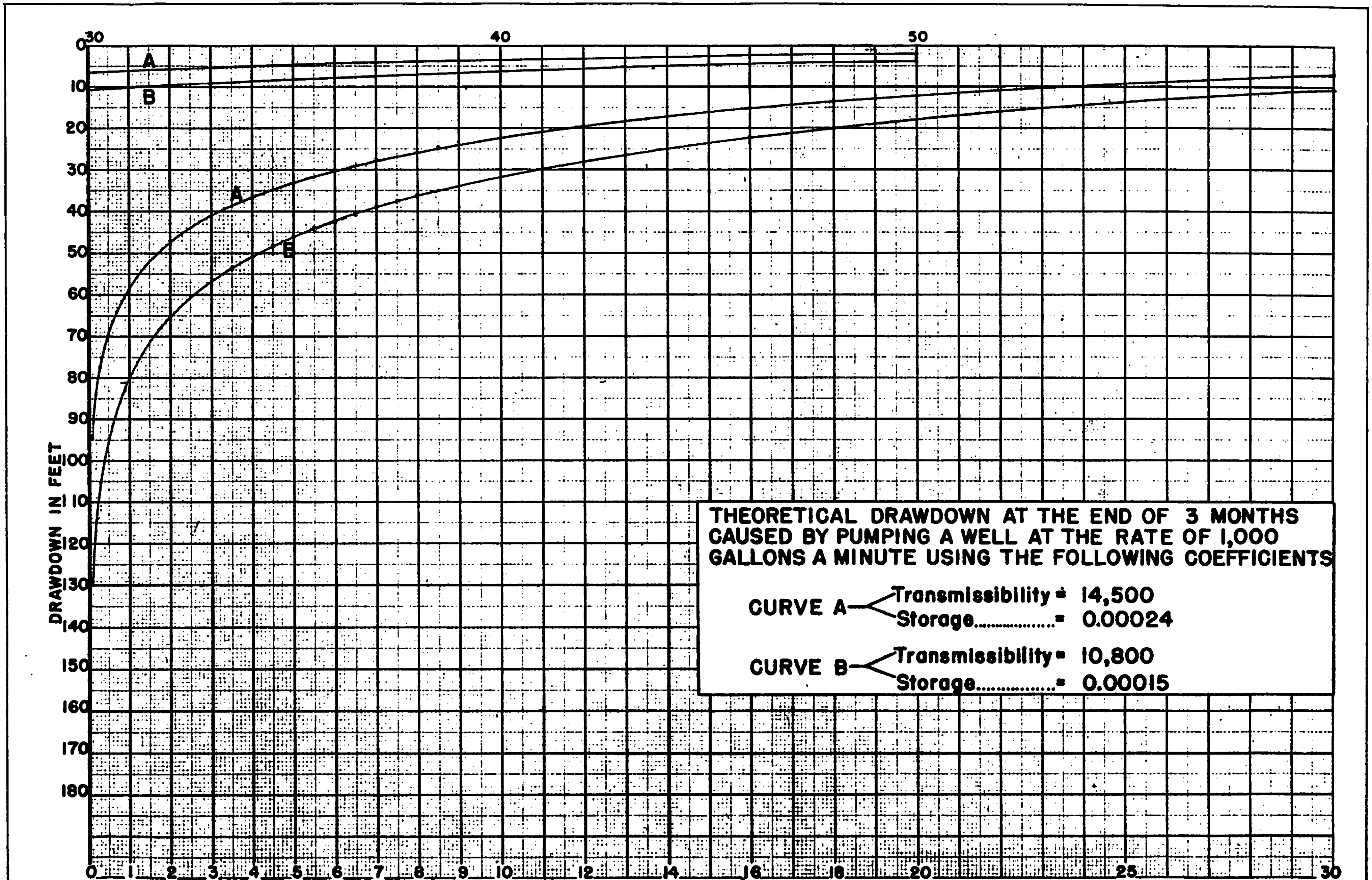
| | Thickness (feet) | Depth (feet) |
|---|---|---|
| **Well 4** | | |
| Clay | 8 | 8 |
| Yellow clay | 24 | 32 |
| Rock | 1 | 33 |
| Gray shale | 46 | 79 |
| Rock | 1 | 80 |
| Gray shale | 13 | 93 |
| Sand and shale | 31 | 124 |
| Shale | 7 | 131 |
| Sandy shale and shell | 16 | 147 |
| Gray shale | 35 | 182 |
| Shale | 22 | 204 |
| Shale and boulders | 5 | 209 |
| Rock | 1 | 210 |
| Shale | 10 | 220 |
| Rock | 1 | 221 |
| Shale | 10 | 231 |
| Rock | 1 | 232 |
| Shale | 2 | 234 |
| Rock | 1 | 235 |
| Gray shale | 29 | 264 |
| Shale and boulders | 27 | 291 |
| Rock | 1 | 292 |
| Gray shale | 31 | 323 |
| Sandy shale | 15 | 338 |
| Gray shale and shells | 21 | 359 |
| Sand with shale breaks. | 30 | 389 |
| Shale | 5 | 394 |
| Sand (tight) | 31 | 425 |
| Shale | 25 | 450 |
| Sandy shale | 69 | 519 |
| Sand | 5 | 524 |
| Shale | 5 | 529 |
| Sand | 68 | 597 |
| Brown shale | 26 | 623 |
| Hard sand | 10 | 633 |
| Sandy shale | 16 | 649 |
| Sandy shale (cored) | 2 | 651 |
| Shale and lime | 8 | 659 |
| Sand and sandy shale | 18 | 677 |

| | Thickness (feet) | Depth (feet) |
|---|---|---|
| **Well 5** | | |
| Black soil | 3 | 3 |
| Yellow clay | 6 | 9 |
| Sandy clay | 8 | 17 |
| Blue clay | 12 | 29 |
| Shale with sand breaks | 60 | 89 |
| Rock | 1 | 90 |
| Shale and shell layers | 28 | 118 |
| Shale | 27 | 145 |
| Rock | 1 | 146 |
| Shale | 24 | 170 |
| Hard shale and layers of hard sand | 113 | 283 |
| Hard rock | 2 | 285 |
| Hard shale, shell and layers of hard sand | 42 | 327 |
| Sand and layers of shale | 8 | 335 |
| Sand and layers of shell | 25 | 360 |
| Sand and layers of shell and sand | 13 | 373 |
| Hard shale and layers of hard sand | 19 | 392 |
| Hard sand | 10 | 402 |
| Sand and layers of shale and shell | 16 | 418 |
| Sand | 9 | 427 |
| Sand and layers of shell and lignite | 22 | 449 |
| Sand with few shale breaks | 16 | 465 |
| Hard sand | 5 | 470 |
| Sand with few hard streaks | 23 | 493 |
| Sand with lignite and shale breaks | 37 | 530 |
| Hard shale | 5 | 535 |
| Sand with few shale breaks | 44 | 579 |
| Sandy shale | 5 | 584 |



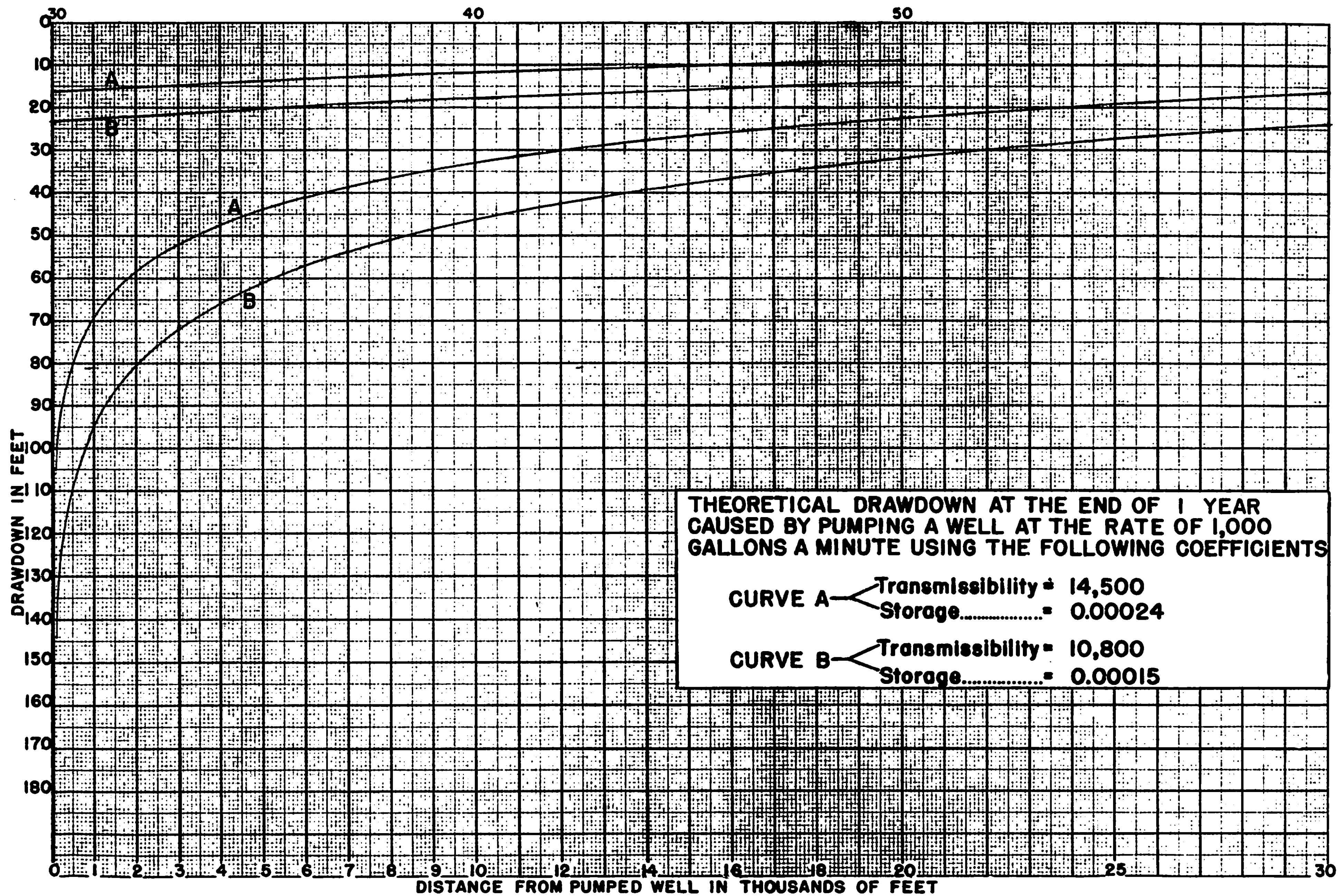

ESTIMATED DAILY PUMPAGE IN MILLION GALLONS
CITY OF BRYAN, TEXAS.

FIG. I.



THEORETICAL DRAWDOWN AT THE END OF 3 MONTHS CAUSED BY PUMPING A WELL AT THE RATE OF 1,000 GALLONS A MINUTE USING THE FOLLOWING COEFFICIENTS
CURVE A
Transmissibility = 14,500
Storage.................. = 0.00024
CURVE B
Transmissibility = 10,800
Storage................ = 0.00015
DRAWDOWN IN FEET
DISTANCE FROM PUMPED WELL IN THOUSANDS OF FEET
A
B


FIG. 2.



THEORETICAL DRAWDOWN AT THE END OF 1 YEAR CAUSED BY PUMPING A WELL AT THE RATE OF 1,000 GALLONS A MINUTE USING THE FOLLOWING COEFFICIENTS
CURVE A — Transmissibility = 14,500
Storage = 0.00024
CURVE B — Transmissibility = 10,800
Storage = 0.00015
DRAWDOWN IN FEET
DISTANCE FROM PUMPED WELL IN THOUSANDS OF FEET
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
0 1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 25 30
30 40 50
A
B


FIG. 3.

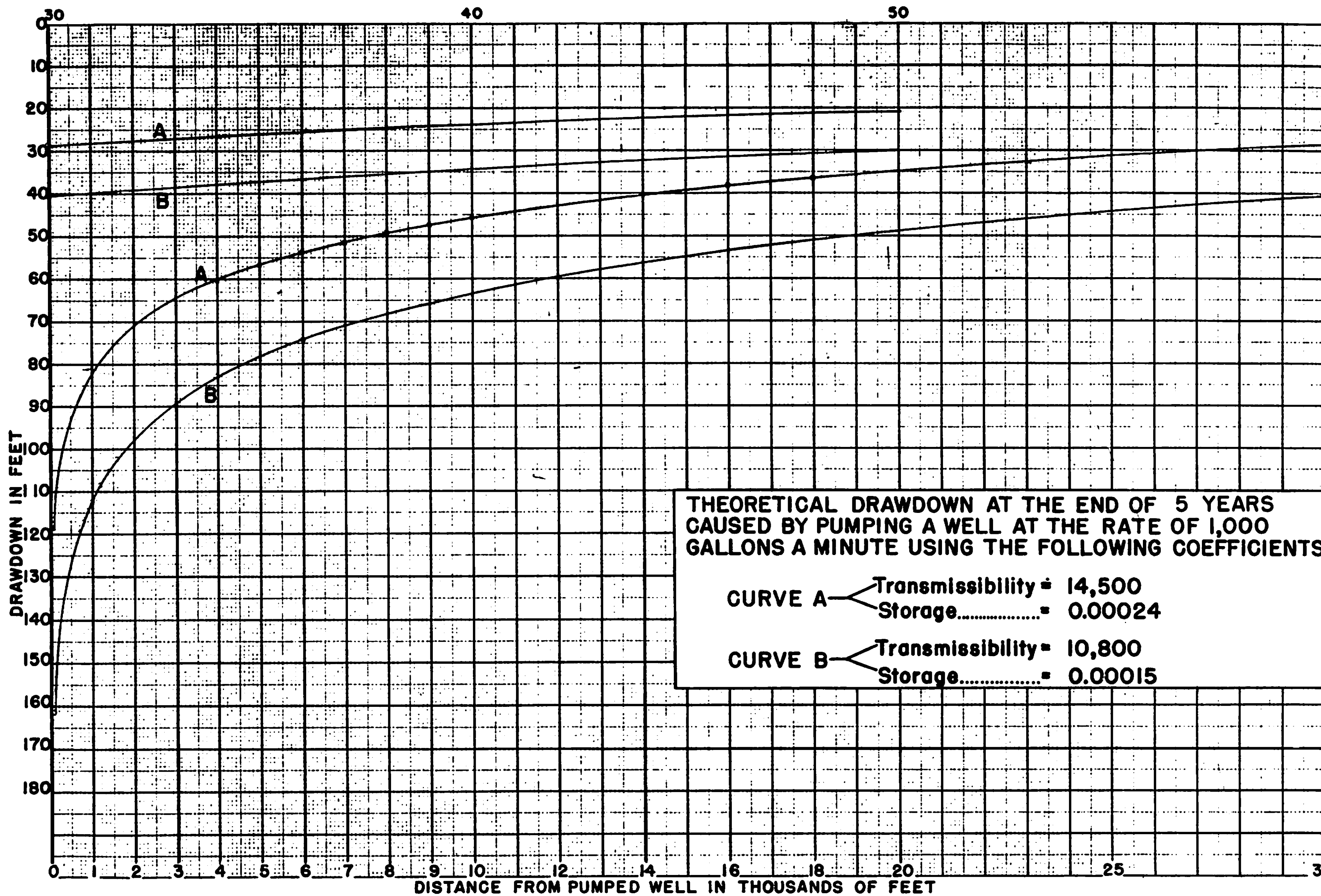

30
40
50
DRAWDOWN IN FEET
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
A
B
A
B
0
1
2
3
4
5
6
7
8
9
10
12
14
16
18
20
25
30
DISTANCE FROM PUMPED WELL IN THOUSANDS OF FEET
THEORETICAL DRAWDOWN AT THE END OF 5 YEARS CAUSED BY PUMPING A WELL AT THE RATE OF 1,000 GALLONS A MINUTE USING THE FOLLOWING COEFFICIENTS
CURVE A
Transmissibility = 14,500
Storage................ = 0.00024
CURVE B
Transmissibility = 10,800
Storage................ = 0.00015

FIG. 4.

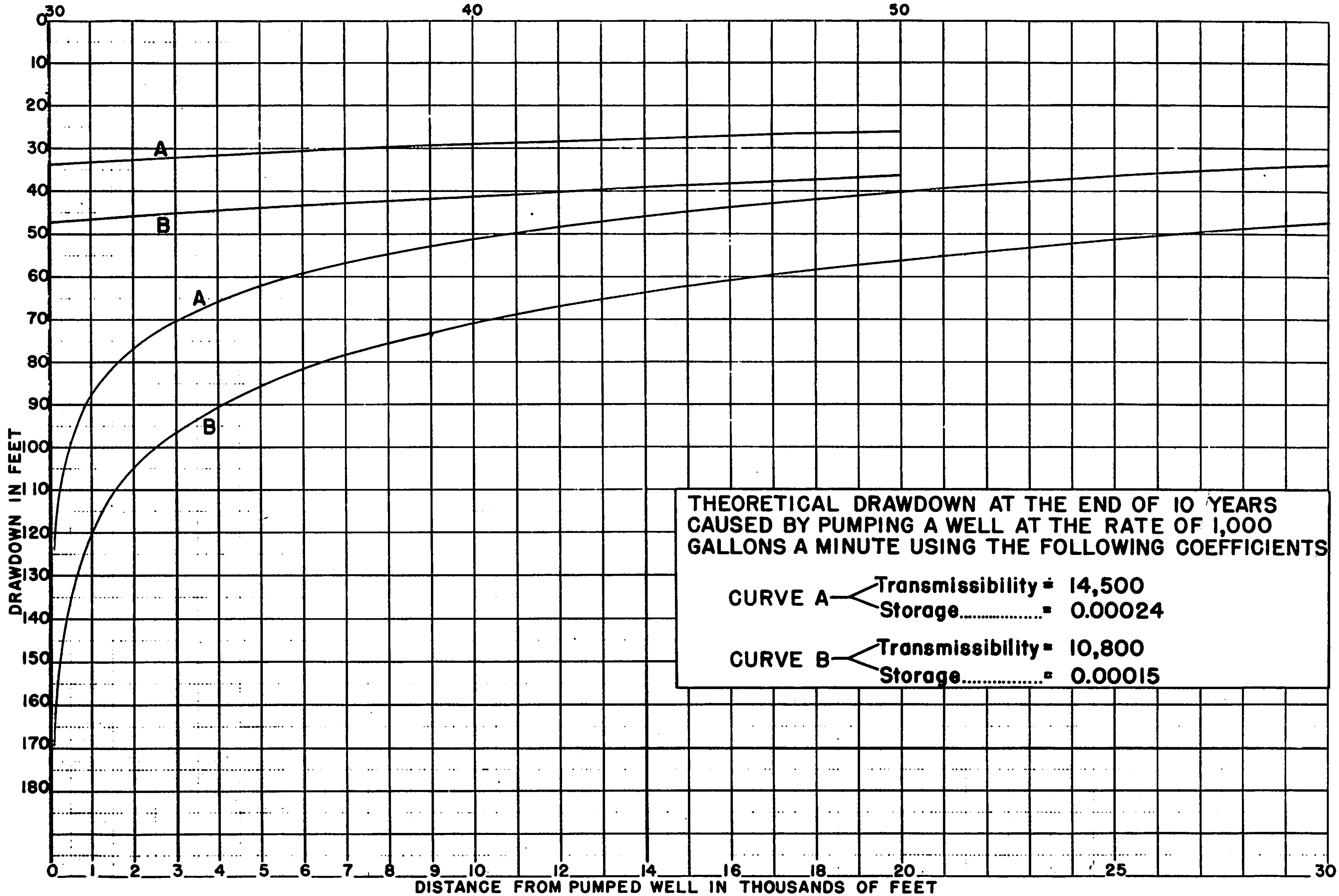

THEORETICAL DRAWDOWN AT THE END OF 10 YEARS CAUSED BY PUMPING A WELL AT THE RATE OF 1,000 GALLONS A MINUTE USING THE FOLLOWING COEFFICIENTS
CURVE A — Transmissibility = 14,500
Storage = 0.00024
CURVE B — Transmissibility = 10,800
Storage = 0.00015
DRAWDOWN IN FEET
DISTANCE FROM PUMPED WELL IN THOUSANDS OF FEET
A
B

FIG. 5.

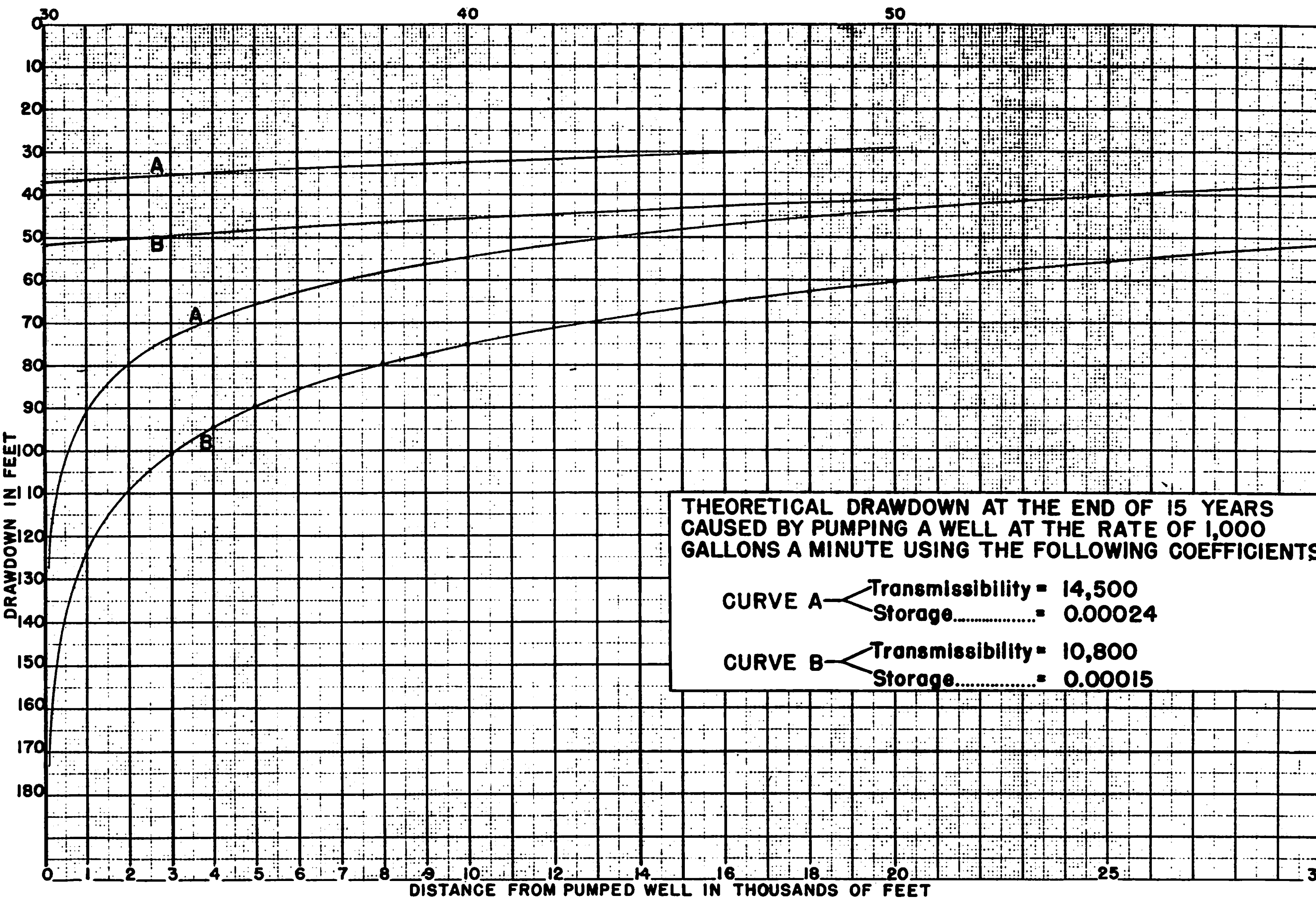
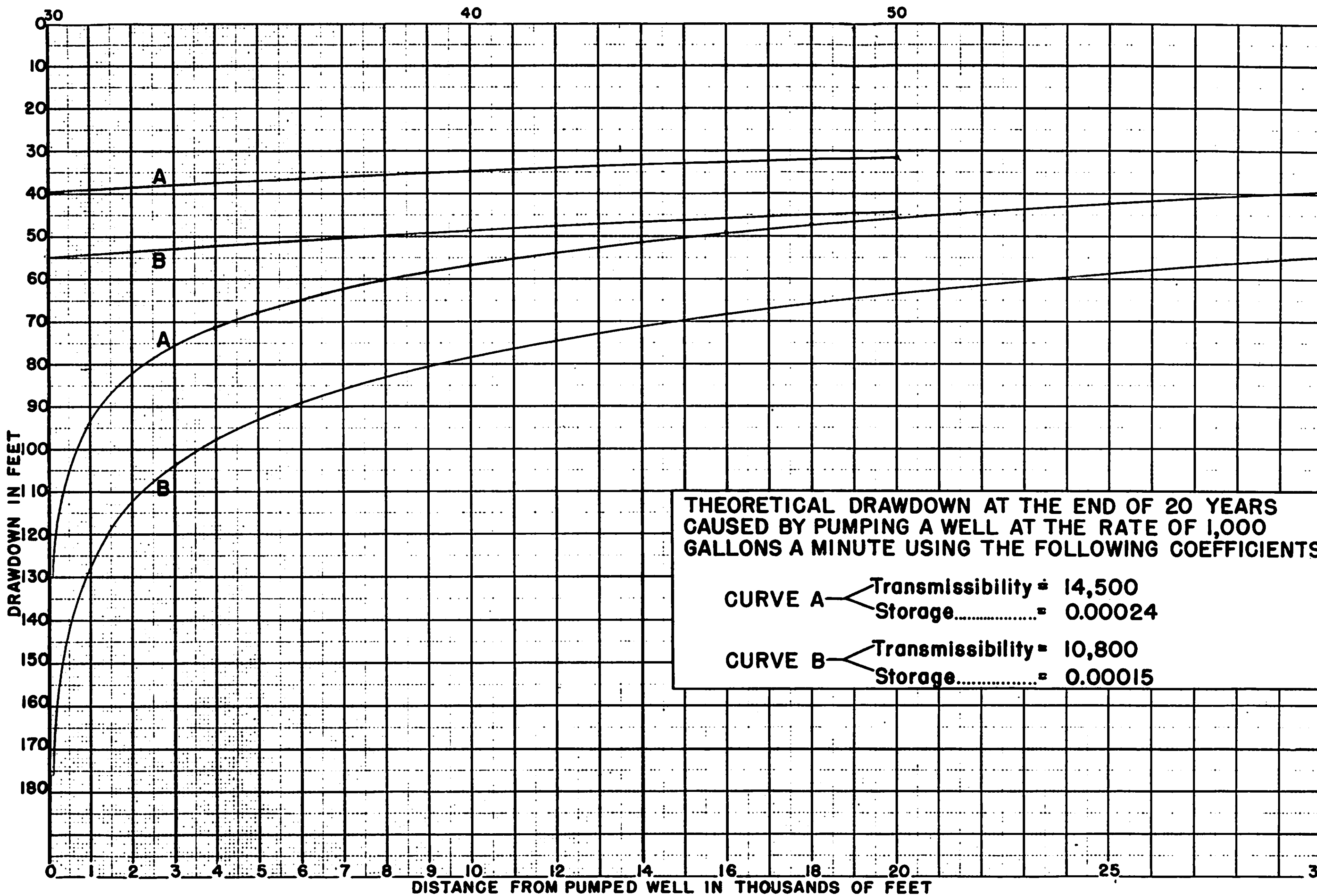

THEORETICAL DRAWDOWN AT THE END OF 15 YEARS CAUSED BY PUMPING A WELL AT THE RATE OF 1,000 GALLONS A MINUTE USING THE FOLLOWING COEFFICIENTS
CURVE A — Transmissibility = 14,500; Storage = 0.00024
CURVE B — Transmissibility = 10,800; Storage = 0.00015
DRAWDOWN IN FEET
DISTANCE FROM PUMPED WELL IN THOUSANDS OF FEET
A
B
A
B

FIG. 6.



30
40
50
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
DRAWDOWN IN FEET
A
B
A
B
0
1
2
3
4
5
6
7
8
9
10
12
14
16
18
20
25
30
DISTANCE FROM PUMPED WELL IN THOUSANDS OF FEET
THEORETICAL DRAWDOWN AT THE END OF 20 YEARS CAUSED BY PUMPING A WELL AT THE RATE OF 1,000 GALLONS A MINUTE USING THE FOLLOWING COEFFICIENTS
CURVE A
Transmissibility = 14,500
Storage.................. = 0.00024
CURVE B
Transmissibility = 10,800
Storage.................. = 0.00015


FIG. 7.

SKETCH OF BRYAN CITY WELL FIELD
SHOWING PRESENT WELLS 1 TO 5
AND TENTATIVE LOCATIONS OF
A-B-C-AND D OF PROPOSED WELL 6

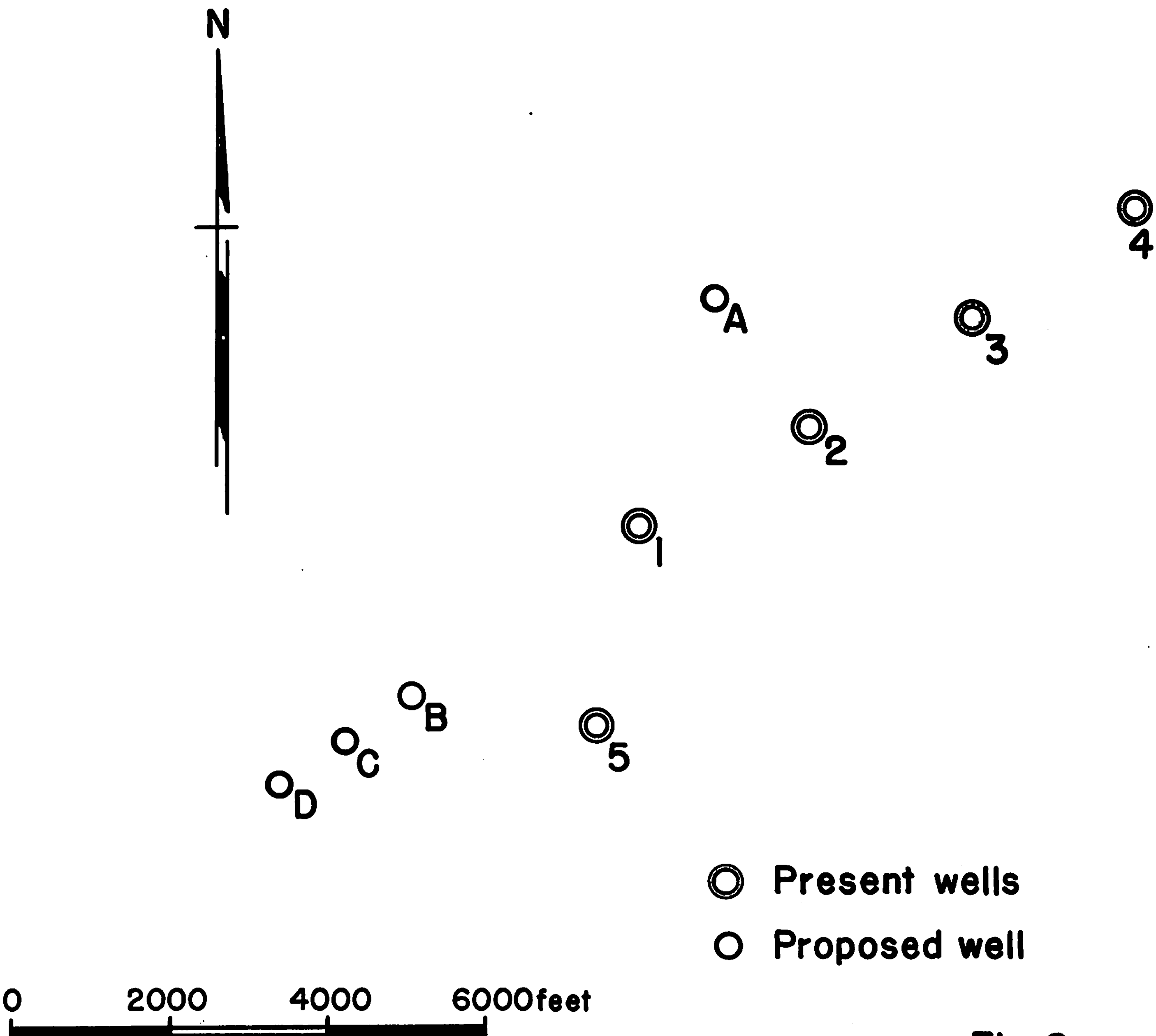



Fig. 8

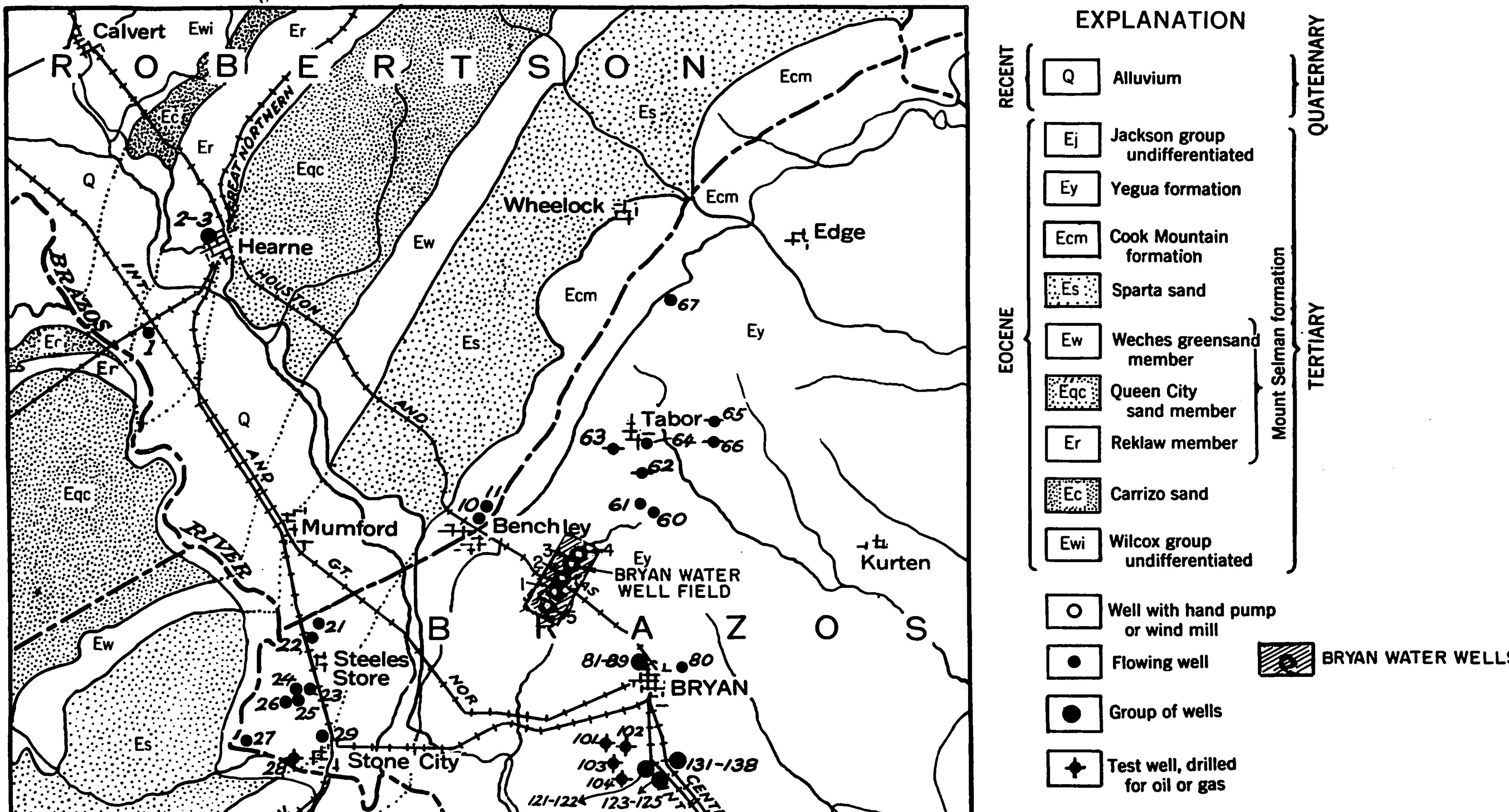
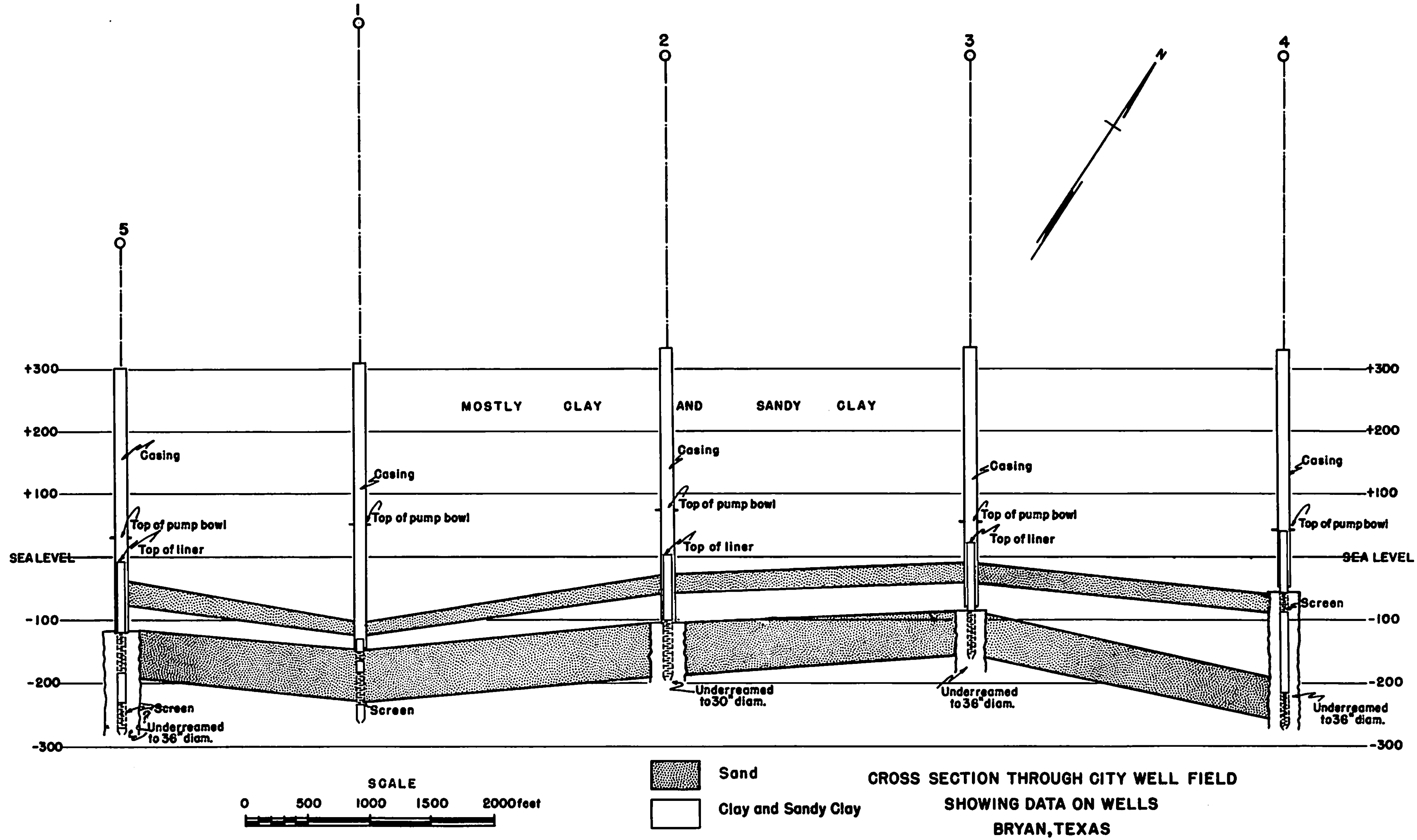



PLATE 1.—MAP OF PART OF BRAZOS, ROBERTSON AND BURLESON COUNTIES, TEXAS, SHOWING OUTCROP AREAS OF GEOLOGIC FORMATIONS AND LOCATION OF WELLS.

Taken from geologic map of Texas, Geological Survey, U. S. Department of Interior, 1937




CROSS SECTION THROUGH CITY WELL FIELD
SHOWING DATA ON WELLS
BRYAN, TEXAS