TEXAS WATER DEVELOPMENT BOARD

REPORT 205

ANALYTICAL STUDY OF THE OGALLALA AQUIFER IN PARMER COUNTY, TEXAS

Projections of Saturated Thickness, Volume of Water in Storage,

Pumpage Rates, Pumping Lifts, and Well Yields

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Projections of Saturated Thickness, Volume of Water in Storage, Pumpage Rates, Pumping Lifts, and Well Yields

CONCLUSIONS

The Ogallala aquifer in Parmer County contained approximately 11.9 million acre-feet of water in 1974. Historical pumpage has exceeded 300,000 acre-feet annually, which is approximately 13 times the rate of natural recharge to the aquifer in the county. This overdraft is expected to continue, ultimately resulting in reduced well yields, reduced acreage irrigated, and reduced agricultural production.

There is a very uneven distribution of ground water in the county. Some areas have ample ground-water resources to support current usage through the year 2020; whereas, in other areas of the county, ground water is currently in short supply.

To obtain maximum benefits from the remaining ground-water resources, Parmer County water users should implement all possible conservation measures so that the remaining ground-water supply is used in the most prudent manner possible and with the least amount of waste.

INTRODUCTION

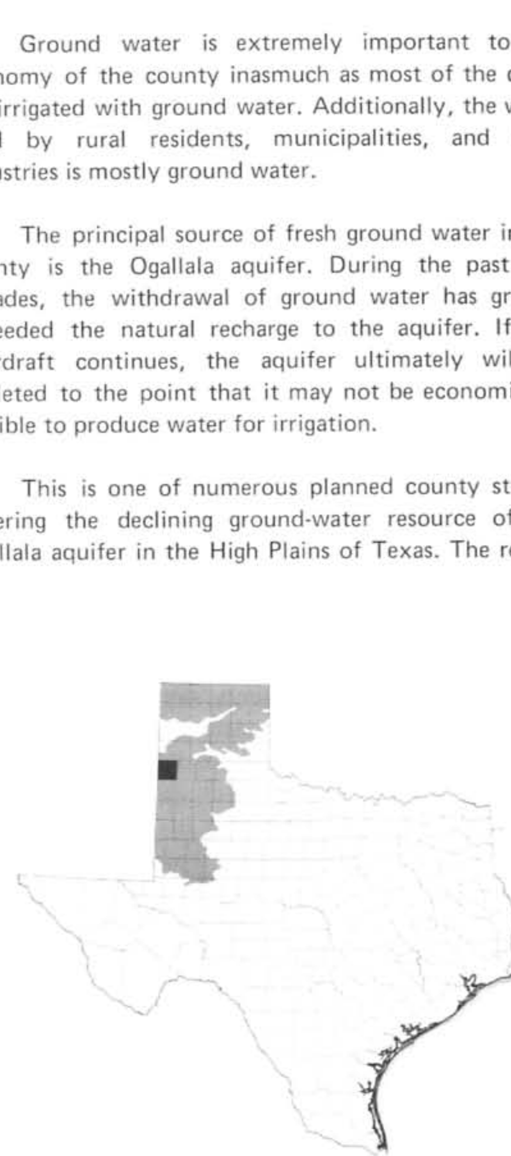
Parmer County is situated in the Southern High Plains of Texas. Farwell, the county seat, is located approximately 95 miles southwest of Amarillo. The county contains an area of about 859 square miles and has a population of approximately 10,000.

Parmer County is one of the leading producers of agricultural crops in the State with a total farm income of over $90 million annually. Leading crops in the county are grain sorghums, wheat, corn, sugar beets, and vegetables. Numerous agribusinesses, including livestock feeding, meat packing, and sale of irrigation equipment supplies, feed and seed, and fertilizer, also make significant contributions to the total county income.

Ground water is extremely important to the economy of the county inasmuch as most of the crops are irrigated with ground water. Additionally, the water used by rural residents, municipalities, and local industries is mostly ground water.

The principal source of fresh ground water in the county is the Ogallala aquifer. During the past two decades, the withdrawal of ground water has greatly exceeded the natural recharge to the aquifer. If this overdraft continues, the aquifer ultimately will be depleted to the point that it may not be economically feasible to produce water for irrigation.

This is one of numerous planned county studies covering the declining ground-water resource of the Ogallala aquifer in the High Plains of Texas. The report



Location of Parmer County, and Extent of the Ogallala Aquifer in Texas

contains maps, charts, and tabulations which reflect estimates of the volume of water in storage in the Ogallala aquifer in Parmer County and the projected depletion of this water supply by decade periods through the year 2020. The report also contains estimates of pumpage, pumping lifts, and other data related to current and future water use in the county. However, the report does not attempt to project that portion of the volume of water in underground storage which may be ultimately recoverable.

PURPOSE AND SCOPE OF STUDY

This study resulted from an immediate need for information to illustrate to the High Plains water users that the ground-water supply is being depleted. It is hoped that this study will help persuade the water users to implement all possible conservation measures, so that the remaining ground-water supply will be used in the most prudent manner possible and with the least amount of waste.

The study was also conducted to provide information to local, State, and federal officials for their use in implementing plans to alleviate the water-shortage problem in the High Plains of Texas.

These immediate needs for current information have resulted in a concerted effort by the Texas Water Development Board to utilize high-speed computers to conduct evaluation and projection studies of ground-water resources. The results of one of these computer studies is contained in this report.

This report does not represent a detailed ground-water study of the county; rather, the report was prepared using only those data which were readily available in the files of the Texas Water Development Board. Information provided for 1974 is considered reliable; however, the projections of future conditions should be used only as a guide to reasonable expectations.

This study represents a new approach by the Water Development Board in making and presenting appraisals of ground-water resources. Consequently, a detailed explanation of the methods and assumptions used in the study is included. A complete set of tabulations and illustrations resulting from this study is presented at the end of the report.

The illustrations were prepared to answer four questions believed to be of prime importance to the Parmer County landowners and water users. These questions, and methods by which a set of answers can be obtained from the illustrations, are as follows:

1. Question: How much water is in storage under any given tract of land in the county and what is expected to happen to this water in the future?

   Answer: First, determine the approximate location of the tract on the most current (1974) map of saturated thickness. Read the value of the contour line at this location (if midway between two contour lines, take an average of the two). This thickness value can then be converted to the approximate volume of water in storage, in acre-feet per surface acre, by multiplying it by the coefficient of storage of 0.15, or 15 percent. To obtain estimates of what can be expected in the future, the same procedure can be followed by using the maps which illustrate projected saturated thickness in the years 1980, 1990, 2000, 2010, and 2020.

2. Question: What can be expected to happen to well yields if the saturated thickness diminishes as illustrated by the maps?

   Answer: Well yields are expected to decline as the aquifer thins; therefore, a map of estimated well yields has been prepared for each year of the study. The landowner need only find the approximate location of his property on the well-yield map that applies to the year in question and read the well-yield estimates directly from the map.

3. Question: With energy cost increasing, pumping lifts (pumping levels) are becoming more and more important. What are the estimates of current pumping lifts and what are they expected to be in the future?

   Answer: Contour maps depicting estimated pumping lifts have been prepared for each year of the study. These maps are contoured in feet below land surface. The landowner need only find the approximate location of his property on the map that applies to the year in question to read the pumping-lift estimates.

4. Question: If an all-out effort is made to conserve ground-water resources, how can landowners and water users determine how

they are doing compared to the projections in the study?

Answer: Using the maps that show rates of water-level declines, the landowners and water users can determine what the changes in water levels are in their area and what they are projected to be in the future. This can be accomplished by finding the approximate location of their property on the map pertaining to the year in question and by reading the estimates of water-level changes which are recorded in feet. To determine how he is doing from year to year, the landowner or water user can make measurements of depth to water in his own wells or obtain copies of measurements made by the Board or the ground-water district for his area. These measurements can then be compared to the projected values on the maps to estimate the effectiveness of conservation efforts.

NATURE OF THE OGALLALA AQUIFER

Because thorough understanding of the Ogallala aquifer is not necessary for the water user, the following discussion of aquifer geology and hydrology is rather general. Readers interested in pursuing the subject in more detail may do so from the numerous reports which have been published on the Ogallala. Most of these publications are included in the list of selected references of this report.

General Geology

Fresh ground water in Parmer County is obtained principally from the Ogallala Formation of Pliocene age. Water in the Ogallala Formation is unconfined and is contained in the pore spaces of unconsolidated or partly consolidated sediments.

The Ogallala Formation principally consists of interfingering bodies of fine to coarse sand, gravel, silt, and clay—material eroded from the Rocky Mountains which was carried southeastward and deposited by streams. The earliest sediments, mainly gravel and coarse sand, filled the valleys cut in the pre-Ogallala surface. Pebbles and cobbles of quartz, quartzite, and chert are typical of these early sediments. After filling the valleys, deposition continued until the entire area that is now the Texas High Plains was covered by sediments from the shifting streams.

The upper part of the formation contains several hard, caliche-cemented, erosionally resistant beds called the "caprock." A wind-blown cover of fine silt, sand, and soil overlies the caprock.

The Ogallala deposits overlie rocks of lower permeability of Triassic and Cretaceous ages. On a broad scale, the erosional surface at the top of the Triassic and Cretaceous rocks dips gently (about 10 feet per mile) toward the southeast, similar to the slope of the land surface. In general, however, this pre-Ogallala surface had greater relief than the present land surface. Low hills and wide valleys which contain deep, narrow stream channels are typical features of the Triassic erosional surface. The Cretaceous rocks, being more resistant to erosion, remain as small buried mesas or buttes. Because the Ogallala was deposited on top of this irregular surface, the formation is very thin in some areas and very thick in others. Often this contrast occurs in relatively short distances.

The Triassic rocks, principally shale, serve as a nearly impermeable floor for the aquifer, but the buried mesas or buttes of Cretaceous rocks, where these are present, generally can yield water to wells. At these locations the Ogallala and Cretaceous waters are in hydrologic continuity; therefore, the water-yielding Cretaceous rocks are considered to be part of the Ogallala aquifer.

The Canadian River has cut deeply through the Ogallala Formation in the northern part of the Texas High Plains area. The valley effectively separates the formation geographically into two units having little hydraulic interconnection. Erosion has also removed the Ogallala from much of its former extent to the east, and to the west in New Mexico. As a result, the Southern High Plains, although relatively flat, stands in high relief and is hydraulically independent of adjacent areas. For this reason, coupled with the scarcity of local rainfall, water that is being withdrawn from the aquifer cannot be replaced quickly by natural recharge and is in effect being mined.

Storage Properties

The coefficient of storage of an aquifer is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. In water-table aquifers such as the Ogallala, the coefficient of storage is nearly equal to the specific yield, which is defined as the quantity of water that a formation will yield under the force of gravity, if it is first saturated and then allowed to drain, the quantity of water being expressed as a percentage of the volume of material drained.

A coefficient of storage of 15 percent has been selected for use in this study based on past studies and the results of numerous aquifer tests published in Water Development Board Report 98 (Myers, 1969). The following chart shows the volumes of water corresponding to various amounts of aquifer saturated thickness, based on a storage coefficient of 15 percent. These are the approximate amounts of water that would drain from the aquifer material by gravity flow if the entire saturated thickness could be drained.

SATURATED THICKNESS (feet)	VOLUME OF WATER IN STORAGE (acre-feet, per surface acre)
25	3.75
50	7.50
75	11.25
100	15.00
150	22.50
200	30.00
250	37.50
300	45.00
400	60.00
500	75.00

Natural Recharge and Irrigation Recirculation

Recharge is the addition of water to an aquifer by either natural or artificial means. Natural recharge results chiefly from infiltration of precipitation. The Ogallala aquifer in Parmer County receives natural recharge by precipitation that falls within the county and in adjoining areas.

The amount and rate of natural recharge from precipitation depend on the amount, distribution, and intensity of the precipitation; the amount of moisture in the soil when the rain or snowmelt begins; and the temperature, vegetative cover, and permeability of the materials at the site of infiltration. Because of the wide variations in these factors, it is difficult to estimate the amount of natural recharge to the ground-water reservoir. Estimates of annual natural recharge to the Ogallala aquifer made by Barnes and others (1949, p. 26-27) indicate only a fraction of an inch. Theis (1937, p. 546-568) suggested less than half an inch, and Havens (1966, p. F1), in a study of the Ogallala in New Mexico, indicated about 0.8 inch per year.

The authors of this report believe that recharge from precipitation may be more than these earlier estimates, due to changes in the soil and land surface that have accompanied large-scale irrigation development in the county. Some of the farming practices which are believed to have altered the recharge rate are: clearing the land of deep-rooted native vegetation; deep plowing of fields, which eliminates hard pans, and the plowing of playa lake bottoms and sides; bench leveling, contour farming, and terracing; maintaining a generally higher soil moisture condition by application of irrigation water prior to large rains; and increasing the humus level in the root zone by plowing under a large amount of foliage from crops grown under irrigation.

Obtaining a reliable estimate of the present recharge rate is further complicated by the consideration which must be given to irrigation recirculation. A substantial portion of the water pumped from the Ogallala for irrigation percolates back to the aquifer. This does not constitute an additional supply of water, but reduces the net depletion of the aquifer. As with natural recharge, many factors are involved in making estimates of recirculation. Some of these factors are the rate, amount, and type of irrigation application; the soil type and the infiltration rate of the soil profile in the root zone; the amount of moisture in the soil prior to the irrigation application; the type of crop being grown, its root development, and its moisture extraction pattern; and the climatic conditions during and following the irrigation application. Tentative estimates of the actual amounts of recharge and irrigation recirculation in Parmer County will be found in a subsequent section on "Calculating Pumpage."

PROCEDURES USED TO OBTAIN PROJECTIONS

Hydrologic Data Base

The Texas Water Development Board and the High Plains Underground Water Conservation District No. 1 cooperatively maintain a network of water-level observation wells in Parmer County. Records from these wells provided the principal data base used in this study. This data base was supplemented in some areas with records from water well drillers' logs collected by both the District and the Board.

The data base included: (1) measurements of the depth to water below land surface, which have been made annually in the wells in the observation network; (2) the dates these measurements were made; and (3) the depth from land surface to the base of the Ogallala aquifer (In many cases, this was identical to the well depth). To facilitate automatic data processing with modern, high-speed computers, the data base also included a unique number for each well and the geographical coordinates of each well location.

Wells chosen from the data base for use in obtaining projections of future conditions were those in which depth to the base of the aquifer could be determined or estimated, and those needed to provide spaced data coverage in the county. Locations of the wells that were selected and used for control are shown on the various maps in this report.

Projecting the Depletion of Saturated Thickness

The water-use patterns between 1960 and 1972 as reflected in the changes in water levels in wells measured in the High Plains of Texas were used as the principal data source for developing an aquifer depletion schedule. The depletion schedule generally reflects average precipitation and precipitation distribution in the area for the duration of the study period. Additionally, in developing and applying the depletion schedule, adjustments through time were made to reflect the effects of depletion of the aquifer on its ability to yield water. That is, as the aquifer's saturated thickness decreases, its ability to yield water to wells is reduced, the well yields decline, less water is pumped, and there results a lessened rate of further aquifer depletion.

The aquifer's hydraulics are such that if a well penetrates the total saturated section and the pump is sized to produce the maximum the aquifer will yield, the well yield will decline at a disproportionately greater rate than the reduction in saturated thickness. Actually, the remaining well yield expressed as a percentage of former yield will be only about half of the remaining saturated thickness expressed as a percentage of former thickness. For example, a well with 60 feet of saturated section and a maximum yield of 900 gpm (gallons per minute) will probably yield only 225 gpm when the saturated section is reduced to 30 feet.

The depletion schedule for Parmer and surrounding counties was developed in the following manner:

1. The records for all water level observation wells for the years 1960 through 1972 in Briscoe, Castro, Deaf Smith, Parmer, and Swisher Counties were separated from the master file. These counties have similar soil types, cropping patterns, depths to water, saturated thickness, and climatic conditions.

2. These well records were then sorted into groups according to the saturated thickness in each well as of 1966 (the middle year). Each group included records of all wells in a 20-foot range of saturated thickness. (Ranges are shown in the tabulation below.)

3. The average decline in water level was calculated for each year for each well group, and these decline values were adjusted to remove the effects of each year's deviation from long-term average precipitation.

4. The average annual decline in water level for the total period (1960-72) was calculated for each well group, incorporating the adjustments for departure from average precipitation.

From the foregoing procedure, the following depletion schedule was developed:

RANGE OF SATURATED THICKNESS (feet)	AVERAGE ANNUAL WATER-LEVEL DECLINE, 1960-72 (feet)
0 to 20	0.50
20 to 40	1.44
40 to 60	1.53
60 to 80	2.75
80 to 100	3.19
100 to 120	3.53
120 to 140	3.50
140 to 160	3.52
160 to 180	3.84
180 to 200	3.90
200 to 220	3.61
220 to 240	3.23
240 to 260	2.99
260 to 280	2.88

Based on this depletion schedule, a computer program was written to calculate future saturated thickness at individual well sites. The following problem is presented to show the computational procedures used.

Problem: A well has a saturated thickness of 110 feet in 1974 and one wants to project what the saturated thickness will be in this well for every year to the year 2020.

Factors:

1. The beginning saturated thickness is 110 feet in 1974.

2. The average decline rate is 3.53 feet per year for wells with saturated sections of 100 to 120 feet.

3. The average decline rate is 3.19 feet per year for wells with saturated sections of 80 to 100 feet.

4. The average decline rate is 2.75 feet per year for wells with saturated sections of 60 to 80 feet.

5. The average decline rate is 1.53 feet per year for wells with saturated sections of 40 to 60 feet.

6. The average decline rate is 1.44 feet per year for wells with saturated sections of 20 to 40 feet.

7. The average decline rate is 0.50 foot per year for wells with saturated sections of 0 to 20 feet.

8. The time interval is 1974 through 2020.

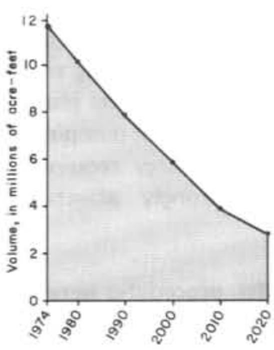
The projected saturated thicknesses in the subject well are calculated and shown in the following table:

YEAR	SATURATED THICKNESS, BEGINNING OF YEAR (feet)	AVERAGE DECLINE RATE (feet)	SATURATED THICKNESS, END OF YEAR (feet)
1974	110.00	3.53	106.47
1975	106.47	3.53	102.94
1976	102.94	3.53	99.41
1977	99.41	3.19	96.22
1978	96.22	3.19	93.03
1979	93.03	3.19	89.84
1980	89.84	3.19	86.65
1981	86.65	3.19	83.46
1982	83.46	3.19	80.27
1983	80.27	3.19	77.08
1984	77.08	2.75	74.33
1985	74.33	2.75	71.58
1986	71.58	2.75	68.83
1987	68.83	2.75	66.08
1988	66.08	2.75	63.33
1989	63.33	2.75	60.58
1990	60.58	2.75	57.83
1991	57.83	1.53	56.30
1992	56.30	1.53	54.77
1993	54.75	1.53	53.24
1994	53.24	1.53	51.71
1995	51.71	1.53	50.18
1996	50.18	1.53	48.65
1997	48.65	1.53	47.12
1998	47.12	1.53	45.59
1999	45.59	1.53	44.06
2000	44.06	1.53	42.53
2001	42.53	1.53	41.00
2002	41.00	1.53	39.47
2003	39.47	1.44	38.03
2004	38.03	1.44	36.59
2005	36.59	1.44	35.15
2006	35.15	1.44	33.71
2007	33.71	1.44	32.27
2008	32.27	1.44	30.83
2009	30.83	1.44	29.39
2010	29.39	1.44	27.95
2011	27.95	1.44	26.51
2012	26.51	1.44	25.07
2013	25.07	1.44	23.63
2014	23.63	1.44	22.19
2015	22.19	1.44	20.75
2016	20.75	1.44	19.31
2017	19.31	.50	18.81
2018	18.81	.50	18.31
2019	18.31	.50	17.81
2020	17.81	.50	17.31

Similar computations were made for each of the selected data-control wells in Parmer County, and the saturated-thickness values for 1974, 1980, 1990, 2000, 2010, and 2020 were extracted from this data set for use in further calculations and mapping.

Mapping Saturated Thickness, and Calculating Volume of Water in Storage

To obtain estimates of the volume of water in storage in the Ogallala aquifer, an electronic digital computer was used to construct maps which reflect the saturated thickness of the aquifer for those years included in the study. These maps were then refined by the computer to reflect the number of acres corresponding to each range of saturated thickness. The number of acres for each range was multiplied by the saturated thickness in feet for that range and then by the coefficient of storage (0.15 or 15 percent), to yield an estimate of the volume of water in storage in each saturated-thickness range. Totaling these volumes produced an estimate of the volume of water in storage in the county. The current (1974) and projected volume estimates are shown in the following graph:



Year	Acre-Feet
1974	11,900,000
1980	10,300,000
1990	7,900,000
2000	5,800,000
2010	4,000,000
2020	2,800,000

Estimated Volume of Water in Storage

Preparing a data base and writing the necessary programs for the computer to use in constructing the saturated-thickness maps and in making the necessary calculations is time consuming; however, once the data base is prepared and programs written, the computer can perform in a few hours calculations that would have required many years of manual effort.

A generalized description of the methodology used in mapping and in computing water volume follows: A base map with a scale of 1 inch equals 2 miles was selected to prepare data for computer processing. All data points (observation wells) were plotted on these base maps by hand and assigned identifying numbers. A machine called a *digitizer* was then used to translate these mapped location data (well locations, county boundaries, etc.) into information processible by the computer. To accomplish this, a latitude and longitude coordinate was recorded on each base map as a central reference point, and all data points and county boundaries were then digitized; that is, measurements were made by the digitizer to reference these data points and boundaries to the initial latitude and longitude coordinate. Then the digitized information was processed by the computer and the maps were re-created by a computer-driven plotter. The computer-plotted image maps were ultimately checked against the hand-constructed maps to verify that the data were plotted accurately.

The assignment of a unique number to each data point (observation well) on the base maps made it possible to machine process the data related to these points and to plot these data back on the maps at the proper location.

To compute the volume of water in storage, the computer was instructed to subdivide the county into units of approximately one-half mile square. The known saturated-thickness values obtained from the data points were filled into the squares in which the data points were located. Based on these known values, the computer filled in a weighted-average value for each remaining square, taking into consideration all known values within a radius of 7 miles. After this step was completed, the computer then counted the numbers of squares having equal values, thus obtaining the approximate area in square miles (later converted to acres) corresponding to each range of saturated thickness. As previously stated, the number of acres in each 25-foot range of saturated thickness was multiplied by the corresponding saturated-thickness value and the storage coefficient (0.15 or 15 percent), to obtain the approximate volume of water in acre-feet in that saturated-thickness range.

Although the calculations were made by the computer from information stored in its image field, the data in the image field were printed out in the form of contoured saturated-thickness maps, which are reproduced in this report. Facing each saturated-thickness map in the report is a corresponding tabulation of the approximate volume of water in storage.

Calculating Pumpage

Estimates of current pumpage were obtained in this study by calculating the storage capacity of the dewatered section of the Ogallala aquifer as reflected in changes in the annual depth-to-water measurements made in the water level observation wells. Factors for natural recharge and irrigation recirculation were then added to these volumetric figures to obtain more realistic pumpage estimates.

The step-by-step procedure involved in making pumpage estimates is similar to the procedures used in calculating the estimates of volume of water in storage; therefore, a more general explanation follows.

Change in water level (decline) maps for the aquifer were made by the computer for the years considered. From these maps, the volume of desaturated material was multiplied by the number of acres corresponding to each 0.25-foot range of decline and then multiplied by the storage coefficient of the aquifer (0.15 or 15 percent), which resulted in an estimate of the volume of water taken from storage for each decline range. Estimates for natural recharge and irrigation recirculation were added to these values to obtain estimates of pumpage.

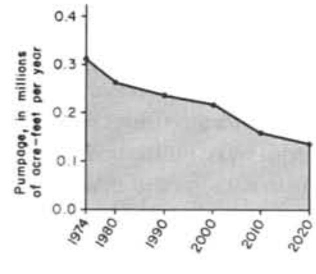
An attempt was made to obtain a reliable estimate of the natural recharge and recirculation for use in this study. This involved obtaining an estimate of the amount of water required by each of the major crops grown in the area. These values, generally referred to as "duty of water," were obtained from Texas Agricultural Experiment Stations located in the High Plains area. The duty of water figure for each major crop was multiplied by the number of crop acres, and the resulting numbers were added together to yield an estimate of the total crop water demand.

The amount of precipitation which fell just prior to and during the growing season was subtracted from the total water demand estimate. The difference between these values should equal that amount which would have been supplied by irrigation, which will be referred to as irrigation makeup water.

The volume figure represented by the dewatered section was then compared to the volume of water which should have been supplied to crops by irrigation makeup water. In all tests, the volume of water represented by the depletion of the aquifer was considerably less than the makeup water estimate. This difference was attributed to irrigation recirculation and natural recharge.

Various combinations of estimates for natural recharge and recirculation were added to the volume represented by aquifer depletion, in an attempt to obtain comparable values with the makeup water estimated for the test years. One-half inch per year of natural recharge, and 10 percent recirculation added to the volume represented by the depletion of the aquifer, most nearly equaled the makeup water estimated in the largest number of instances in Parmer County and in adjoining counties with similar conditions.

These amounts were added to the previously calculated storage capacity of the dewatered section to obtain estimates for current (1974) and future pumpage. The following graph shows the current and projected estimates of pumpage:



Year	Acre-Feet
1974	311,000
1980	267,000
1990	239,000
2000	214,000
2010	160,000
2020	134,000

Estimated Pumpage

Calculating Pumping Lifts

The pumping lift (pumping level) is the depth from land surface to the water level in a pumping well; it is equal to the depth of the static water level plus the drawdown due to pumping. The amount of pumping lift largely determines the amount of energy required to produce the water, and thus strongly affects the pumping costs.

In calculating pumping lifts, procedures were used that are similar to those used in making estimates of the volume of water in storage and the estimates of pumpage. Again, the computer and original data base were used as previously described.

In making estimates of pumping lifts, it was assumed: (1) that the yield of each pumping well is 900 gpm except as limited by the capacity of the aquifer (this conforms with the historical trend of equipping new wells with 8-inch or smaller pumps); (2) that the specific well yield is 15 gpm per foot of drawdown; and (3) that once the well yield equals the capacity of the aquifer, the well will continue to be produced at a rate near the capacity of the aquifer until pumping lifts are within 10 feet of the base of the aquifer. After that time, it is assumed that the pumping lift will remain constant because of greatly diminished well yields. It should be noted that this 10-foot minimum is somewhat arbitrarily chosen, as one cannot predict accurately the minimum saturated thickness that will be feasible for producing irrigation water under future economic conditions.

The above assumptions restrict the drawdown in wells to a maximum of 60 feet (maximum well yield of 900 gpm divided by specific well yield of 15 gpm per foot equals 60 feet of maximum drawdown).

Based on the above assumptions, pumping lifts were calculated separately for each of the selected data-control wells in the county. The factors involved were the historical and projected saturated-thickness values, the historical and projected static water levels, and the drawdown value assigned to the Parmer County area.

In all areas where the aquifer's saturated thickness was 70 feet or greater (areas where a well, pumped at full capacity, would be drawn down 60 feet to yield 900 gpm), the computer was instructed to add 60 feet (the drawdown) to the static water level to determine pumping lift. For a well with a saturated thickness of less than 70 feet, the pumping lift was calculated by subtracting 10 feet from the depth of the well (base of the aquifer). These calculations were made for each year of record to be reported (1974, 1980, 1990, 2000, 2010, and 2020) for each well. The pumping-lift values were stored in the computer and printed out in the form of contour maps. Additionally, the surface area corresponding to each interval between the mapped contours was calculated and printed out in tabular form.

Well-Yield Estimates

Estimates of the rate, in gallons per minute, at which the Ogallala aquifer should be capable of yielding water to wells in various areas of the county are presented on maps for each year of record reported (1974, 1980, 1990, 2000, 2010, and 2020). These well-yield estimates are based on capabilities of the aquifer to yield water to irrigation wells of prevailing construction as reflected by the very large number of pumping tests which have been conducted in various saturated-thickness intervals in the Texas High Plains. The estimates are adjusted to reflect the expected decreases in well yields through time due to the reduced saturated thickness as depletion of the aquifer progresses.

The well-yield estimates are subject to deviations caused by localized geological conditions. The Ogallala is not a homogeneous formation; that is, silt, clay, sand, and gravel which generally comprise the formation vary from place to place in thickness of layers, layering position, and grain-size sorting. The physical composition of the formation material can drastically affect the ability of the formation to yield water to wells. As an example, in areas where the saturated portion of the formation is comprised of thick beds of coarse and well-sorted grains of sand, the well yields probably will exceed the estimates shown on the maps. In other localized areas, the saturated portion of the formation may be comprised principally of thick beds of silt and clay which can be expected to restrict well yields to less than those shown on the maps.

The following can be used as a general guide in the Texas High Plains in estimating well yields based on saturated thickness:

SATURATED THICKNESS (feet)	WELL YIELD (gallons per minute)
Less than 20	Less than 100
20 to 30	100 to 250
30 to 40	250 to 500
40 to 60	500 to 800
60 to 80	800 to 1,000
More than 80	More than 1,000

The maps presented in this report are intended for use as general guidelines only and are not recommended for use in determining water availability when buying and selling specific tracts of land. Inasmuch as the availability of ground water constitutes a large portion of the price of land bought and sold in this area, it is recommended that a qualified ground-water hydrologist be consulted to make appraisals of ground-water conditions when such transactions are contemplated.

DISTINCTION BETWEEN PROJECTIONS AND PREDICTIONS

The actions of the Parmer County water user will determine whether the projections of this study come to pass, as the rate of depletion of the ground-water resource is determined by the rate of water use. The authors have not made predictions of what will occur, but have furnished projections based on past trends and presently available information.

There are many unpredictable factors which can influence the future rates of withdrawal of ground water from the Ogallala aquifer for irrigation farming. These factors include: (1) the amounts and distribution of precipitation which will be received in the area in the future; (2) federal crop acreage controls or the lack of these; (3) the price and demand for food and fiber grown in the area; (4) the cost and availability of energy to produce water from the aquifer; (5) farm labor cost and availability of farm labor; (6) results of continuing research that seeks to develop more frugal water-application methods for irrigation, crops having less water demand, and methods for inducing clouds to yield more water as rain; and (7) most important, the degree to which feasible soil and water conservation measures are employed by the High Plains irrigator. Any of these factors could appreciably influence the rate of use of ground water in the future; however, the projections in this study provide a reasonable set of general expectations on the further depletion of the aquifer.

SATURATED THICKNESS AND VOLUME OF

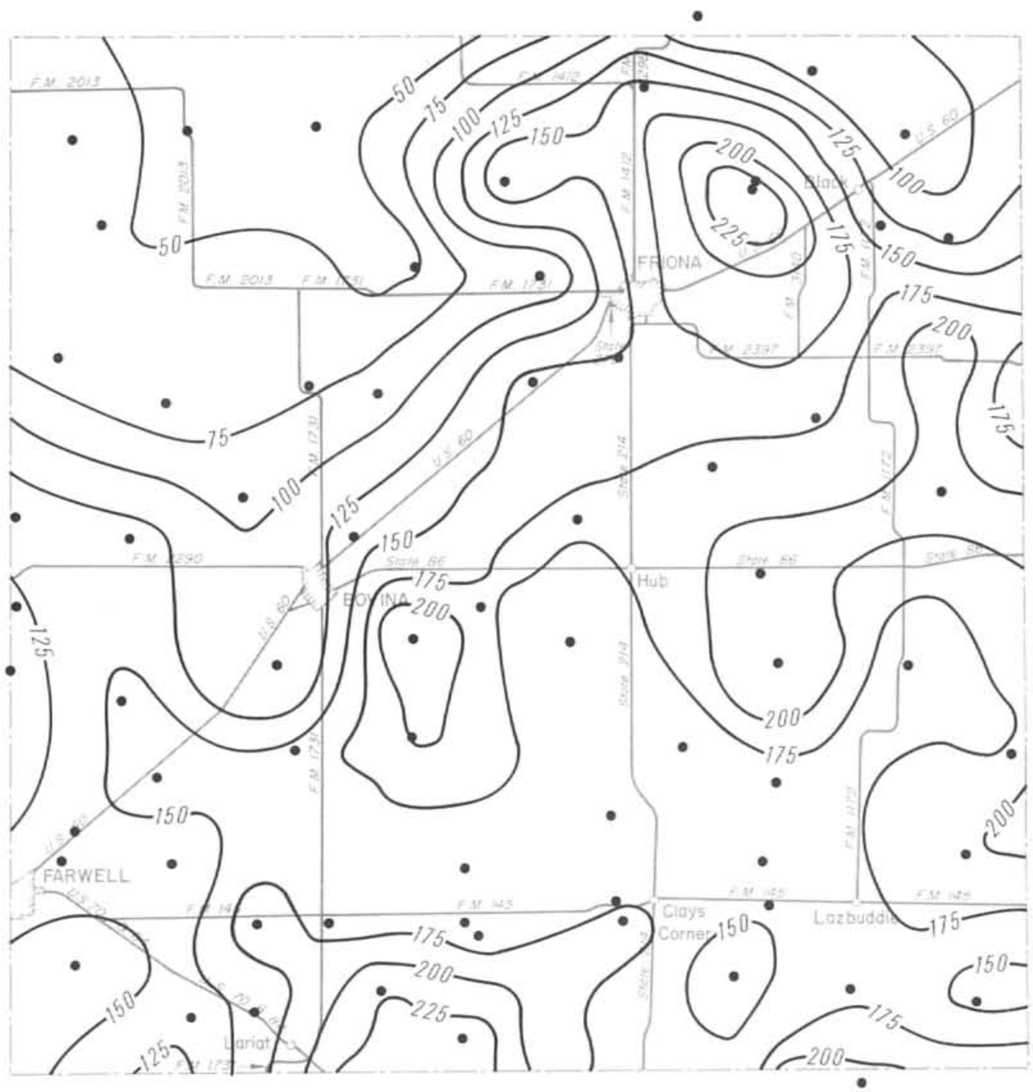
WATER IN THE OGALLALA AQUIFER

1974

Volume of Water in Storage Corresponding to Mapped Saturated-Thickness Intervals

(Coefficient of Storage: 15 percent)

MAPPED SATURATED-THICKNESS INTERVAL (feet)	SURFACE AREA (acres)	VOLUME OF WATER IN STORAGE (acre-feet)
0– 25	797	2,812
25– 50	31,074	182,228
50– 75	46,879	433,210
75–100	46,450	614,234
100–125	48,115	812,696
125–150	72,038	1,493,951
150–175	168,119	4,116,921
175–200	100,875	2,803,326
200–225	35,787	1,120,136
225–250	8,717	306,264
250–275	990	37,648
TOTAL	559,834	11,923,345

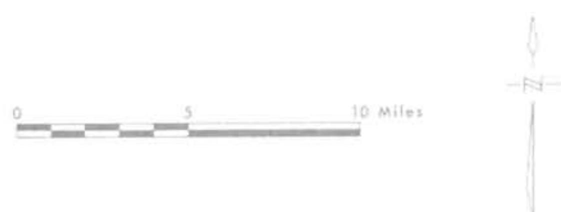


EXPLANATION

•
Well used for control

——— 150 ———
Line showing approximate saturated thickness of the Ogallala aquifer, in feet.

Interval is 25 feet



1974

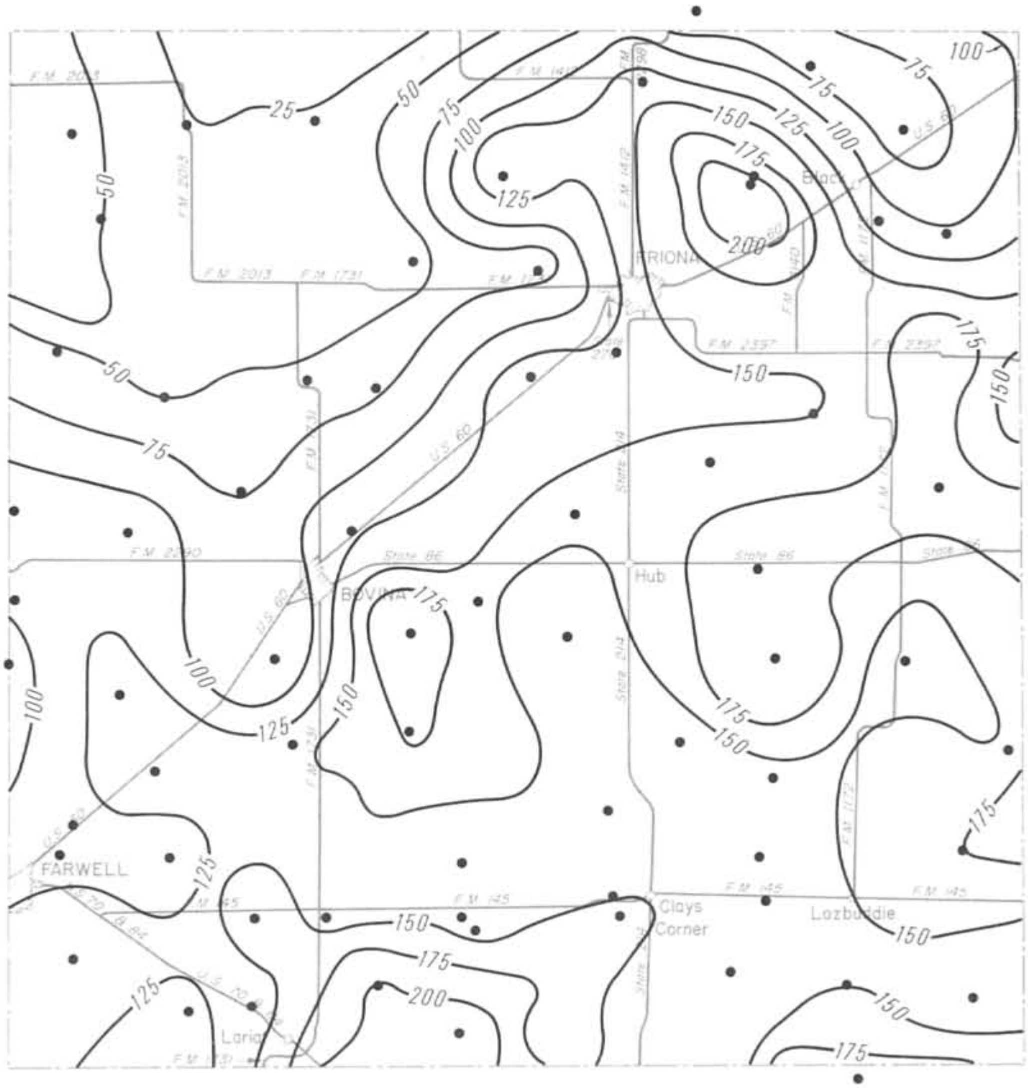
Estimated Saturated Thickness

1980

Volume of Water in Storage Corresponding to Mapped Saturated-Thickness Intervals

(Coefficient of Storage: 15 percent)

MAPPED SATURATED-THICKNESS INTERVAL (feet)	SURFACE AREA (acres)	VOLUME OF WATER IN STORAGE (acre-feet)
0– 25	8,802	29,755
25– 50	56,389	326,642
50– 75	47,960	457,118
75–100	47,870	625,994
100–125	70,639	1,200,820
125–150	162,007	3,372,807
150–175	108,639	2,607,803
175–200	44,030	1,215,734
200–225	12,015	379,595
225–250	1,485	52,054
TOTAL	559,833	10,288,257



EXPLANATION

• Well used for control

——— 150 ——— Line showing approximate saturated thickness of the Ogallala aquifer, in feet.

Interval is 25 feet

0 5 10 Miles

N

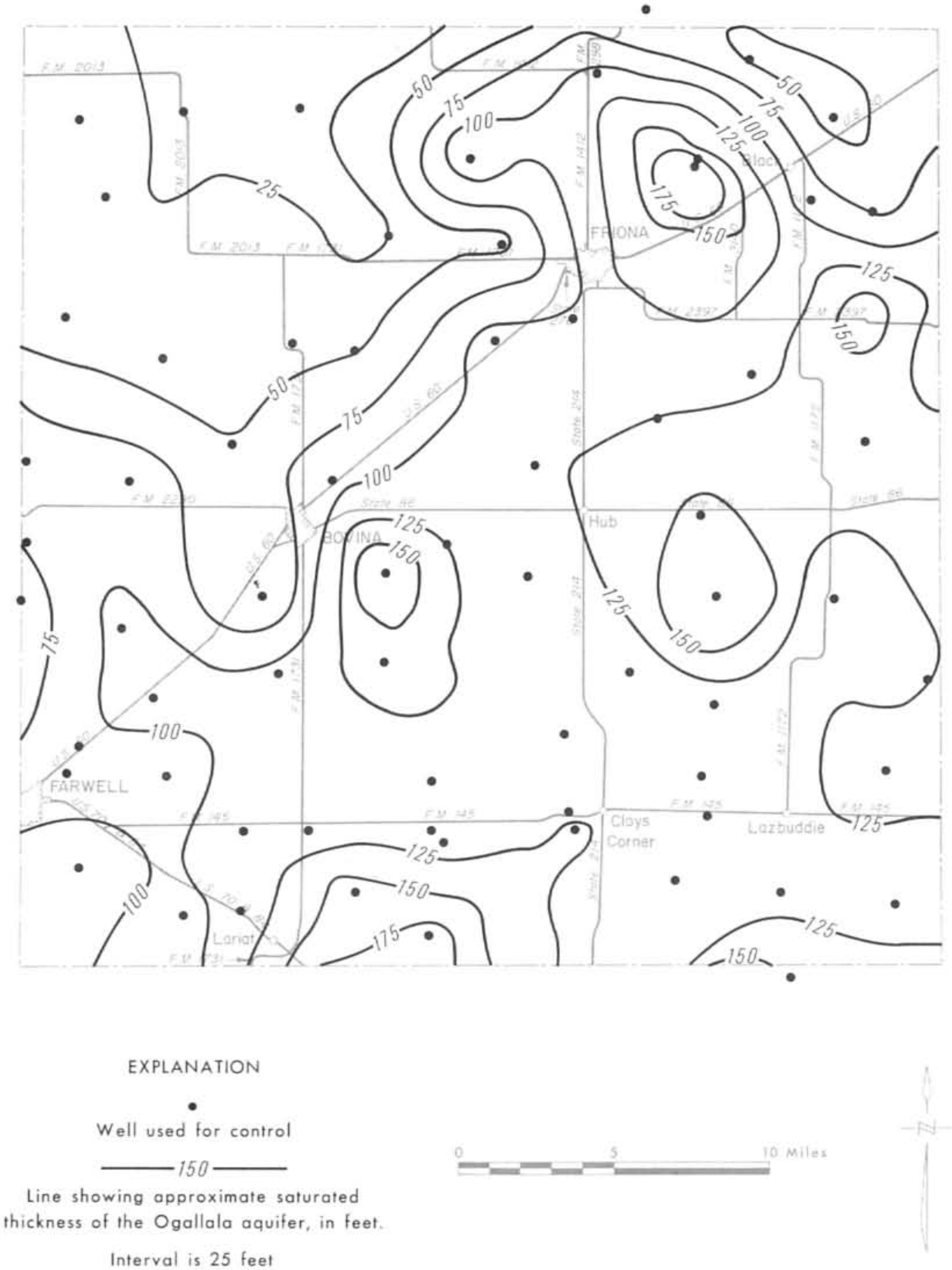
1980
Projected Saturated Thickness

1990

Volume of Water in Storage Corresponding to Mapped Saturated-Thickness Intervals

(Coefficient of Storage: 15 percent)

MAPPED SATURATED-THICKNESS INTERVAL (feet)	SURFACE AREA (acres)	VOLUME OF WATER IN STORAGE (acre-feet)
0– 25	36,492	93,151
25– 50	71,268	390,968
50– 75	57,025	531,017
75–100	87,492	1,170,049
100–125	193,380	3,244,073
125–150	85,014	1,733,272
150–175	21,270	512,787
175–200	6,904	190,217
200–225	990	30,264
TOTAL	559,833	7,895,757



1990

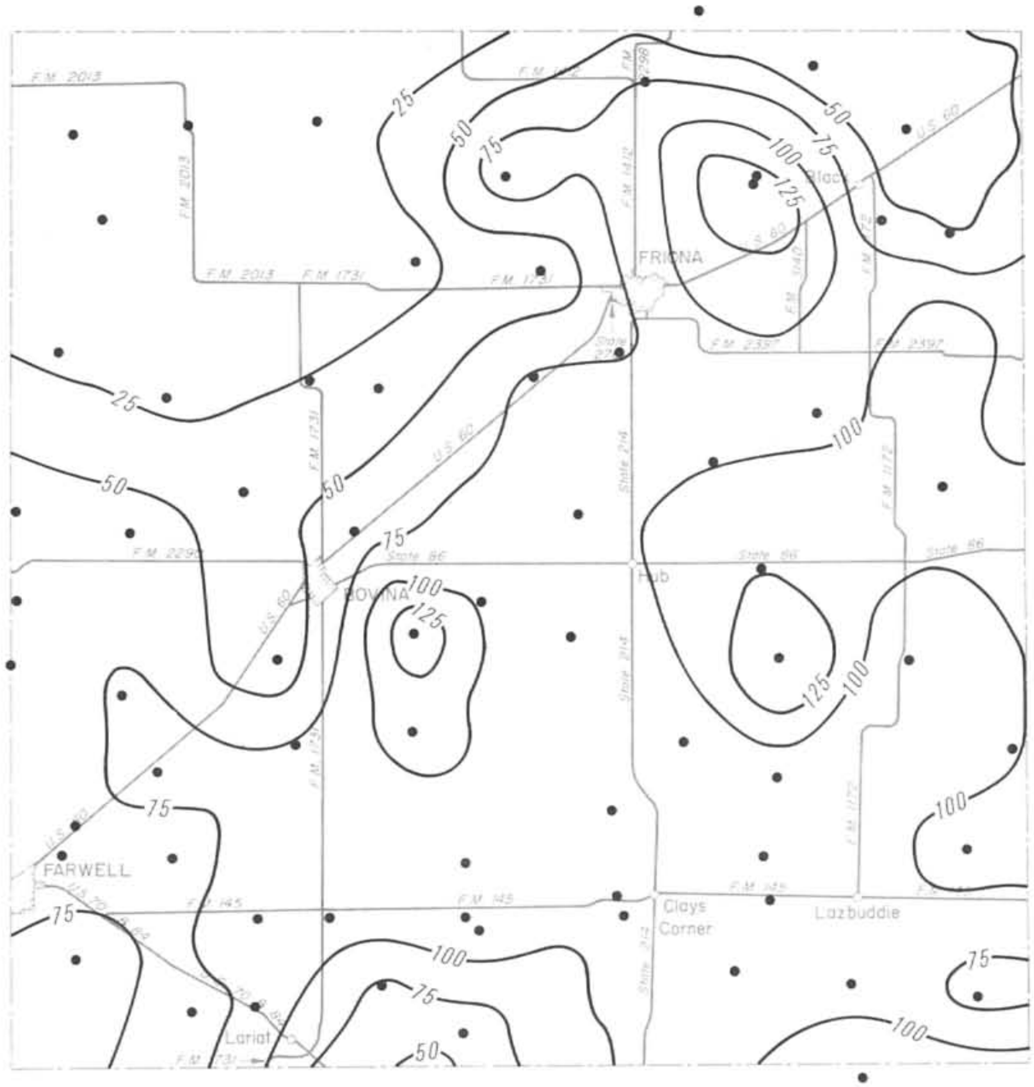
Projected Saturated Thickness

2000

Volume of Water in Storage Corresponding to Mapped Saturated-Thickness Intervals

(Coefficient of Storage: 15 percent)

MAPPED SATURATED-THICKNESS INTERVAL (feet)	SURFACE AREA (acres)	VOLUME OF WATER IN STORAGE (acre-feet)
0– 25	82,094	184,076
25– 50	79,605	438,523
50– 75	107,737	1,028,196
75–100	201,914	2,611,686
100–125	70,543	1,156,630
125–150	14,157	287,292
150–175	3,622	85,139
175–200	165	4,336
TOTAL	559,833	5,795,846



EXPLANATION

•
Well used for control

——— 150 ———
Line showing approximate saturated thickness of the Ogallala aquifer, in feet.

Interval is 25 feet

0 5 10 Miles

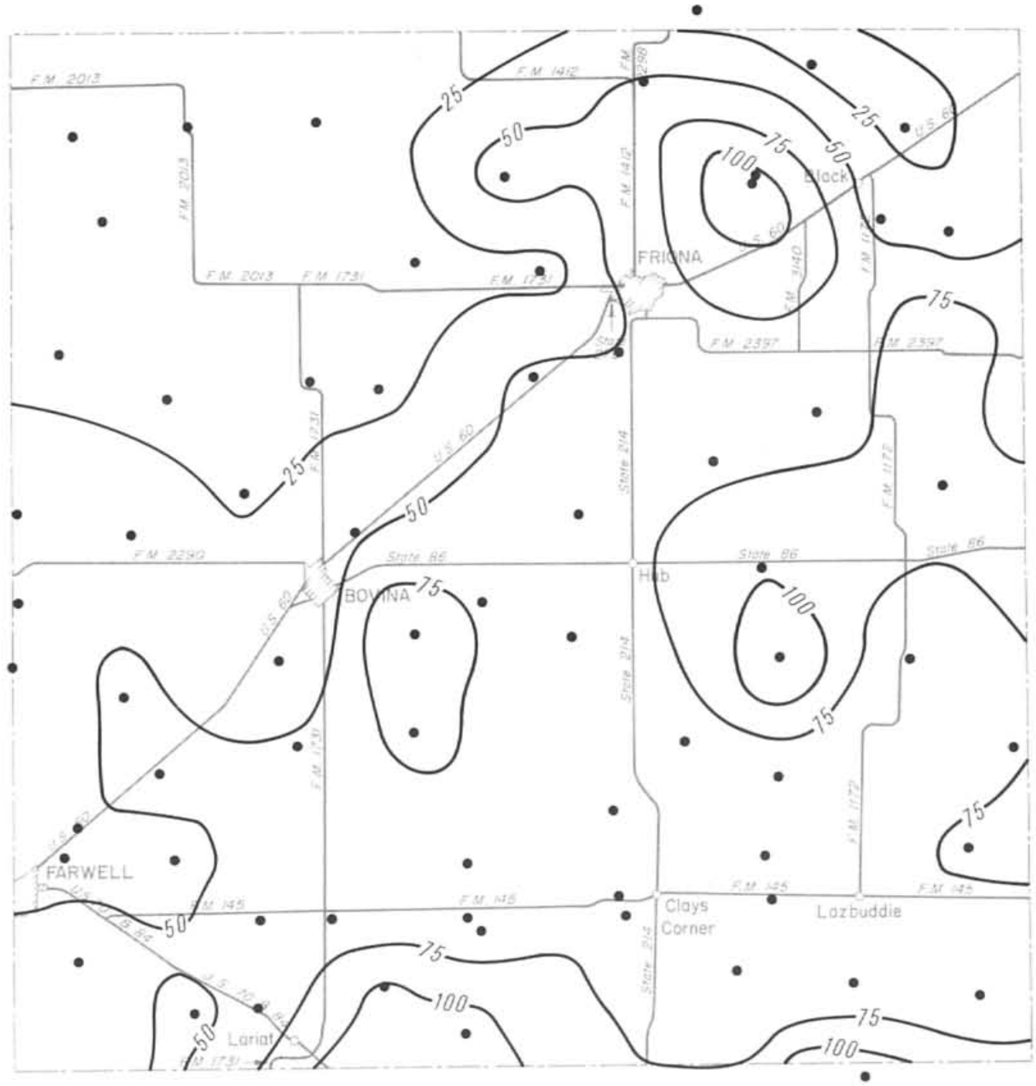
2000
Projected Saturated Thickness

2010

Volume of Water in Storage Corresponding to Mapped Saturated-Thickness Intervals

(Coefficient of Storage: 15 percent)

MAPPED SATURATED-THICKNESS INTERVAL (feet)	SURFACE AREA (acres)	VOLUME OF WATER IN STORAGE (acre-feet)
0– 25	129,898	270,454
25– 50	153,574	917,277
50– 75	200,953	1,804,474
75–100	62,413	783,398
100–125	12,010	196,399
125–150	990	19,248
TOTAL	559,833	3,991,232



EXPLANATION

•

Well used for control

——— 150 ———

Line showing approximate saturated thickness of the Ogallala aquifer, in feet.

Interval is 25 feet

2010

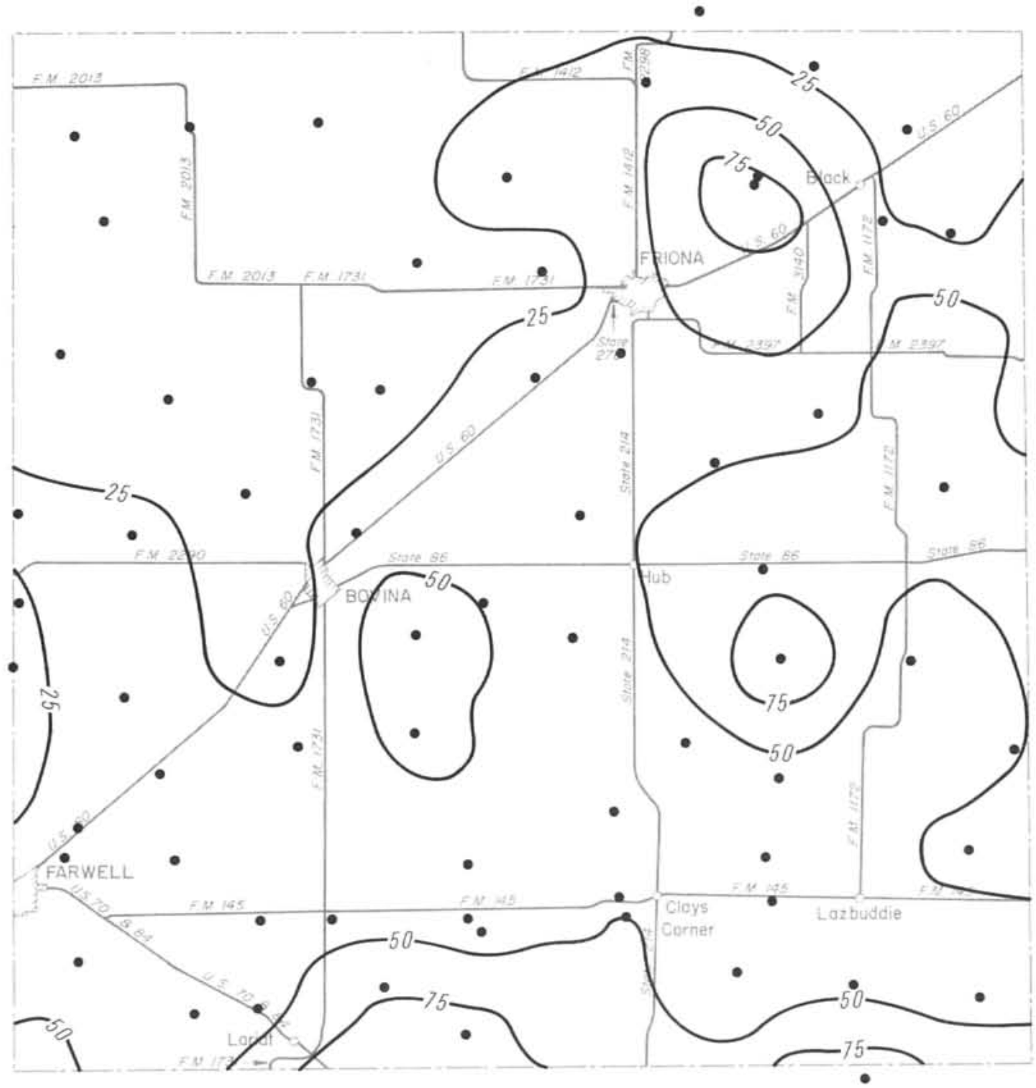
Projected Saturated Thickness

2020

Volume of Water in Storage Corresponding to Mapped Saturated-Thickness Intervals

(Coefficient of Storage: 15 percent)

MAPPED SATURATED-THICKNESS INTERVAL (feet)	SURFACE AREA (acres)	VOLUME OF WATER IN STORAGE (acre-feet)
0– 25	190,835	422,195
25– 50	287,248	1,574,361
50– 75	69,760	607,225
75–100	11,829	149,712
100-125	165	2,547
TOTAL	559,833	2,756,029



EXPLANATION

• Well used for control

——150—— Line showing approximate saturated thickness of the Ogallala aquifer, in feet.

Interval is 25 feet

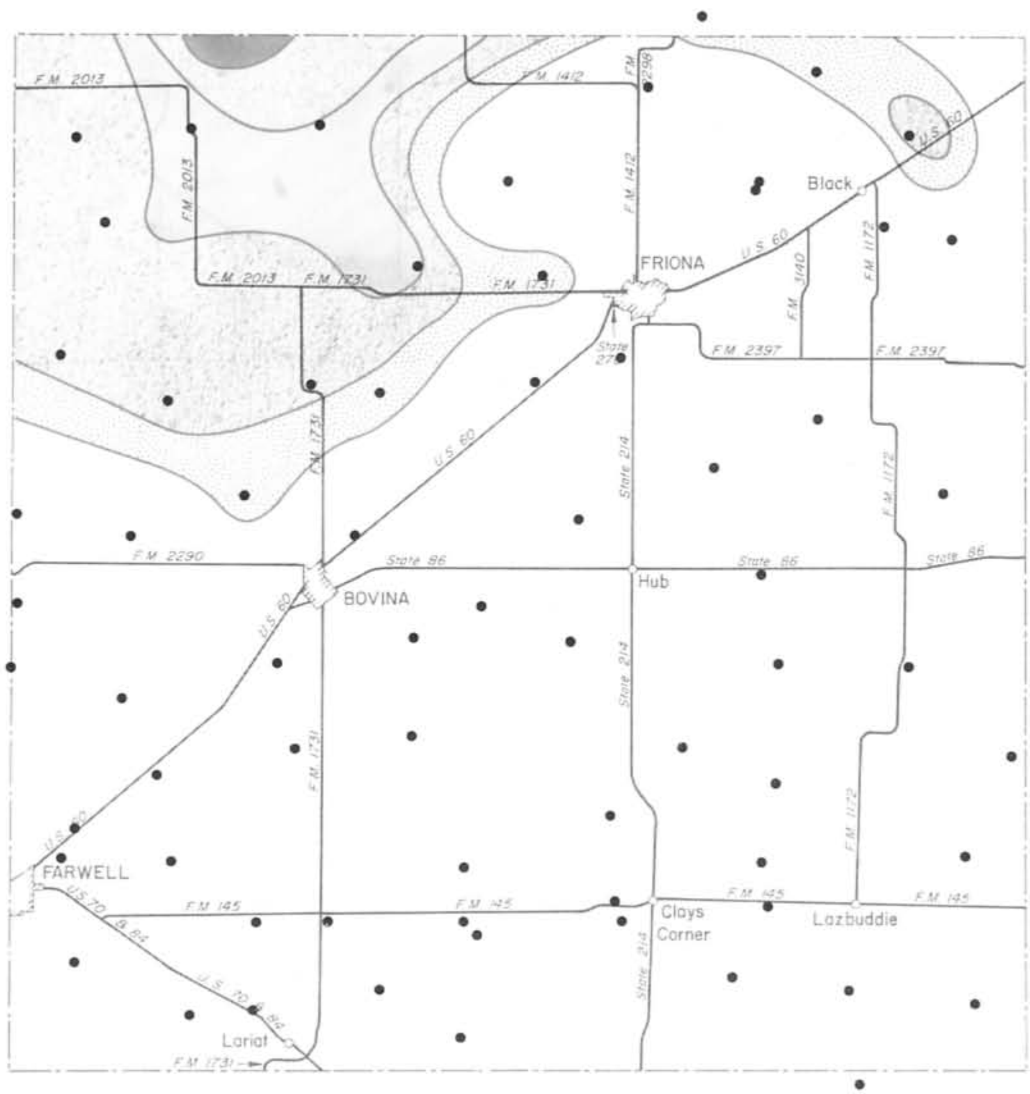
0 5 10 Miles

2020
Projected Saturated Thickness

POTENTIAL WELL YIELD OF THE OGALLALA AQUIFER

1974

Estimated Potential Yield



EXPLANATION

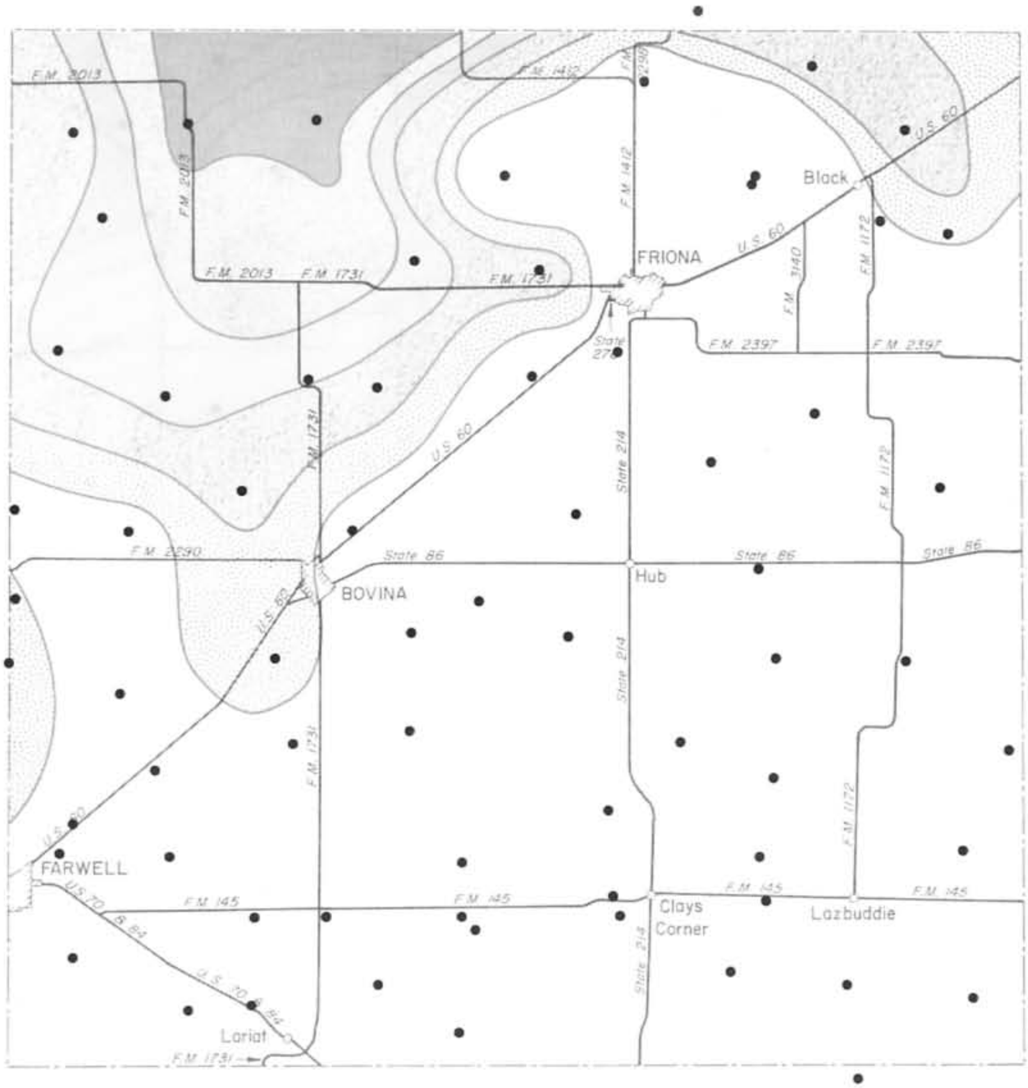
Potential well yields, in gallons per minute

less than 100	500-800
100-250	800-1000
250-500	more than 1000

0 5 10 Miles

N

1980
Projected Potential Yield



EXPLANATION

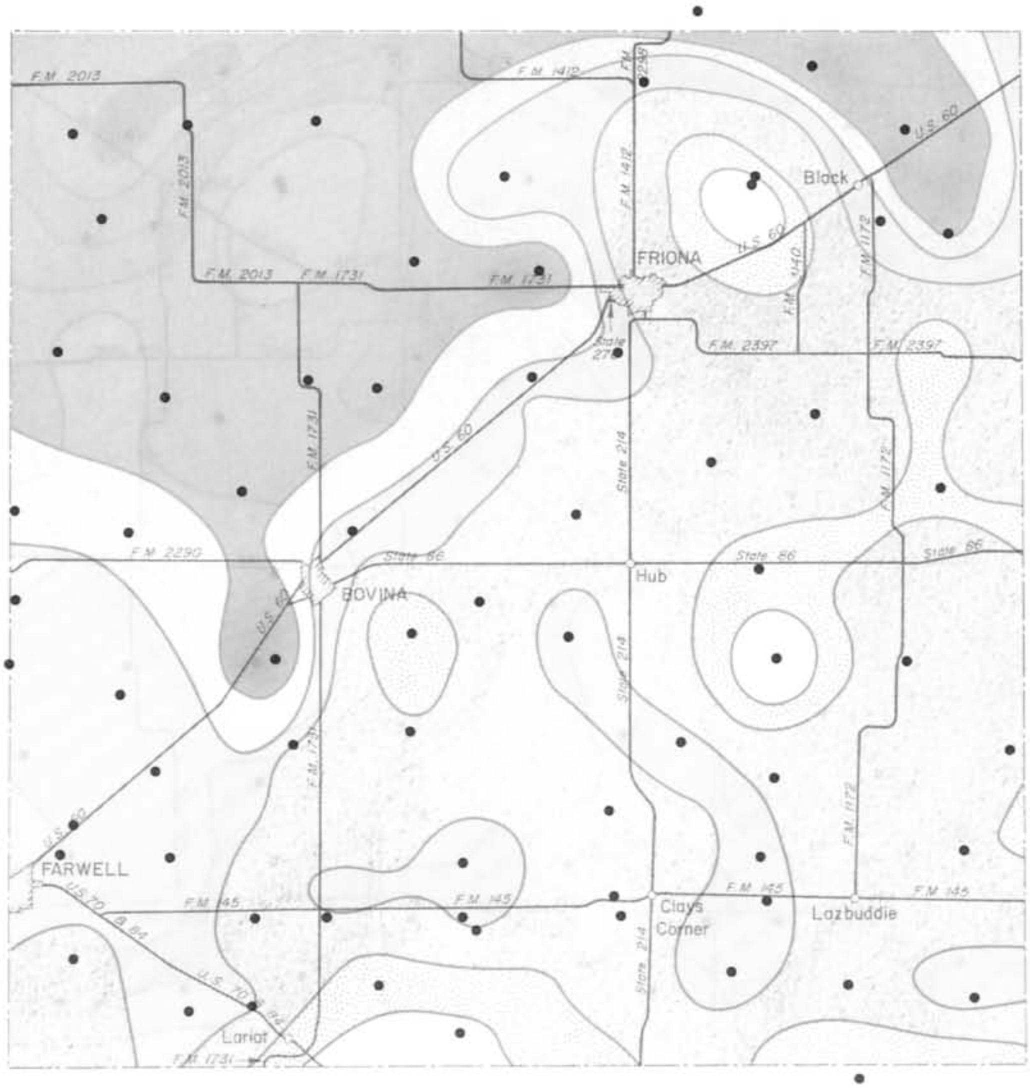
Potential well yields, in gallons per minute

less than 100	500-800
100-250	800-1000
250-500	more than 1000

1990
Projected Potential Yield

2000
Projected Potential Yield

2010
Projected Potential Yield



EXPLANATION

Potential well yields, in gallons per minute

less than 100	500-800
100-250	800-1000
250-500	more than 1000

0 5 10 Miles

N

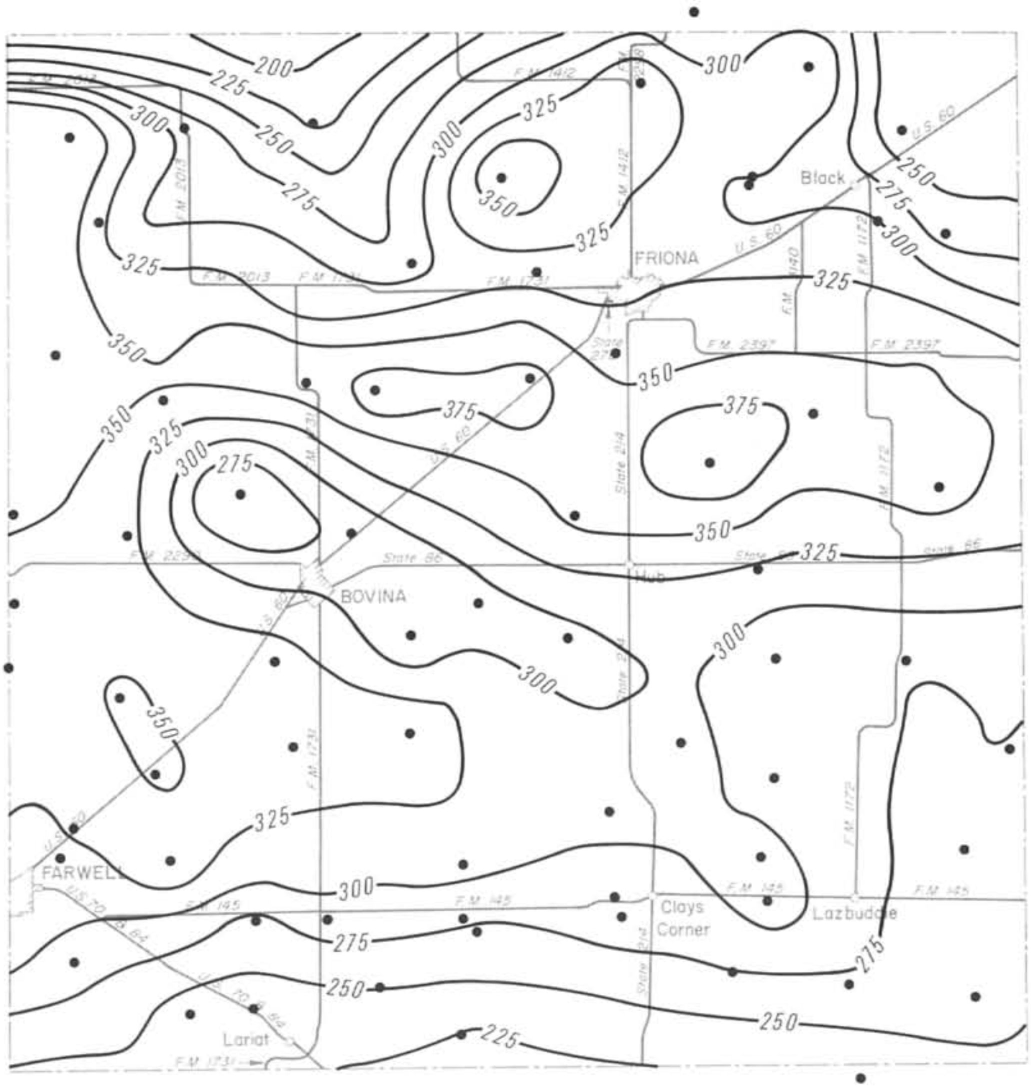
2020
Projected Potential Yield

PUMPING LIFTS IN THE OGALLALA AQUIFER

1974

Surface Area Corresponding To Mapped Pumping-Lift Intervals

MAPPED PUMPING-LIFT INTERVAL (feet)	SURFACE AREA (acres)
175–200	2,905
200–225	9,453
225–250	46,074
250–275	64,256
275–300	104,283
300–325	124,536
325–350	125,747
350–375	52,883
375–400	10,730
400–425	165
TOTAL	541,030



EXPLANATION

Well used for control

200

Line showing approximate pumping lift, in feet.

Interval is 25 feet

0 5 10 Miles

N

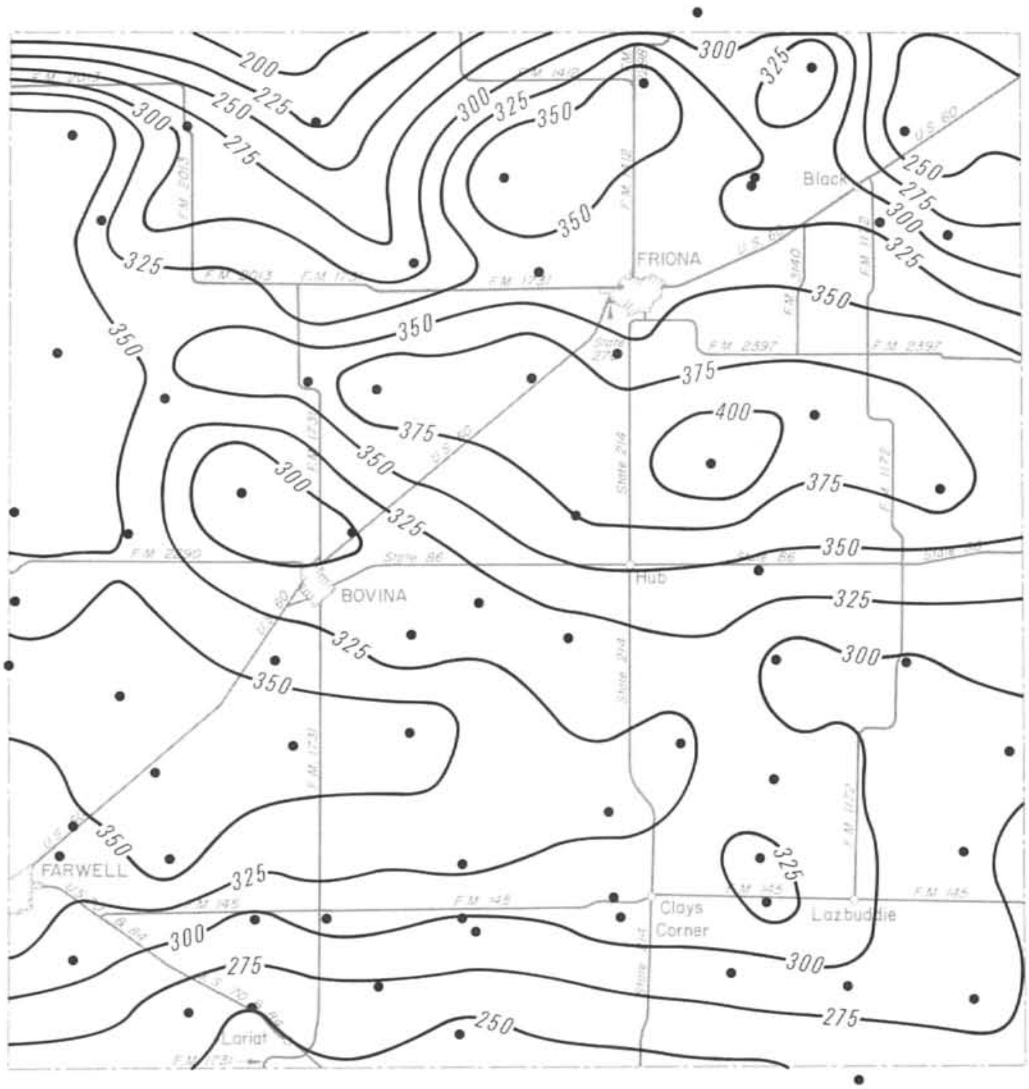
1974

Estimated Pumping Lifts

1980

Surface Area Corresponding to Mapped Pumping-Lift Intervals

MAPPED PUMPING-LIFT INTERVAL (feet)	SURFACE AREA (acres)
175–200	2,905
200–225	6,369
225–250	24,324
250–275	44,420
275–300	77,428
300–325	115,582
325–350	126,359
350–375	100,601
375–400	37,432
400–425	5,612
TOTAL	541,030



EXPLANATION

• Well used for control

——200—— Line showing approximate pumping lift, in feet.

Interval is 25 feet

0 5 10 Miles

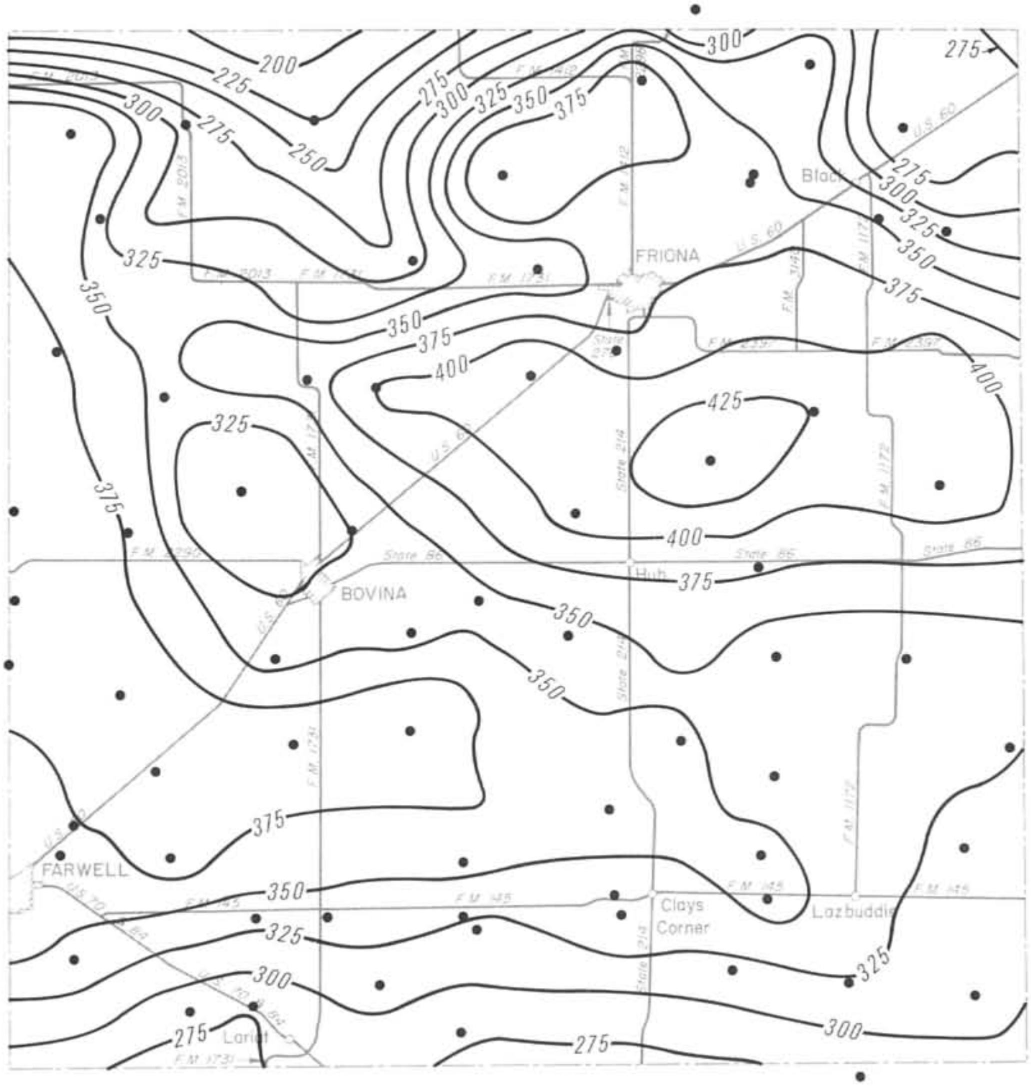
N

1980
Projected Pumping Lifts

1990

Surface Area Corresponding to Mapped Pumping-Lift Intervals

MAPPED PUMPING-LIFT INTERVAL (feet)	SURFACE AREA (acres)
175–200	2,905
200–225	6,369
225–250	8,892
250–275	22,820
275–300	47,303
300–325	68,176
325–350	120,341
350–375	120,581
375–400	89,705
400–425	45,521
425–450	7,758
450–475	660
TOTAL	541,030



EXPLANATION

• Well used for control

——200—— Line showing approximate pumping lift, in feet.

Interval is 25 feet

0 5 10 Miles

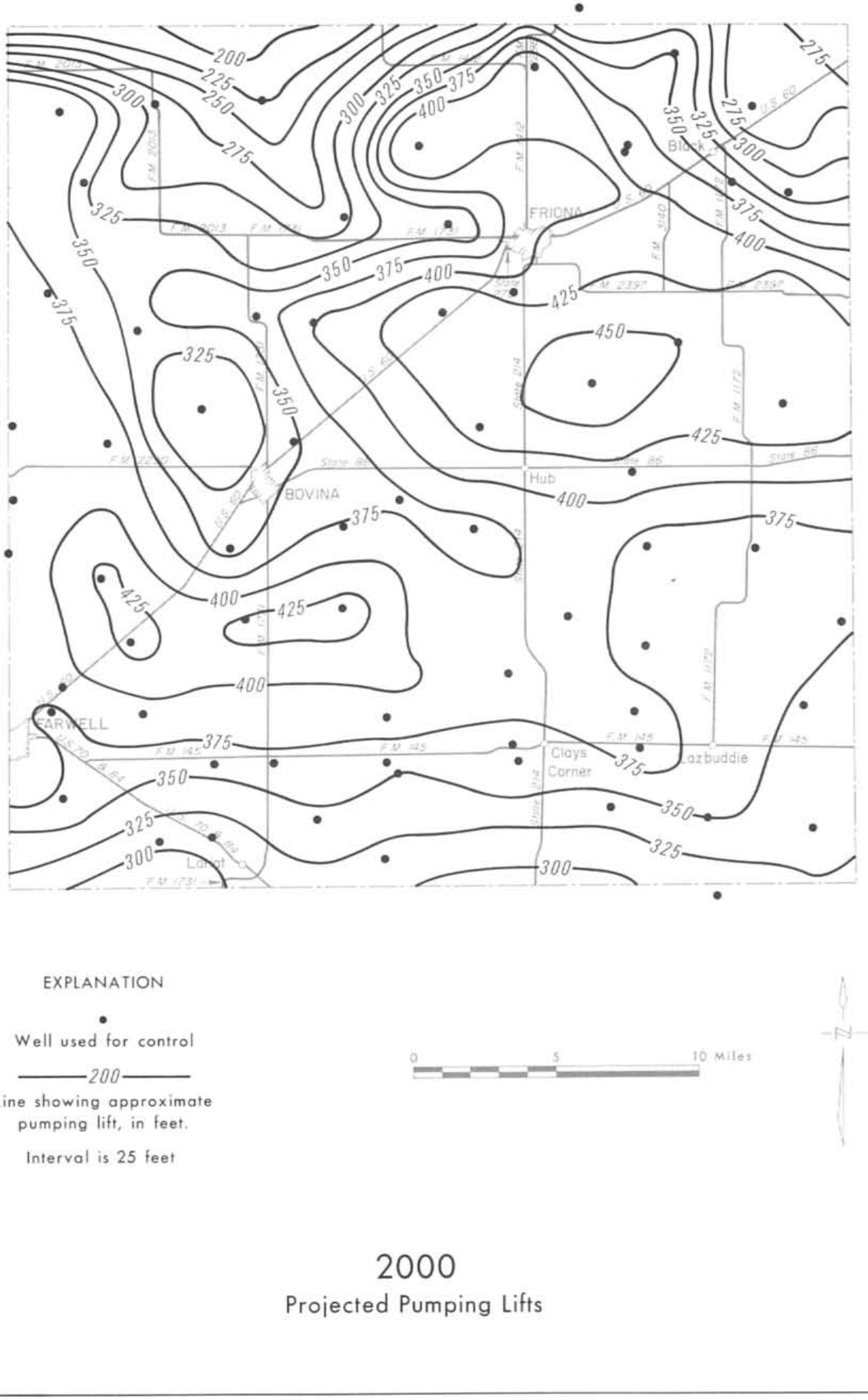
N

1990
Projected Pumping Lifts

2000

Surface Area Corresponding to Mapped Pumping-Lift Intervals

MAPPED PUMPING-LIFT INTERVAL (feet)	SURFACE AREA (acres)
175–200	2,905
200–225	6,369
225–250	8,066
250–275	15,562
275–300	26,581
300–325	48,026
325–350	73,881
350–375	104,756
375–400	118,106
400–425	75,732
425–450	49,978
450–475	9,244
475–500	825
TOTAL	541,030

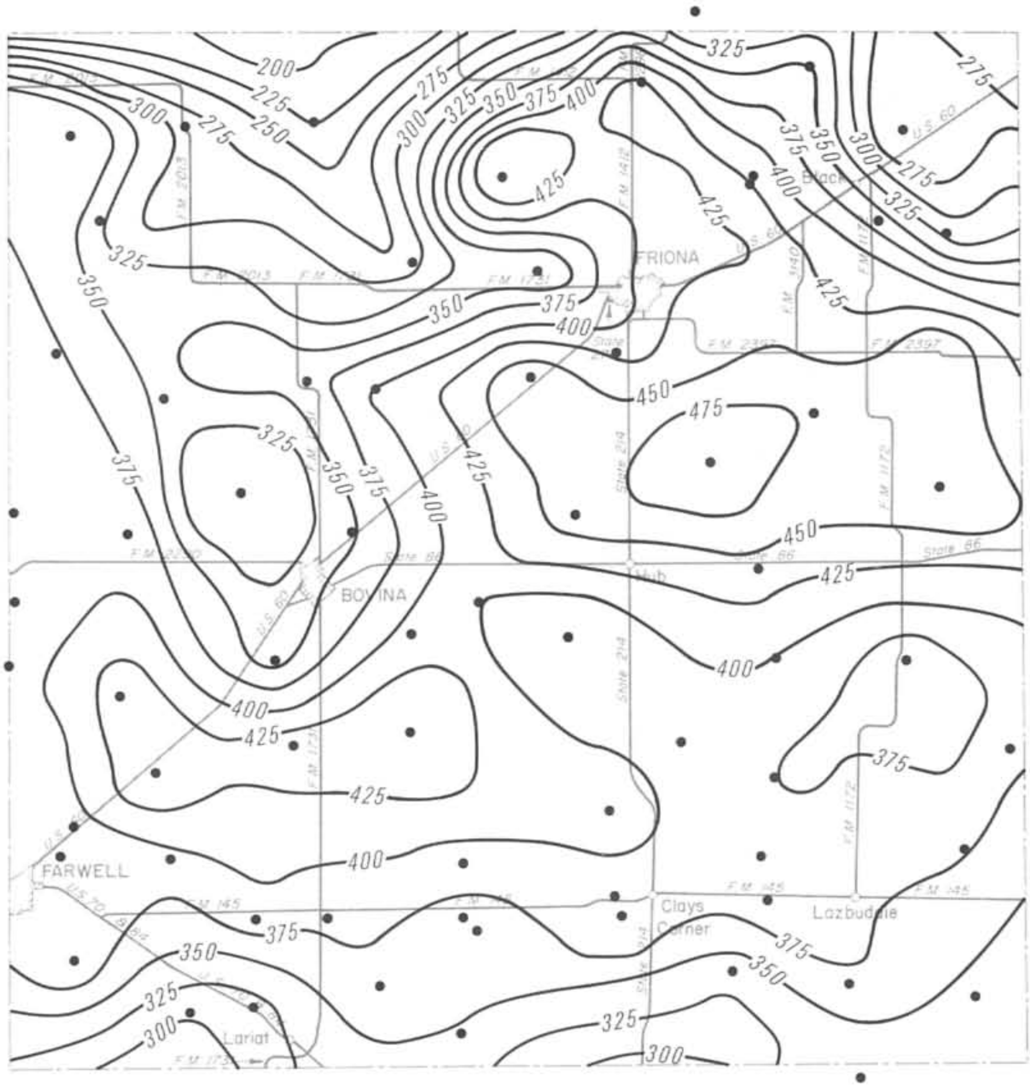


2000
Projected Pumping Lifts

2010

Surface Area Corresponding to Mapped Pumping-Lift Intervals

MAPPED PUMPING-LIFT INTERVAL (feet)	SURFACE AREA (acres)
175–200	2,905
200–225	6,369
225–250	7,901
250–275	14,758
275–300	23,336
300–325	37,037
325–350	62,507
350–375	76,362
375–400	123,563
400–425	83,490
425–450	55,591
450–475	39,618
475–500	6,107
500–525	1,485
TOTAL	541,030



EXPLANATION

•
Well used for control

———200———
Line showing approximate pumping lift, in feet.

Interval is 25 feet

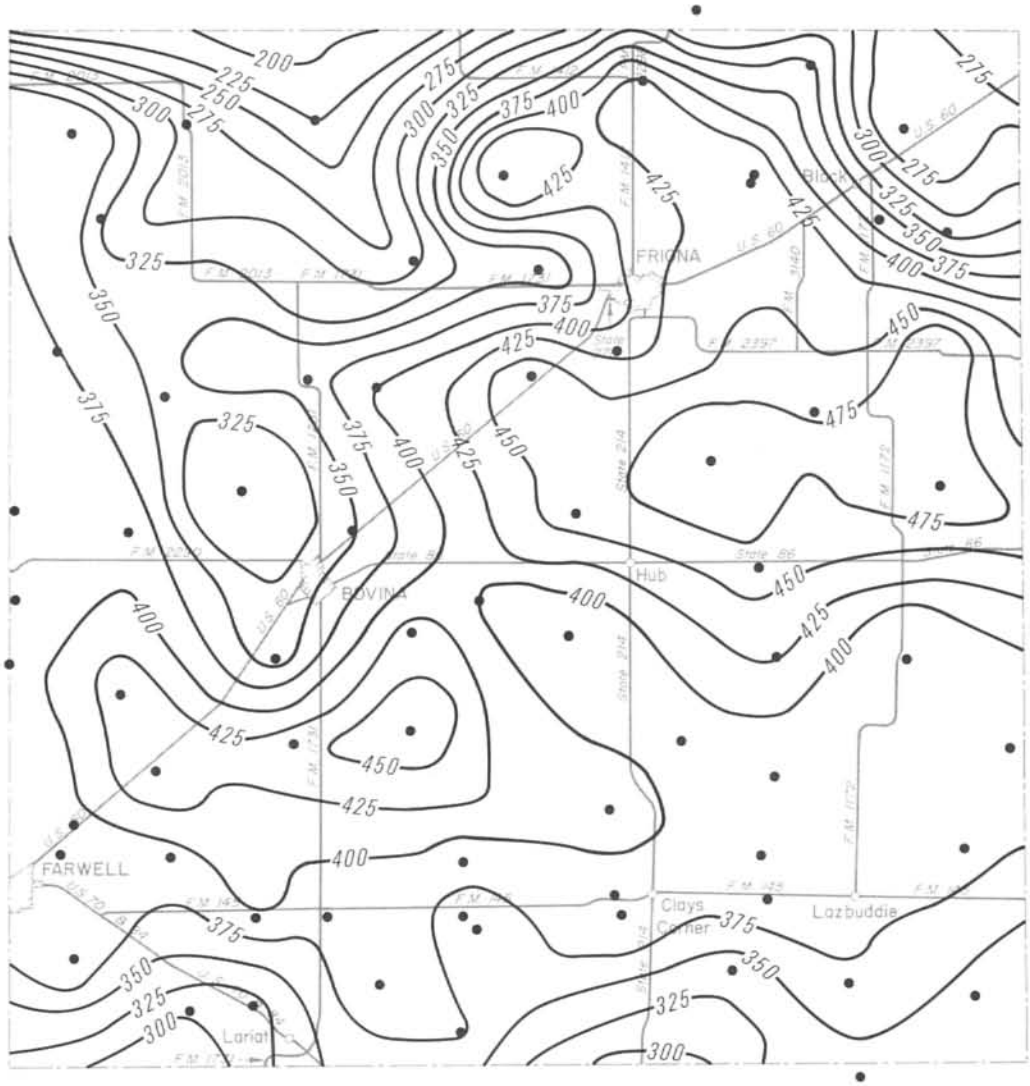
0 5 10 Miles

2010
Projected Pumping Lifts

2020

Surface Area Corresponding to Mapped Pumping-Lift Intervals

MAPPED PUMPING-LIFT INTERVAL (feet)	SURFACE AREA (acres)
175–200	2,905
200–225	6,369
225–250	7,901
250–275	14,593
275–300	23,336
300–325	34,091
325–350	55,926
350–375	70,537
375–400	127,690
400–425	74,246
425–450	52,524
450–475	36,647
475–500	22,615
500–525	1,660
TOTAL	541,030



EXPLANATION

•
Well used for control

——200——
Line showing approximate pumping lift, in feet.

Interval is 25 feet

0 5 10 Miles

N

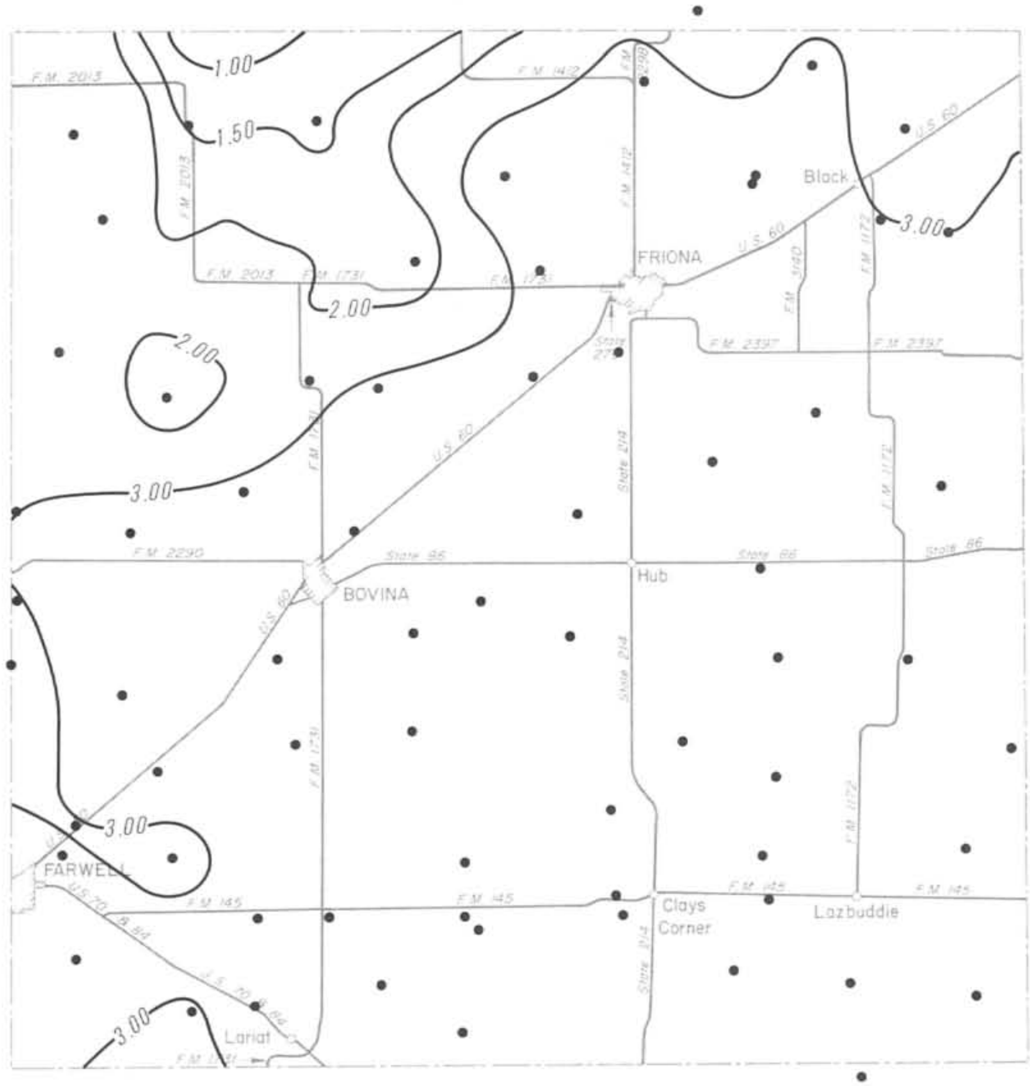
2020
Projected Pumping Lifts

PUMPAGE FROM THE OGALLALA AQUIFER

1974

Pumpage Corresponding to Mapped Decline-Rate Intervals

MAPPED DECLINE-RATE INTERVAL (feet)	SURFACE AREA (acres)	STORAGE CAPACITY OF DEWATERED SECTION (acre-feet)	ESTIMATED PUMPAGE RATE, INCLUDING NATURAL RECHARGE AND IRRIGATION RECIRCULATION (acre-feet per year)
0.75–1.00	1,941	256	371
1.00–1.50	12,283	2,409	3,213
1.50–2.00	28,310	7,462	9,528
2.00–3.00	84,968	33,324	40,551
3.00–4.00	413,529	216,959	257,608
TOTAL	541,030	260,432	311,271

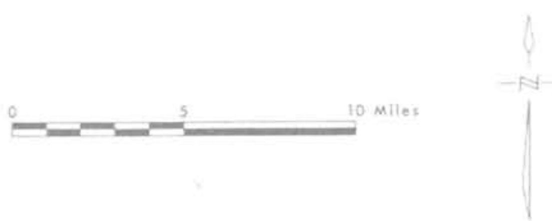


EXPLANATION

•
Well used for control

——— 1.25 ———
Line showing approximate rate of decline in water level, in feet per year.

Interval is variable

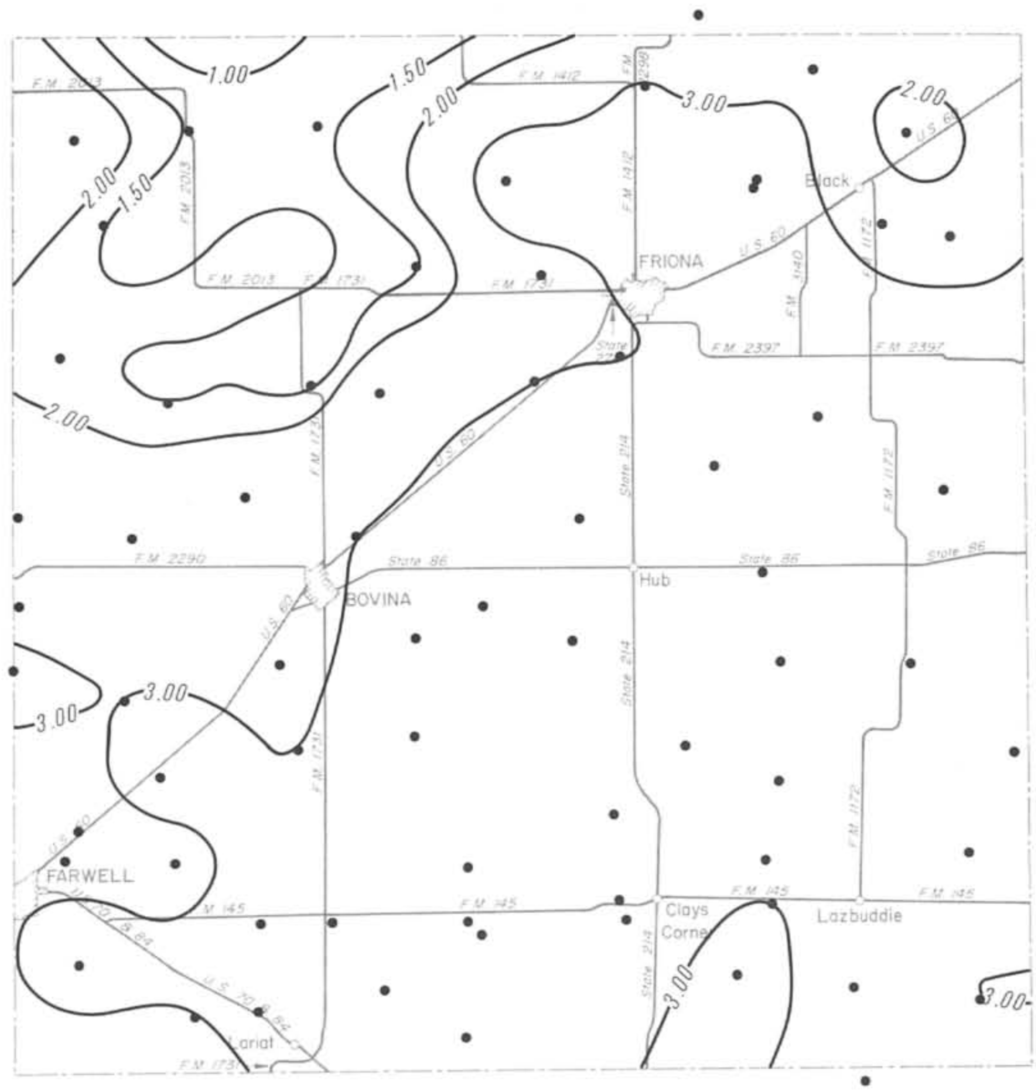


1974
Estimated Rates of Water-Level Decline

1980

Pumpage Corresponding to Mapped Decline-Rate Intervals

MAPPED DECLINE-RATE INTERVAL (feet)	SURFACE AREA (acres)	STORAGE CAPACITY OF DEWATERED SECTION (acre-feet)	ESTIMATED PUMPAGE RATE, INCLUDING NATURAL RECHARGE AND IRRIGATION RECIRCULATION (acre-feet per year)
1.00–1.50	29,287	6,183	7,848
1.50–2.00	35,394	8,935	11,034
2.00–3.00	158,511	62,318	73,058
3.00–4.00	307,115	152,854	175,590
TOTAL	530,305	230,291	267,530

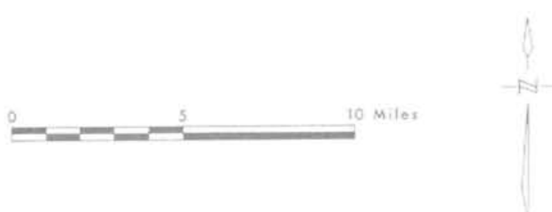


EXPLANATION

•
Well used for control

——1.25——
Line showing approximate rate of decline in water level, in feet per year.

Interval is variable

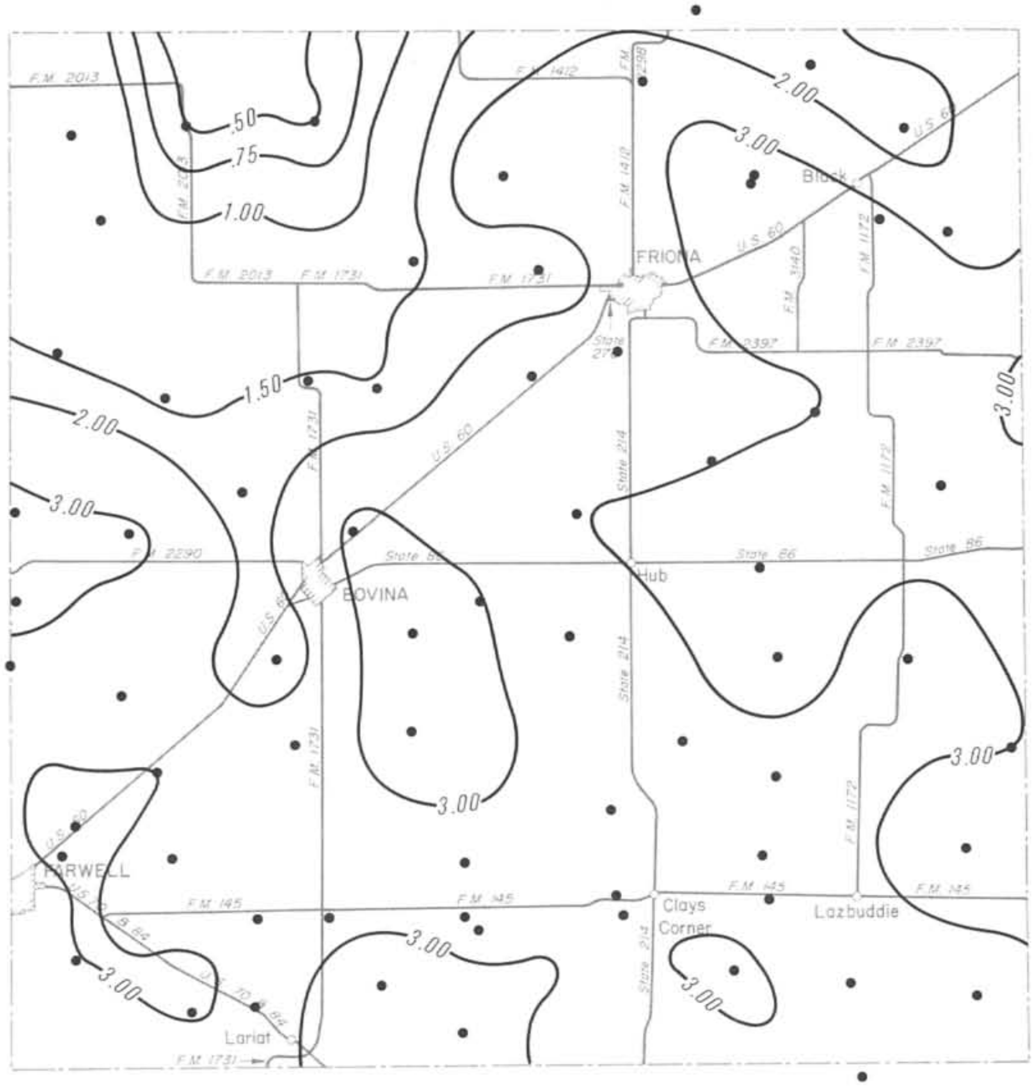


1980
Projected Rates of Water-Level Decline

1990

Pumpage Corresponding to Mapped Decline-Rate Intervals

MAPPED DECLINE-RATE INTERVAL (feet)	SURFACE AREA (acres)	STORATE CAPACITY OF DEWATERED SECTION (acre-feet)	ESTIMATED PUMPAGE RATE, INCLUDING NATURAL RECHARGE AND IRRIGATION RECIRCULATION (acre-feet per year)
0.25–0.50	7,356	473	826
.50– .75	7,560	710	1,086
.75–1.00	7,899	1,059	1,472
1.00–1.50	33,660	6,586	8,468
1.50–2.00	49,771	12,975	15,951
2.00–3.00	275,413	109,199	127,915
3.00–4.00	148,648	72,648	83,572
TOTAL	530,305	203,651	239,290



EXPLANATION

•
Well used for control

——1.25——
Line showing approximate rate of decline in water level, in feet per year.

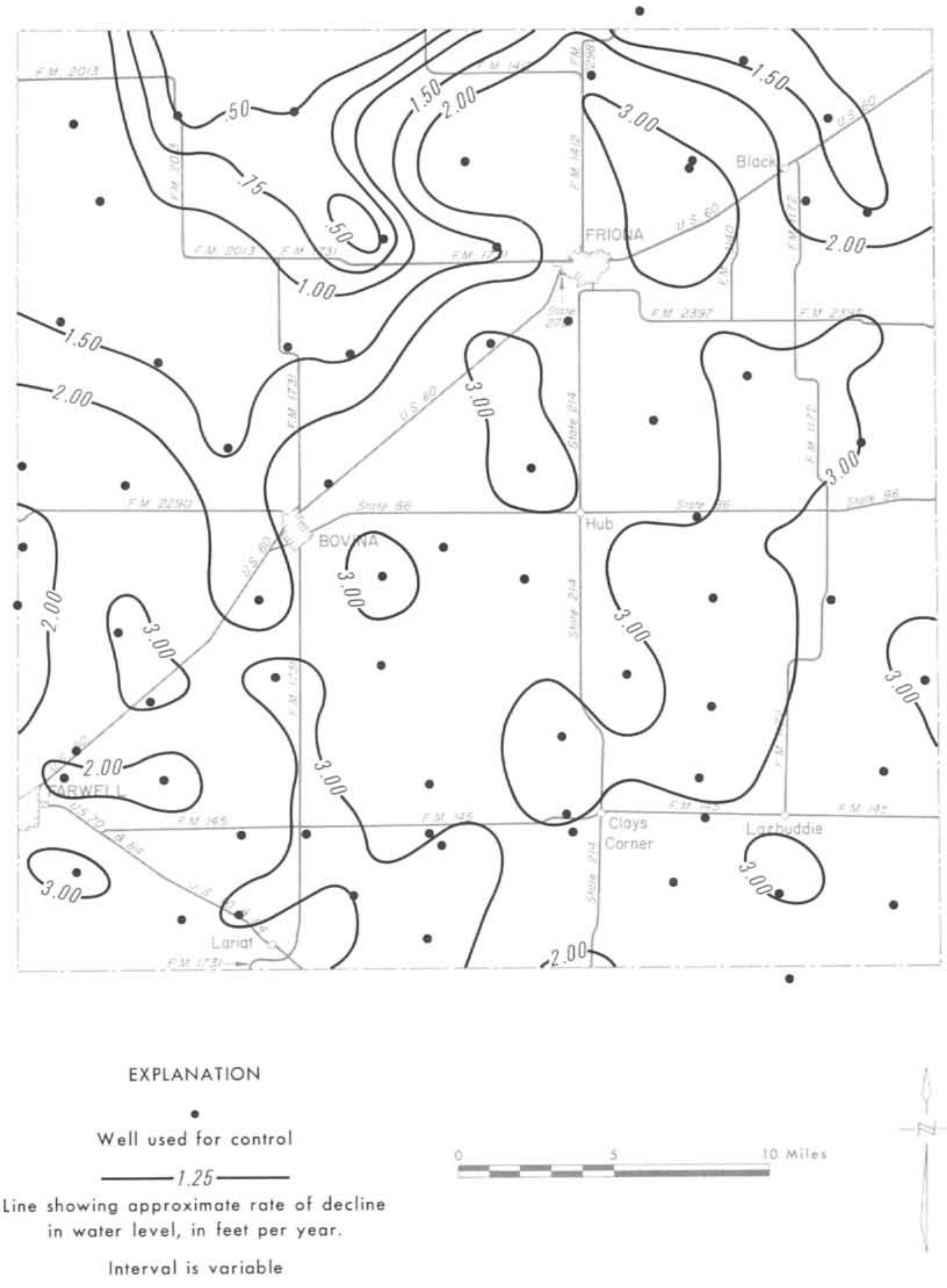
Interval is variable

0 5 10 Miles

1990
Projected Rates of Water-Level Decline

Pumpage Corresponding to Mapped Decline-Rate Intervals

MAPPED DECLINE-RATE INTERVAL (feet)	SURFACE AREA (acres)	STORAGE CAPACITY OF DEWATERED SECTION (acre-feet)	ESTIMATED PUMPAGE RATE, INCLUDING NATURAL RECHARGE AND IRRIGATION RECIRCULATION (acre-feet per year)
0.25–0.50	11,812	781	1,350
.50– .75	29,348	2,653	4,109
.75–1.00	15,778	2,048	2,868
1.00–1.50	45,697	8,986	11,543
1.50–2.00	72,271	18,761	23,078
2.00–3.00	272,726	107,976	126,500
3.00–4.00	82,673	38,920	44,907
TOTAL	530,305	180,127	214,355



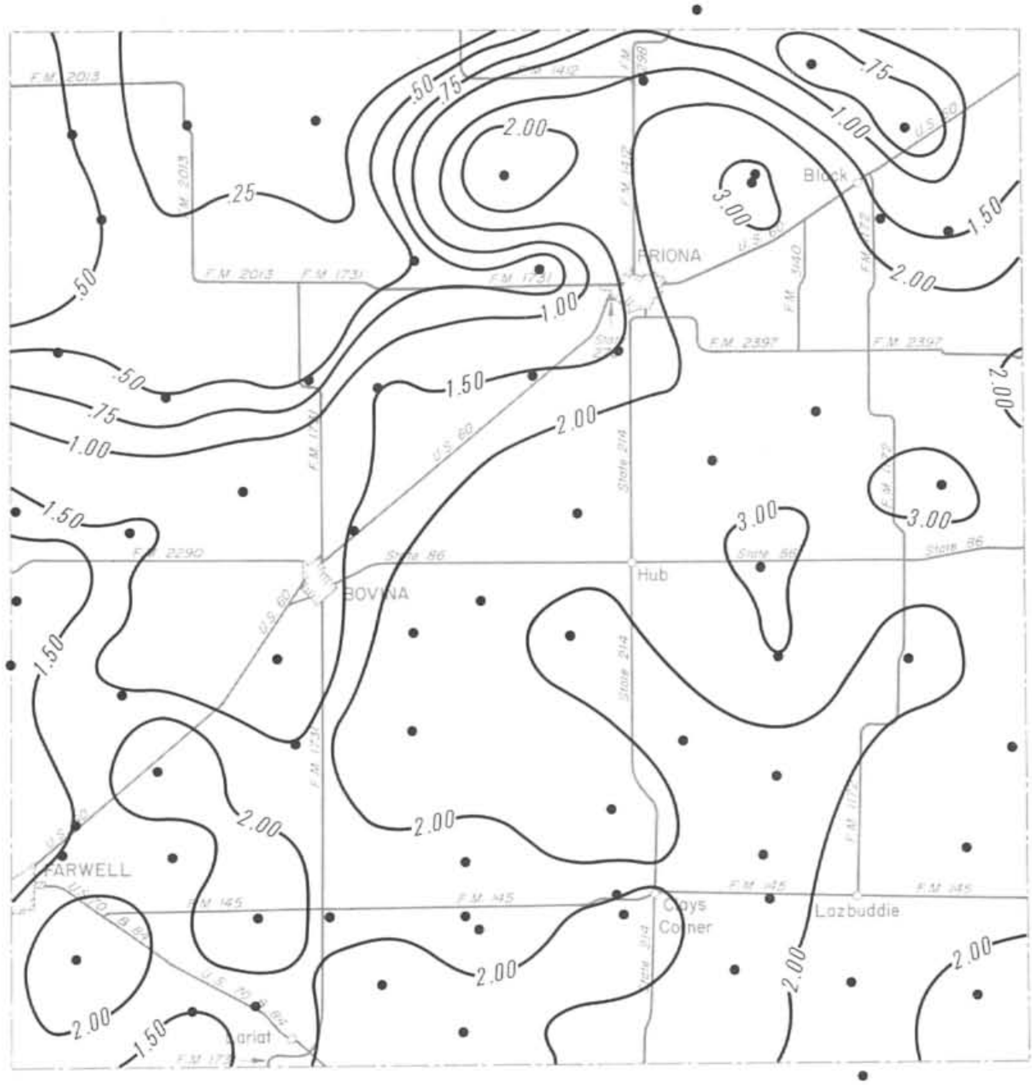
2000

Projected Rates of Water-Level Decline

2010

Pumpage Corresponding to Mapped Decline-Rate Intervals

MAPPED DECLINE-RATE INTERVAL (feet)	SURFACE AREA (acres)	STORAGE CAPACITY OF DEWATERED SECTION (acre-feet)	ESTIMATED PUMPAGE RATE, INCLUDING NATURAL RECHARGE AND IRRIGATION RECIRCULATION (acre-feet per year)
0.25–0.50	34,250	2,523	4,187
.50– .75	45,972	4,133	6,412
.75–1.00	32,333	4,212	5,892
1.00–1.50	94,855	18,861	24,182
1.50–2.00	170,430	43,572	53,713
2.00–3.00	144,544	52,235	61,753
3.00–4.00	7,922	3,661	4,230
TOTAL	530,305	129,198	160,369



EXPLANATION

•

Well used for control

——— 1.25 ———

Line showing approximate rate of decline in water level, in feet per year.

Interval is variable

0 5 10 Miles

N

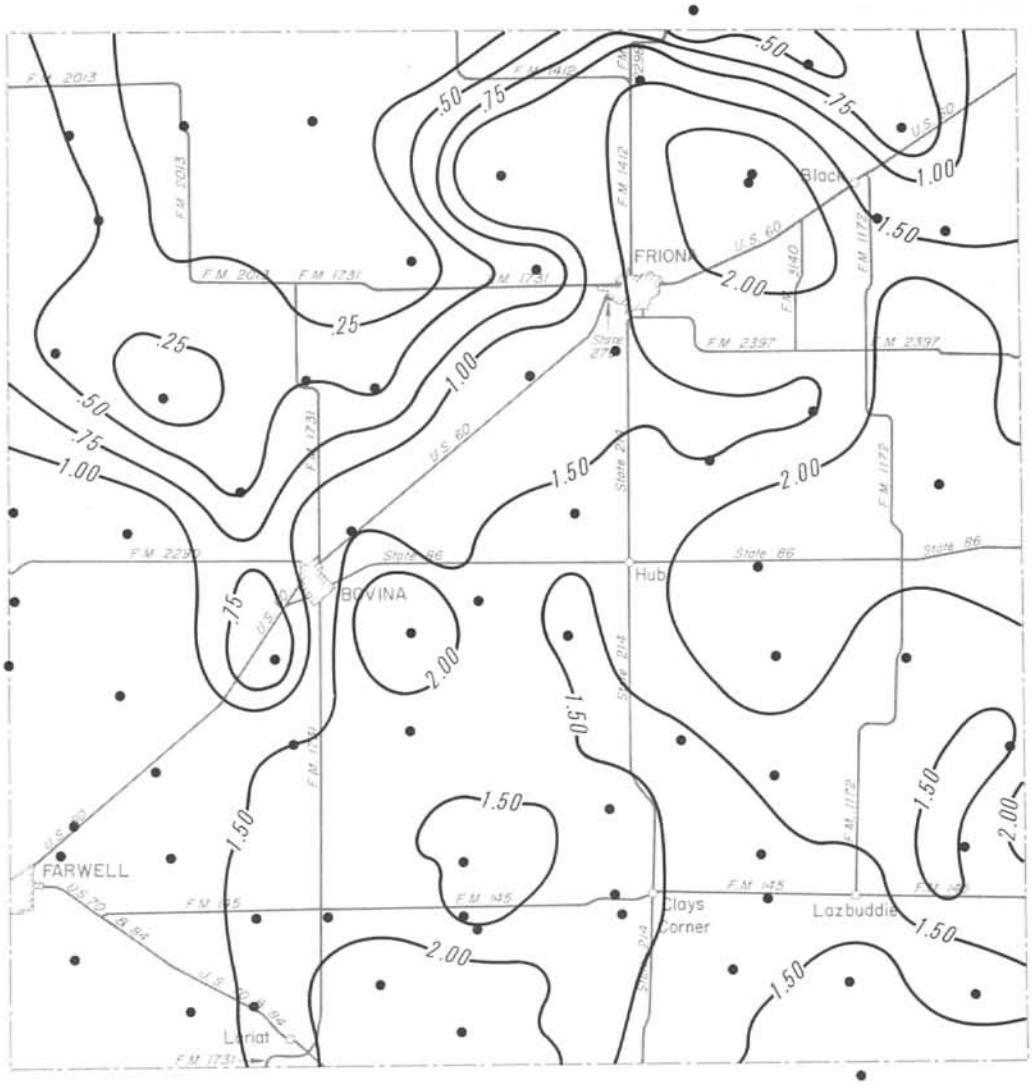
2010

Projected Rates of Water-Level Decline

2020

Pumpage Corresponding to Mapped Decline-Rate Intervals

MAPPED DECLINE-RATE INTERVAL (feet)	SURFACE AREA (acres)	STORAGE CAPACITY OF DEWATERED SECTION (acre-feet)	ESTIMATED PUMPAGE RATE, INCLUDING NATURAL RECHARGE AND IRRIGATION RECIRCULATION (acre-feet per year)
0.25–0.50	34,580	2,550	4,231
.50– .75	59,871	5,426	8,396
.75–1.00	48,050	6,316	8,817
1.00–1.50	237,247	47,782	61,127
1.50–2.00	107,198	27,107	33,468
2.00–3.00	42,370	14,814	17,574
3.00–4.00	990	457	528
TOTAL	530,305	104,454	134,141



EXPLANATION

Well used for control

1.25

Line showing approximate rate of decline in water level, in feet per year.

Interval is variable

0 5 10 Miles

2020

Projected Rates of Water-Level Decline

ACKNOWLEDGEMENTS

Special appreciation is expressed to the Parmer County landowners and water users for allowing their wells to be measured by Board and Water District personnel. This study could not have been accomplished without their cooperation and the records obtained from their wells.

Special thanks are also expressed to the staff of the High Plains Underground Water Conservation District No. 1, Mr. Frank A. Rayner, general manager, for providing records and consultation during the study.

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STAFF INVOLVEMENT

This report was prepared principally in the Texas Water Development Board's Ground Water Data and Protection Division, Mr. Fred L. Osborne, Jr., director. Numerous staff members of this Division assisted the authors in assembling and evaluating data and information. The Board's Information Systems and Services Division, Mr. David L. Ferguson, director, provided automated data processing and computational services, and prepared the manuscript copy of tabular and graphical displays.

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