IOWA OBSERVATION WELL NETWORK: PAST, PRESENT AND FUTURE

U.S. GEOLOGICAL SURVEY

Open-File Report 80-755

Prepared in cooperation with the

IOWA NATURAL RESOURCES COUNCIL

and

IOWA GEOLOGICAL SURVEY

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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BY
JOHN D. LOGEL

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IOWA CITY, IOWA
JULY 1980

UNITED STATES DEPARTMENT OF INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

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ABSTRACT

Water-level measurements in wells were started by the USGS in Iowa in 1935.

Since then a total of about 450 different wells have been measured. The present network consists of about 70 wells. The measurement of these water levels aids in evaluating the present and future water resources of the State.

Many factors influence water-level fluctuations. These factors include atmospheric pressure, withdrawals by pumping, earthquakes, earth tides, change in surface loading, discharge to streams, evapotranspiration, and precipitation. Fluctuations produced by artifical discharge through pumping is a common phenomena but unlike the other factors can be regulated and controlled.

All present and past USGS observation wells for the State of Iowa since 1935 are listed and located on maps. It is recommended that improvement of the observation-well network by the addition of wells in specific areas should be undertaken as soon as possible.

INTRODUCTION

Ground-water is one of Iowa's most valuable natural resources. Its use for private and public water supply, and industrial use is vital to the economy and prosperity of the State. Ground water is also used extensively for irrigation. The objective of the USGS water-level data-collection program is to provide records of short term changes and long term trends of water levels throughout the State.

Specific uses of water-level data are to: 1) identify detrimentally low or high ground-water levels; 2) facilitate predictions of future ground-water supplies; 3) evaluate water bearing properties of ground-water reservoirs; 4) appraise the water level fluctuation-precipitation relationship; 5) indicate the status of ground water in transit; 6) aid in estimating base flow of streams; 7) provide a long term framework of water-level records that can be correlated to short-term projects; and 8) furnish data for basic research and management of ground-water resources. Fluctuations of water levels indicate reaction to external factors. These factors include atmospheric pressure, earthquakes, earth tides, changes in surface loading, withdrawals, discharge to streams, evapotranspiration, and precipitation.

SCOPE OF REPORT

This report provides a general summary of water-level monitoring activities in Iowa from 1935 through 1979. Water-level data for wells which are no longer being measured are of interest to numerous individuals, government agencies and consultants who are concerned with specific ground-water problems. These historical water levels should provide an information base to aid future water planners and managers in the years ahead. This report will serve as an index of measurements available. General recommendations will be made about continuation of existing observation wells and the feasibility of adding new wells to the program.

The observation-well network in Iowa is constantly being reevaluated. Wells that are a part of a specific water-resources project or other available wells which are found to be valuable to the existing observation-well program may be added. Measurements of wells are discontinued when they duplicate records of other wells, the information is no longer useful, or the well has been destroyed.

In 1935, systematic measurement of ground-water levels was begun in two counties in Iowa (Page and Montgomery) for a water-resources study of the Tarkio Creek Basin. Between 1935 and 1979, water-levels for 450 different observation wells were published or are available in USGS files (plate 1, table 1). At present there are 70 observation wells being periodically measured in the State. Ten have continuous recorders and the remainder are measured monthly or bimonthly. Present observation wells are shown by aquifer in figures 1 thru 7. In addition there are 19 project observation wells concentrated in and around the metropolitan area of Cedar Rapids, Iowa. Of this number, 8 are equipped with continous recording gages. A second project in northwest Iowa has about 20 observation wells at the present time (1979), with more being drilled.

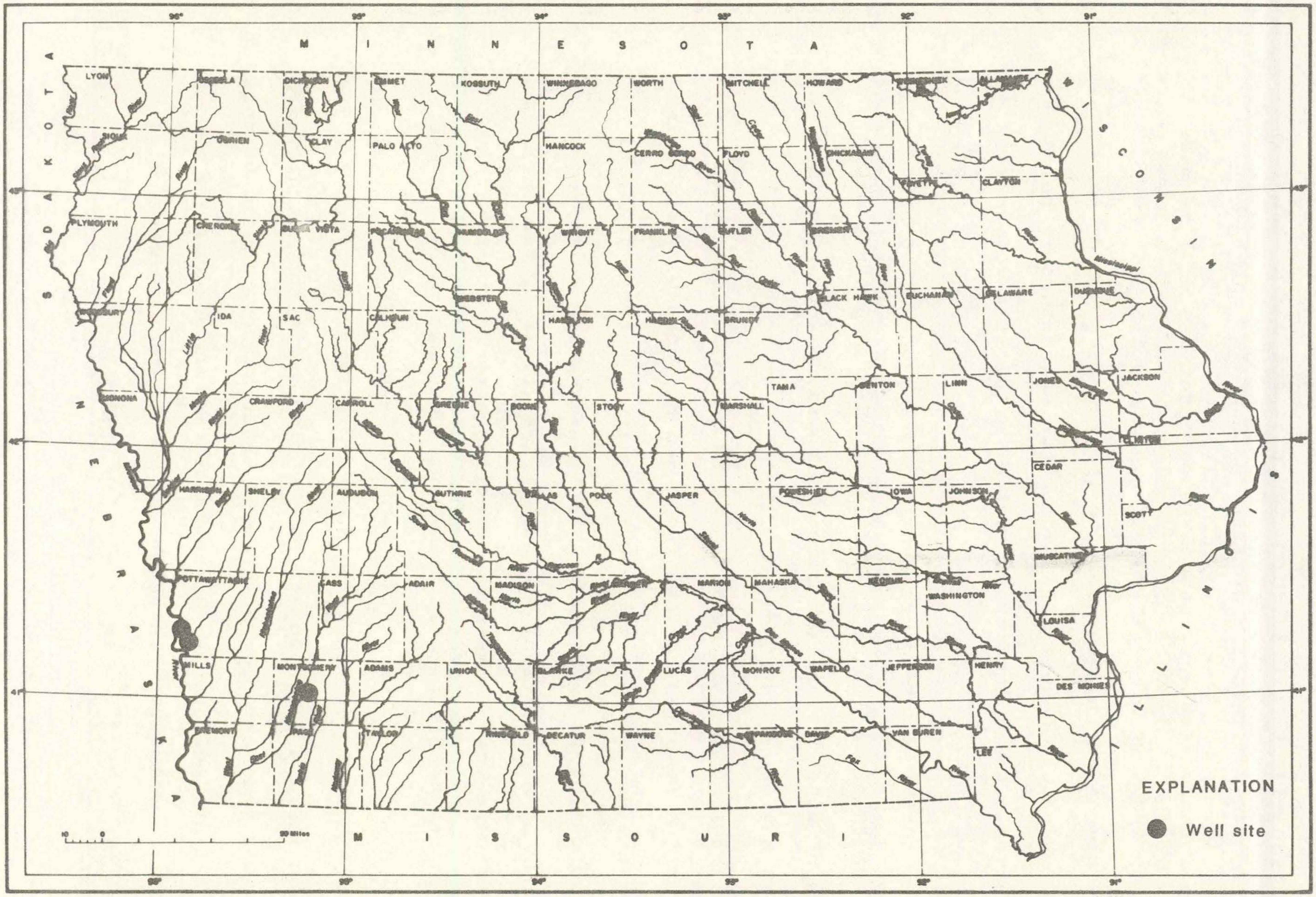


Figure 1.--Present observation wells in the Alluvial aquifer.

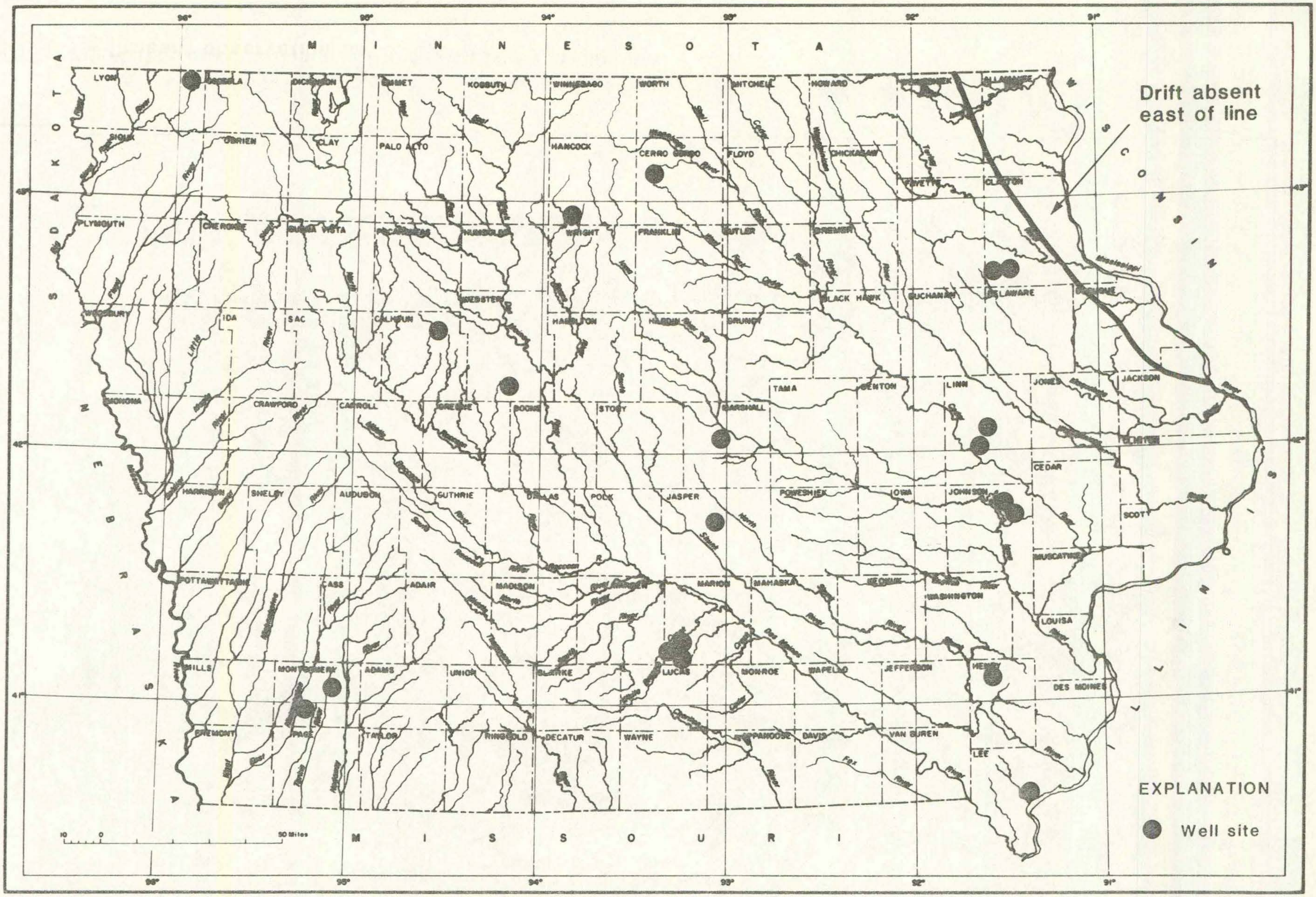


Figure 2.--Present observation wells in the Drift aquifer.

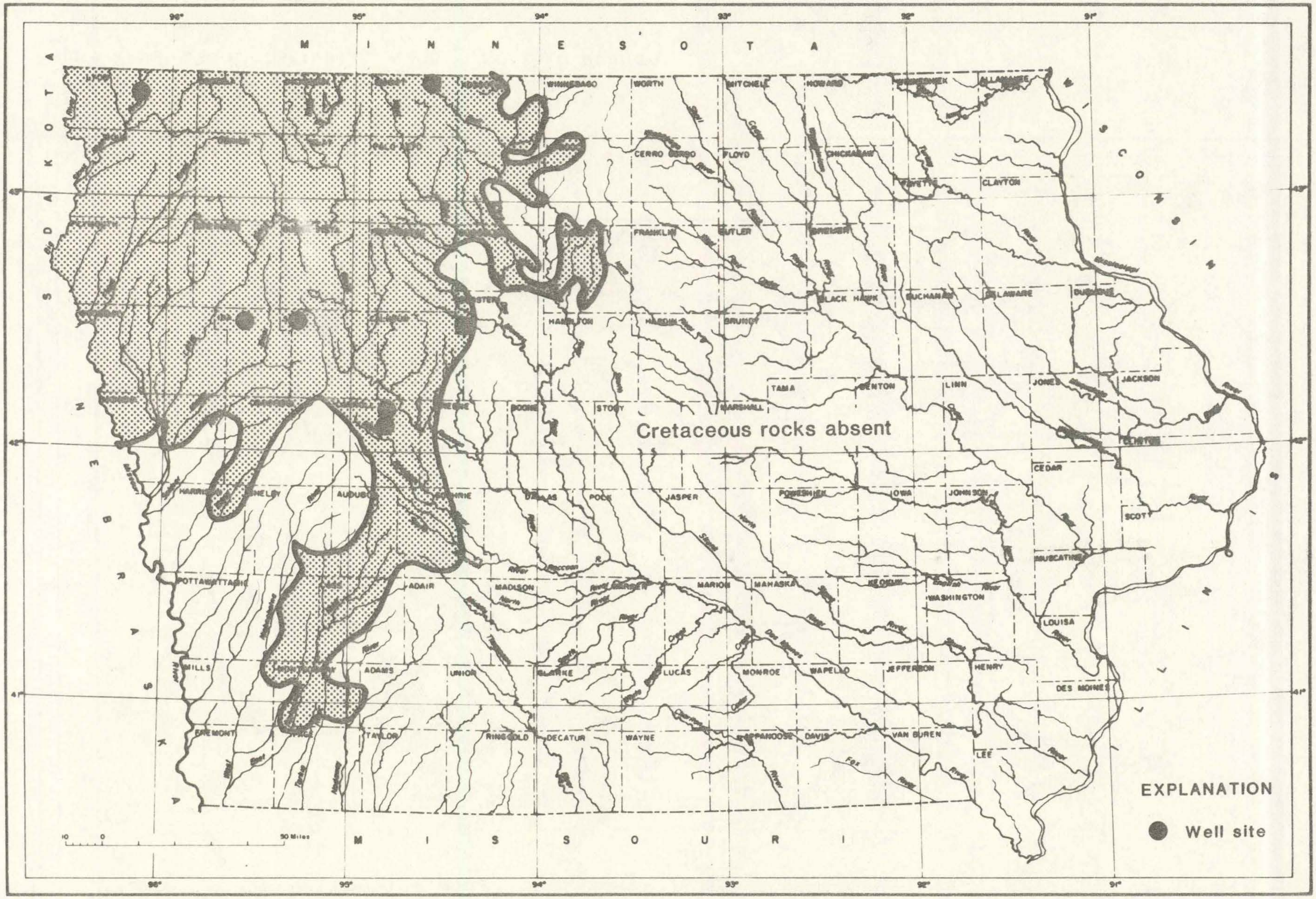


Figure 3.--Present observation wells in the Cretaceous aquifer.

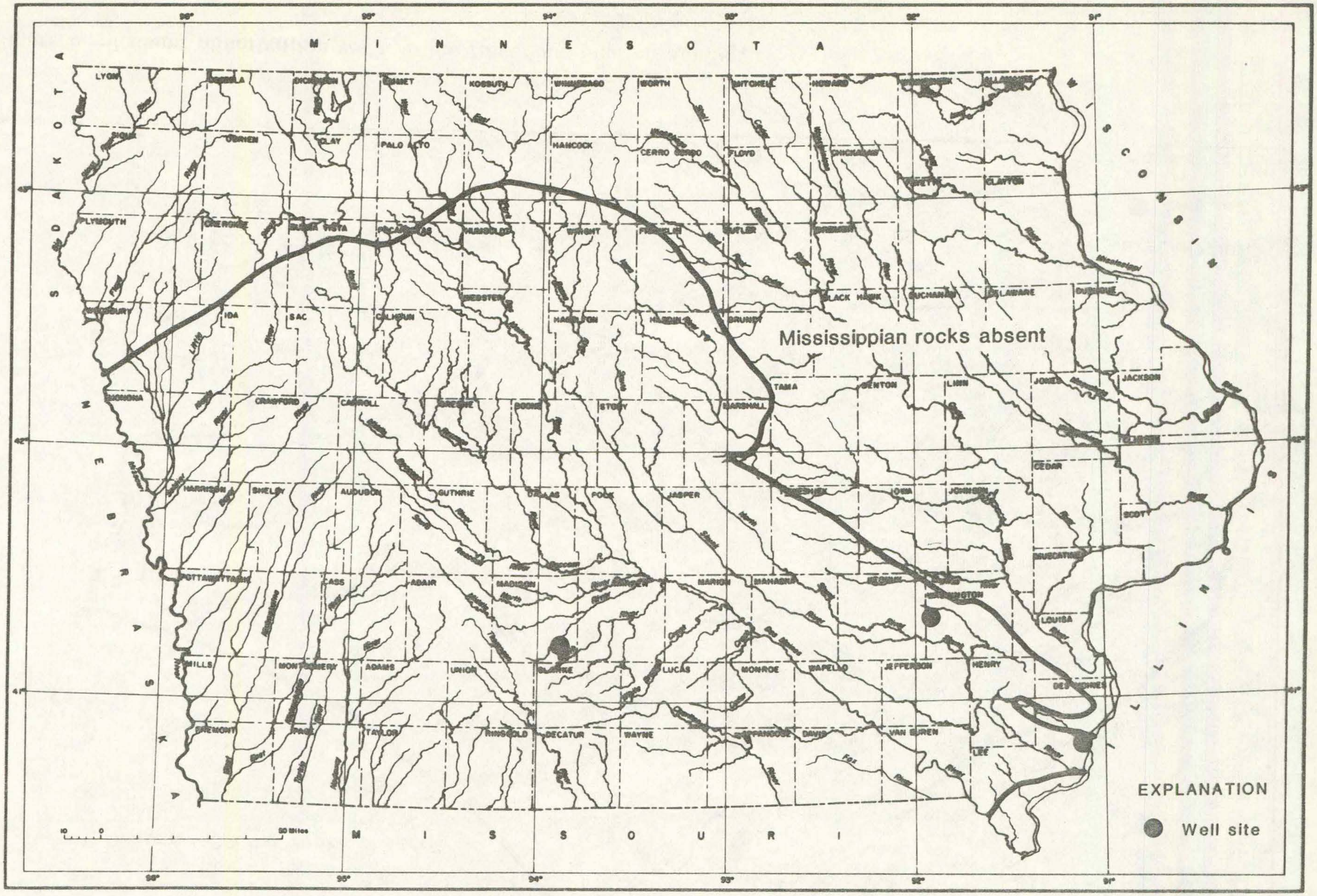


Figure 4.--Present observation wells in the Mississippian aquifer.

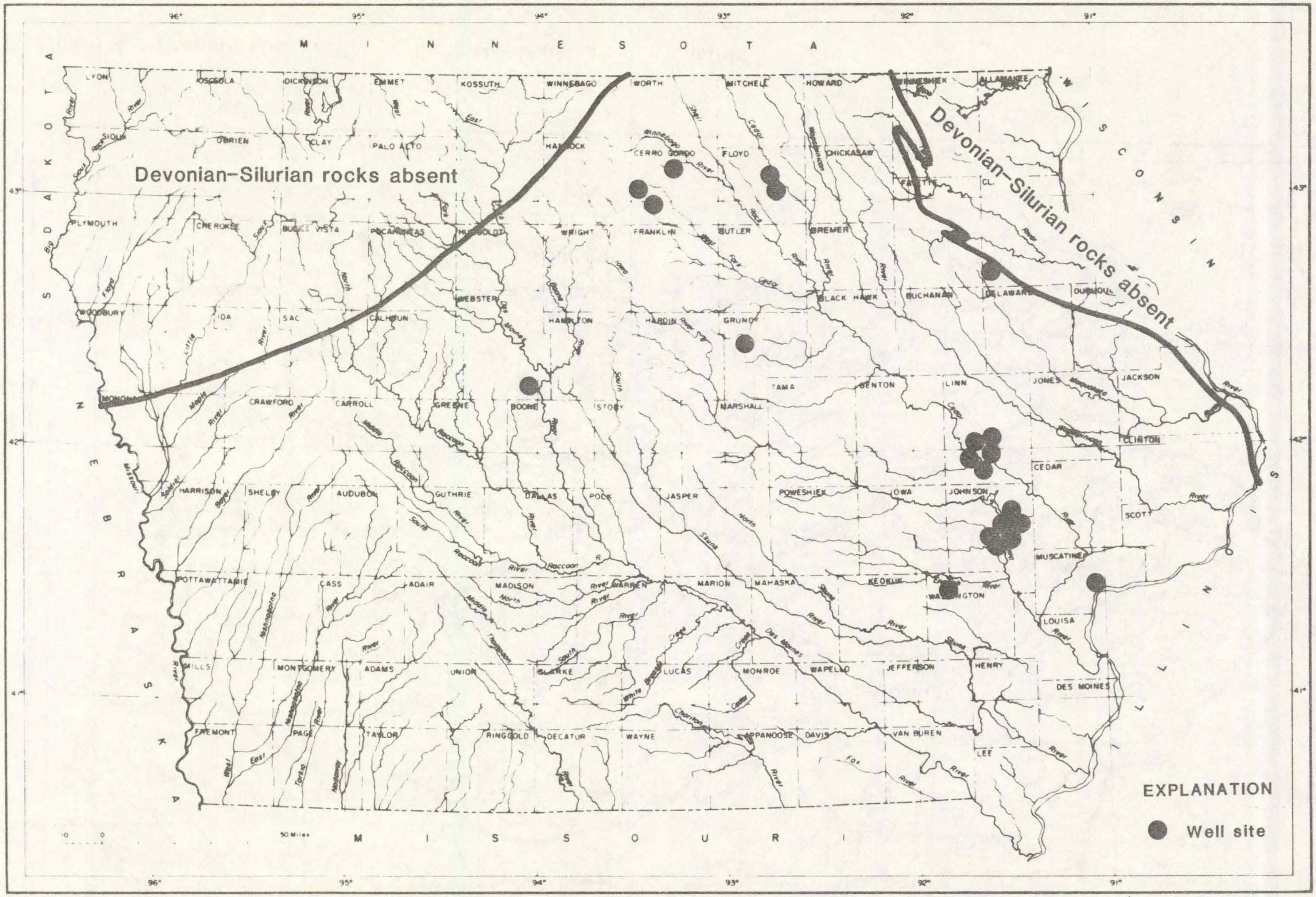


Figure 5.--Present observation wells in the Devonian-Silurian aquifer.

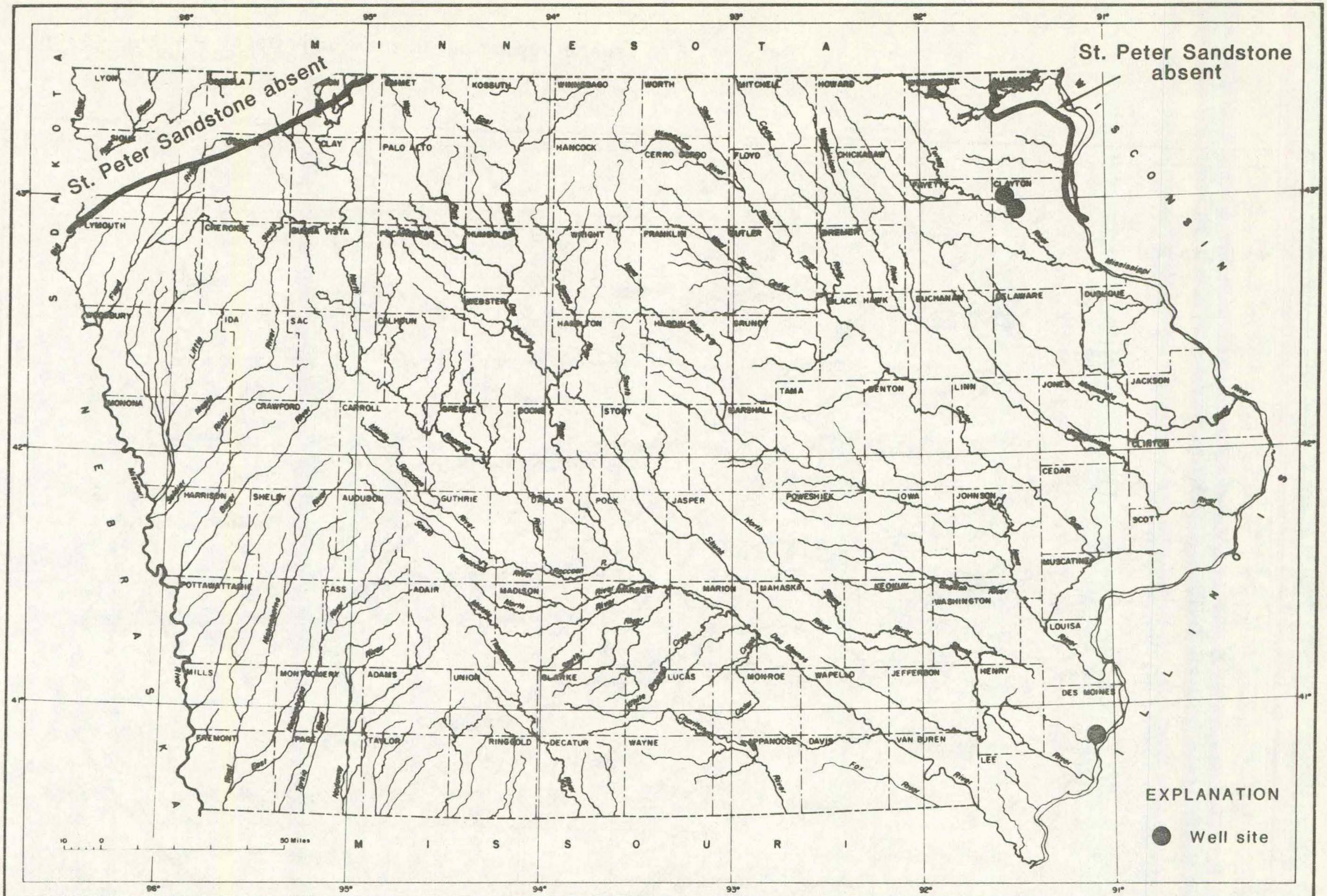


Figure 6.--Present observation wells in the St. Peter aquifer.

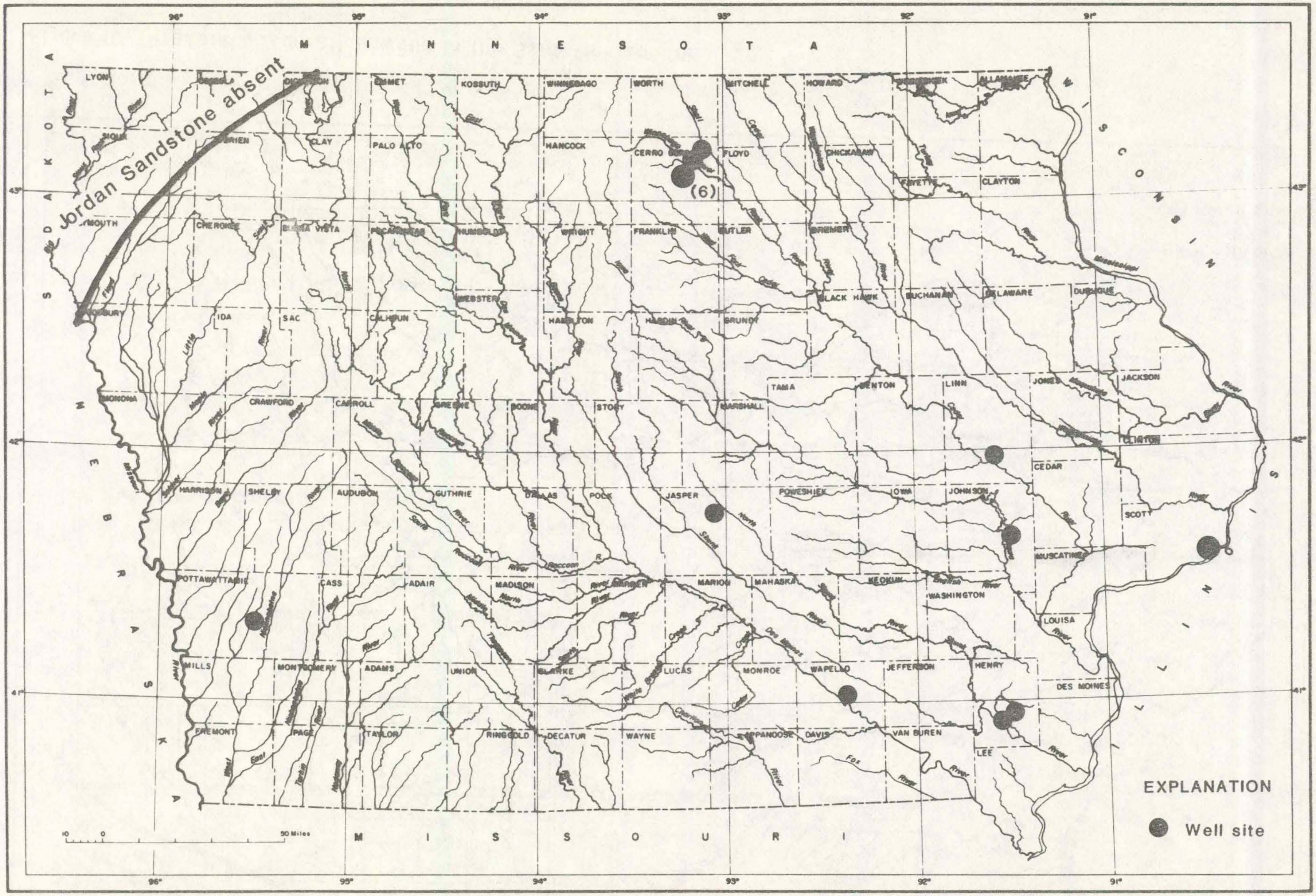


Figure 7.--Present observation wells in the Jordan aquifer.

WELL-NUMBERING SYSTEM

In Iowa the well-numbering system is based on the Bureau of Land Management's system of land subdivision. Each well number is made up of four segments. The first number is the county number (table 2), the second is the township, the third is the range, and the fourth is the section (fig. 8). The letters after the section number, which subdivide the section, are assigned to subdivided quarters in a counter-clockwise direction (beginning with "a" in the northeast quarter), thus the first letter denotes the 160-acre tract, the second the 40-acre tract, the third the 10-acre tract, and the fourth the 2.5-acre tract. Where needed, numbers are added as suffixes to distinguish wells in the same tract.

CLIMATE

Many changes in water levels are directly related to climate. Precipitation recharges the ground-water reservoir and temperature influences evapotranspiration which depletes the reservoir. Precipitation in Iowa varies from 25 inches in the northwest to 35 inches in the southeast (figure 9, Paul Waite, written communication, 1979). Almost 80 percent of this precipitation falls during the normal growing season (April through September, figure 10). Seasonally, temperature directly affects the infiltration rate and indirectly the rate of ground water withdrawal. The annual mean temperature of Iowa ranges from 46 degrees (F) in the north to 53 degrees (F) in the south.

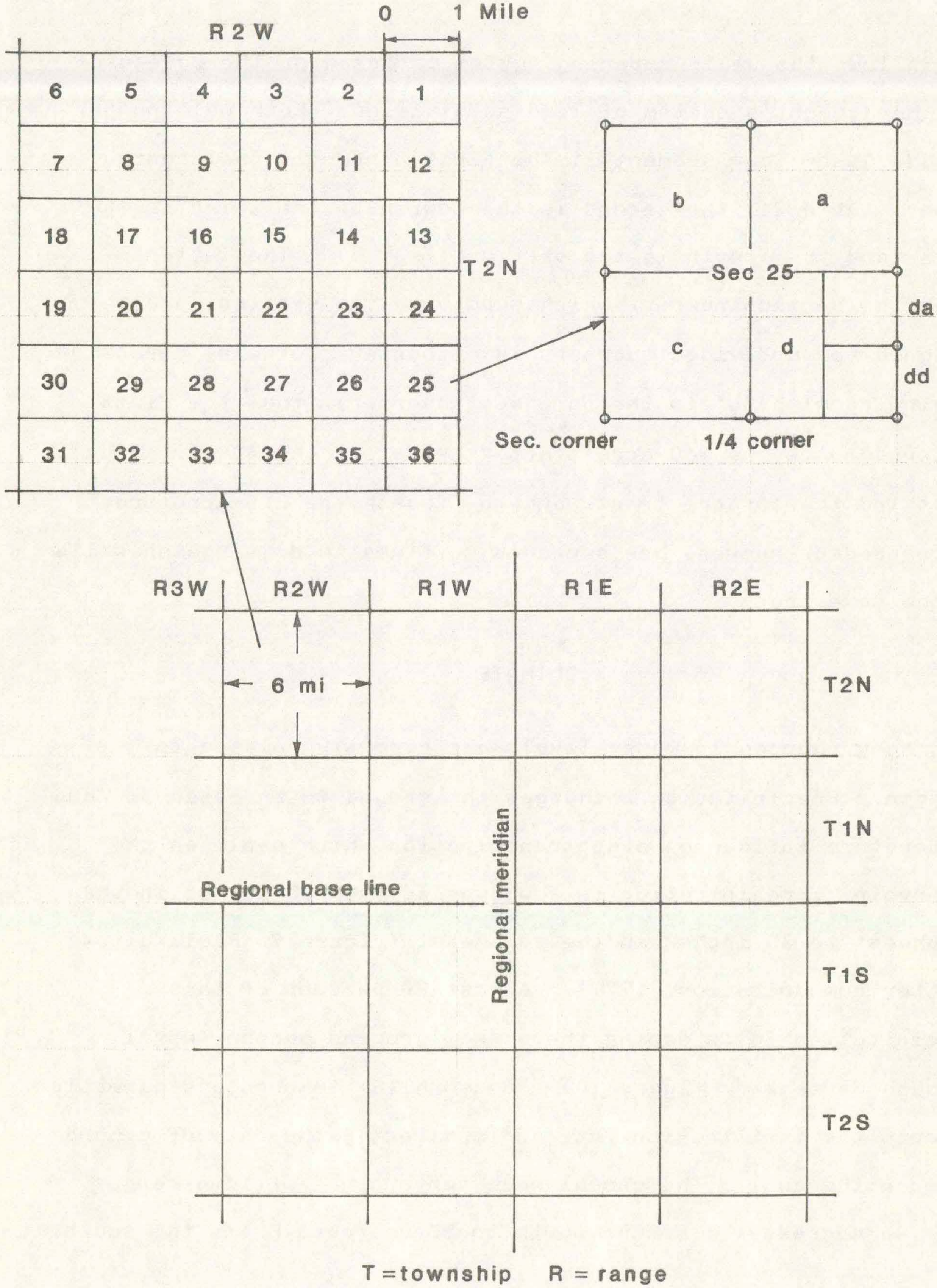


Figure 8.--Division of land by Township and Range.

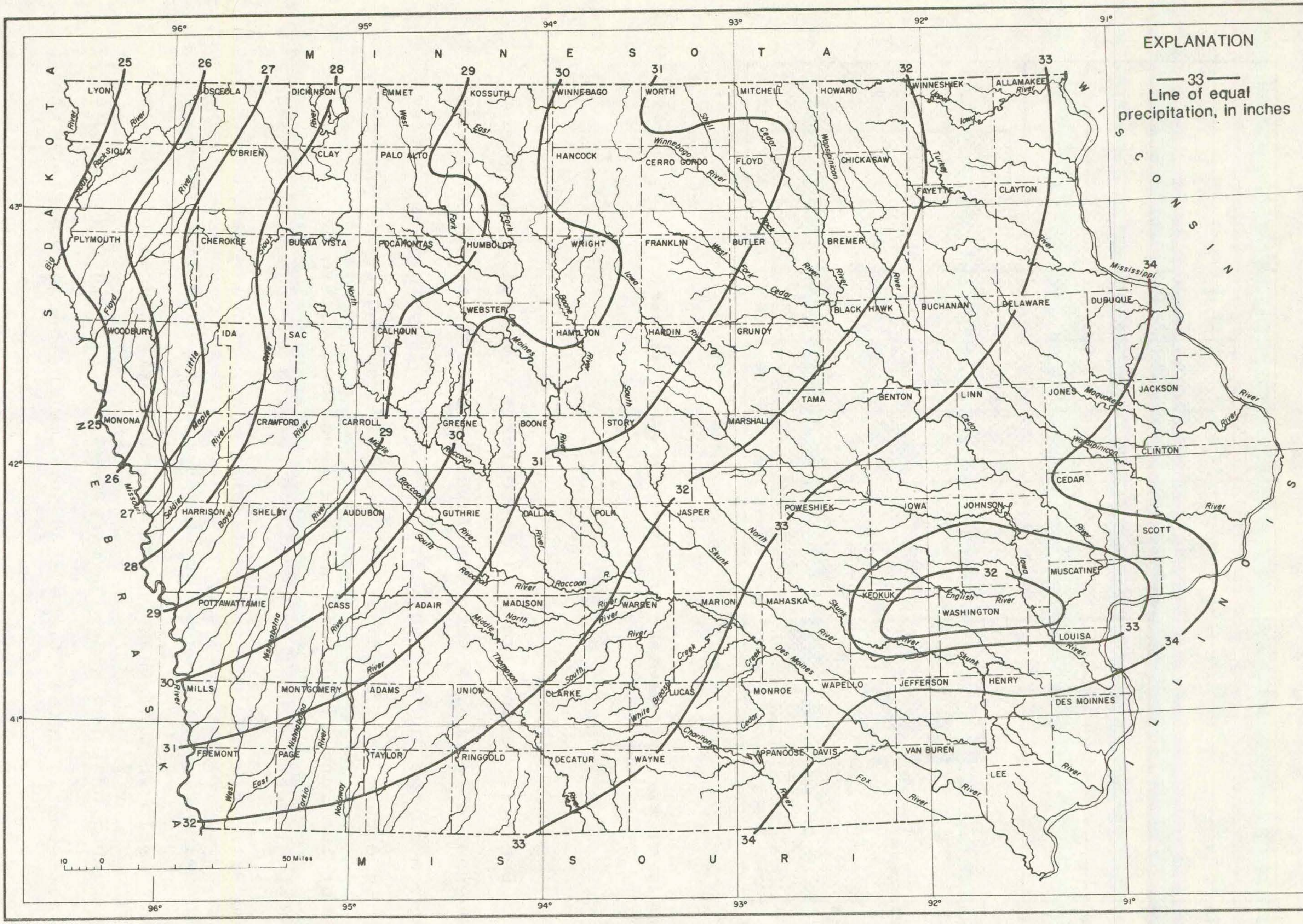


Figure 9. Iowa normal annual precipitation (from Waite, P.J., 1970).

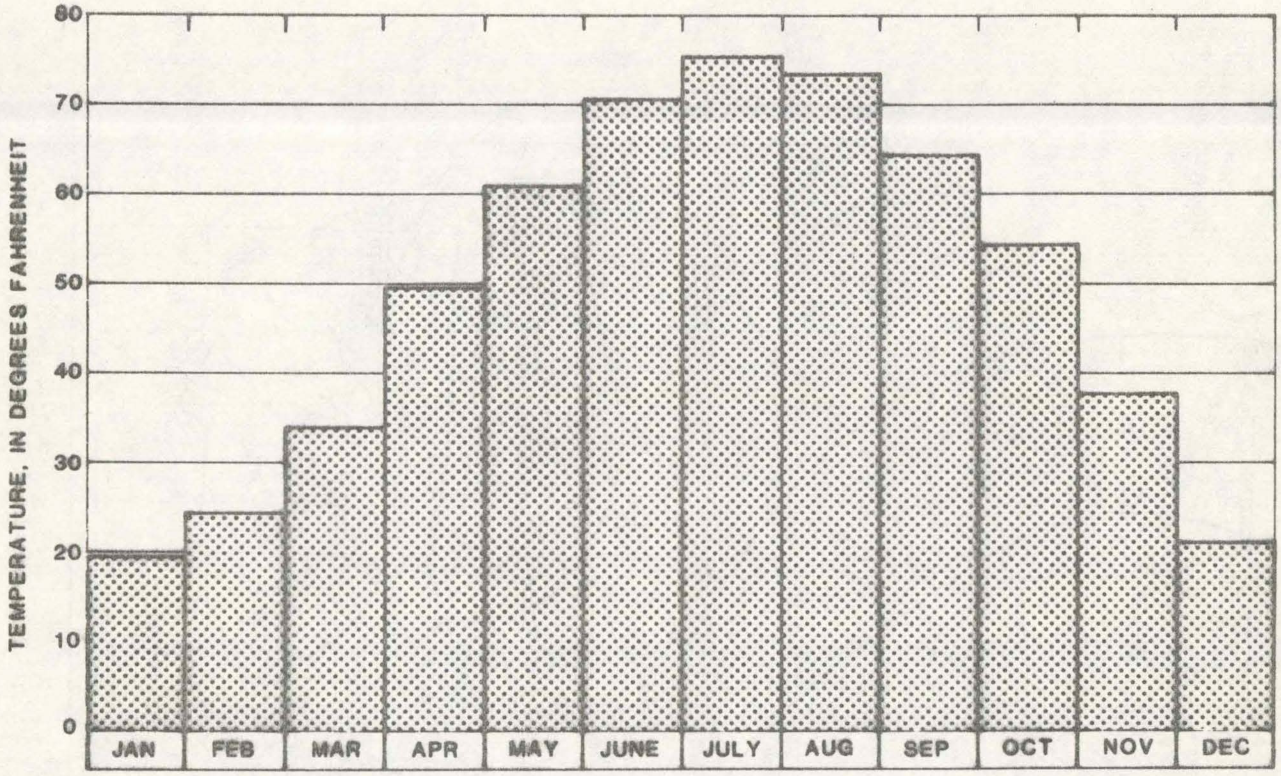


Figure 10.--Monthly mean temperature for 1941-1970 at Des Moines, Iowa

GEOLOGY

Geologic factors control the occurrence, availability, and movement of ground water. In Iowa the base of the ground-water system is the low permeability Precambrian crystalline complex, which occurs at a depth of 5200 feet in southwestern Iowa and is at the land surface in northwestern Iowa (table 3) (Steinhilber and Horick, 1970). Overlying the basement complex are Paleozoic strata of consolidated sedimentary rocks; predominately sandstones, dolomites, shales, and limestones. Over geologic time these rocks have been structurally deformed and erosional processes have exposed Cambrian through Devonian stratigraphic units at the land surface in the northeastern part of the State.

In the northwestern quarter of the State the Paleozoic sediments are unconformably overlain by relatively flat lying sandstones and shales of Cretaceous age.

The erosional surface of the Paleozoic and Cretaceous bedrock was extensively dissected before glaciation occurred during the Pleistocene. Except in a small part of northeastern Iowa, several periods of glaciation overlaid the bedrock with an average of 200 feet of unconsolidated glacial drift and wind deposited loess (Steinhilber and Horick, 1970). The present day stream valleys which are cut into the Pleistocene or into the bedrock generally are underlain by Holocene age alluvial deposits.

HYDROLOGY

Permeable rock zones that contain and transmit water are called aquifers. A well-sorted sand aquifer will usually yield more water to a well than a clayey or silty aquifer. Yield from a limestone or dolomite aquifer is dependent on the number and size of solution openings or fractures intercepted by the well.

Table 3 and Figures 11 and 12 show the six major aquifers in the ground-water system of Iowa, which are: the surficial aquifer, the Dakota aquifer, the Mississippian aquifer, the Silurian-Devonian aquifer, the Cambrian-Ordovician aquifer, and the Dresbach aquifer (Steinhilber and Horick, 1970). In general the Pennsylvanian rocks are principally confining beds, but they do contain some local and subregional aquifers (Cagle and Heinitz, 1978).

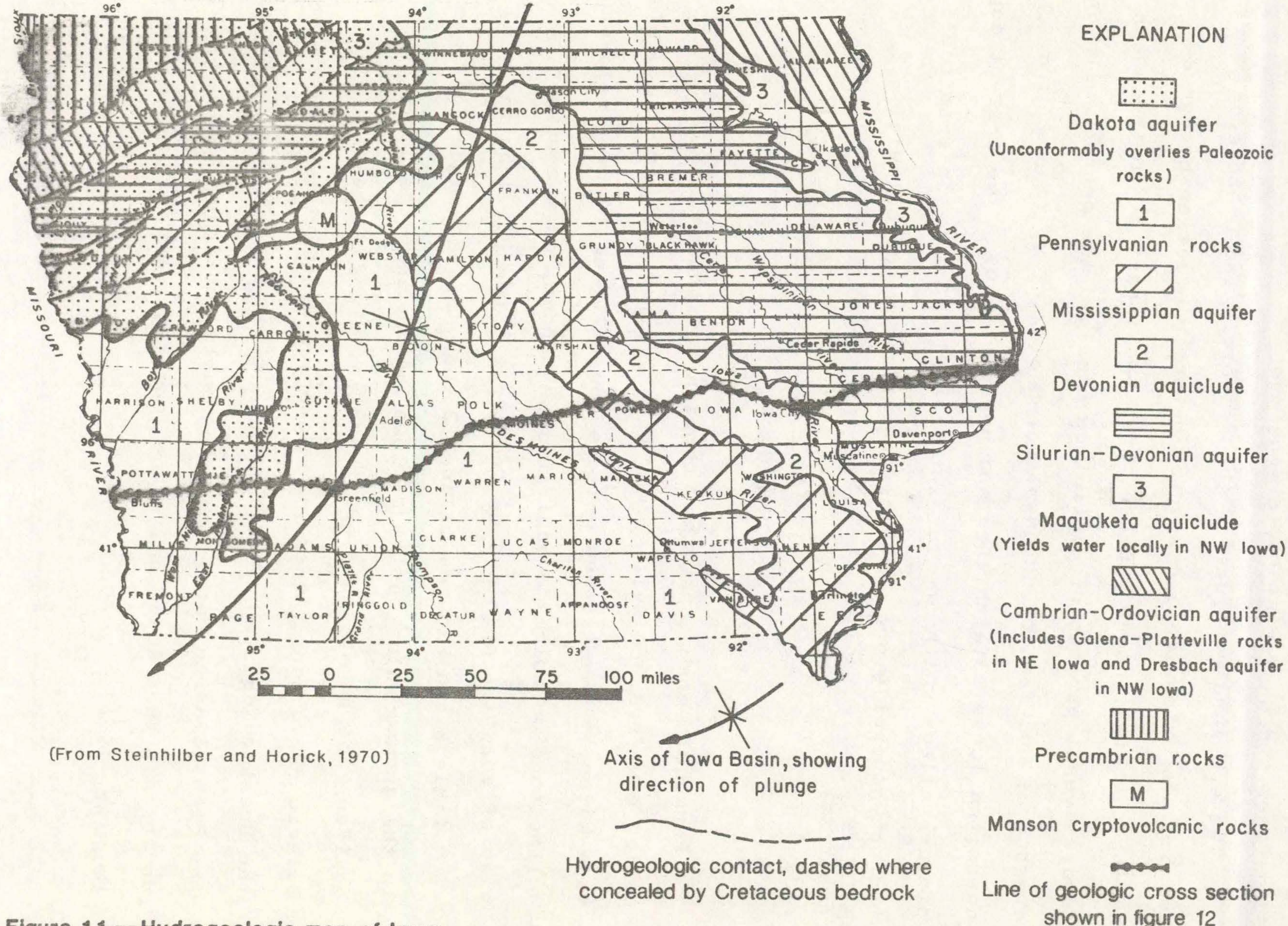
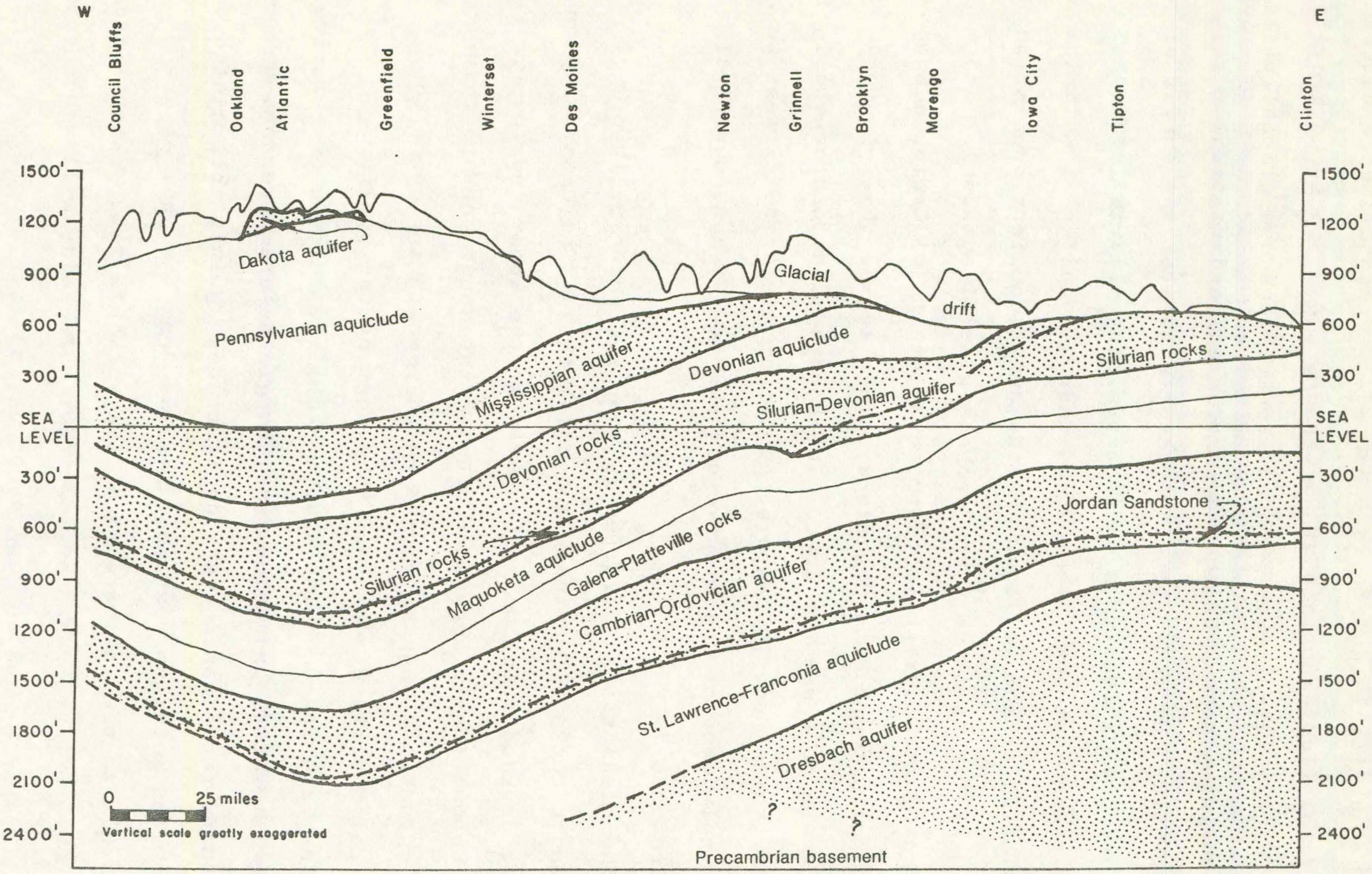


Figure 11.--Hydrogeologic map of Iowa.



(From Steinhilber and Horick, 1970)

Figure 12.--Generalized hydrogeologic section of Iowa.

The surficial aquifer is composed of unconsolidated material of glacial-fluvial origin of Quaternary age. Sands and gravels in the surficial deposits are aquifers; clays and glacial tills are confining beds. On the basis of areal and vertical distribution and water-bearing characteristics, the surficial aquifers are divided into three types; the alluvial aquifers along present streams, the buried channel aquifers in glacial or pre-glacial stream valleys, and the drift aquifers consisting mainly of lenses of sand and gravel (glacial outwash).

The Dakota aquifer is composed of strata of Cretaceous age, principally the Dakota Sandstone. This is the chief bedrock aquifer in northwestern Iowa. The Dakota Sandstone generally is a fine-grained poorly cemented sand that yields sufficient water for rural domestic and stock requirements and many municipal requirements.

The Mississippian aquifer is composed principally of carbonate rocks (limestones and dolomites). The Mississippian can be divided into two main aquifers, the upper and lower. This separation is important because the upper part contains some gypsum and anhydrite beds which seem to influence the chemical quality of water in that part of the aquifer.

The Silurian-Devonian aquifer consists chiefly of relatively dense limestones and dolomites, and yields are dependent on secondary rock opening such as fractures, joints, brecciated zones, and solution openings. Yields from the aquifer are difficult to predict because of the variable size, extent, and frequency of occurrence of openings; but yields will range from 1 gallon per minute to over 4,000 gallons per minute.

The Cambrian-Ordovician aquifer system is the most consistently productive hydrologic unit in the State. The system is predominantly dolomite with two major quartzose sandstone units (the Jordan Sandstone and the St. Peter Sandstone) within it.

The Dresbach aquifer consists of a sequence of coarse to fine-grained sandstones between the Franconia Sandstone and the Precambrian crystalline rocks. The Dresbach Group is divided into three geologic formations (in decending order), the Galesville Sandstone, the Eau Claire Formation, and the Mount Simon Sandstone. The Dresbach is a significant aquifer in a few eastern counties of Iowa.

WATER LEVELS

The water level in a well represents the vertical position of the potentiometric surface at the well site. A number of water-level measurements in wells throughout an area can be compiled on maps, and the water surface can be represented by contours the same way that the land surface is portrayed. Nonpumping water levels in a proposed well can be predicted from these maps.

The configuration of the potentiometric surfaces tells an important story about ground-water movement in an area. Water in each aquifer moves from areas of high head (high contour values) to areas of low head (low contour values) and the general direction of flow is perpendicular to the contour lines. Thus, in an unconfined aquifer water moves through the rock in a direction of flow determined by the slope of the water table and in a confined aquifer water moves in a direction determined by the slope of the potentiometric surface.

Potentiometric maps for some deep aquifers indicate that water is moving regionally and local topography and streams have little or no effect on the direction of movement. These aquifers may recieve a portion of their recharge from outside the State; usually southern Minnesota and South Dakota. Shallower aquifers are affected by local topography because recharge and discharge may take place within the State; often within a drainage basin. Recharge to these aquifers is from local precipitation; discharge is to nearby streams.

The major part of the annual recharge reaches the water-table and shallow artesian aquifers during two periods of the year. The first period is between the spring thaw and the start of the growing season. The second is after the first killing frost in the fall and before the ground is frozen. During these periods part of the precipitation can infiltrate the unfrozen soil, and because plant transpiration activity is low the water can move down to the water table. During the growing season, only infiltration of precipitation in excess of plant demands may reach the saturated zone. Hence, water levels in water-table and shallow artesian aquifers generally are highest in late spring, and are lowest in late summer and early winter. Figure 13 shows water-level fluctuations and precipitation for 1959 and 1960.

A comparison between cumulative departure from mean annual precipitation in Cedar Rapids, Iowa and changes in water levels in the Shaver Park well, also in Cedar Rapids, is shown in figure 14.

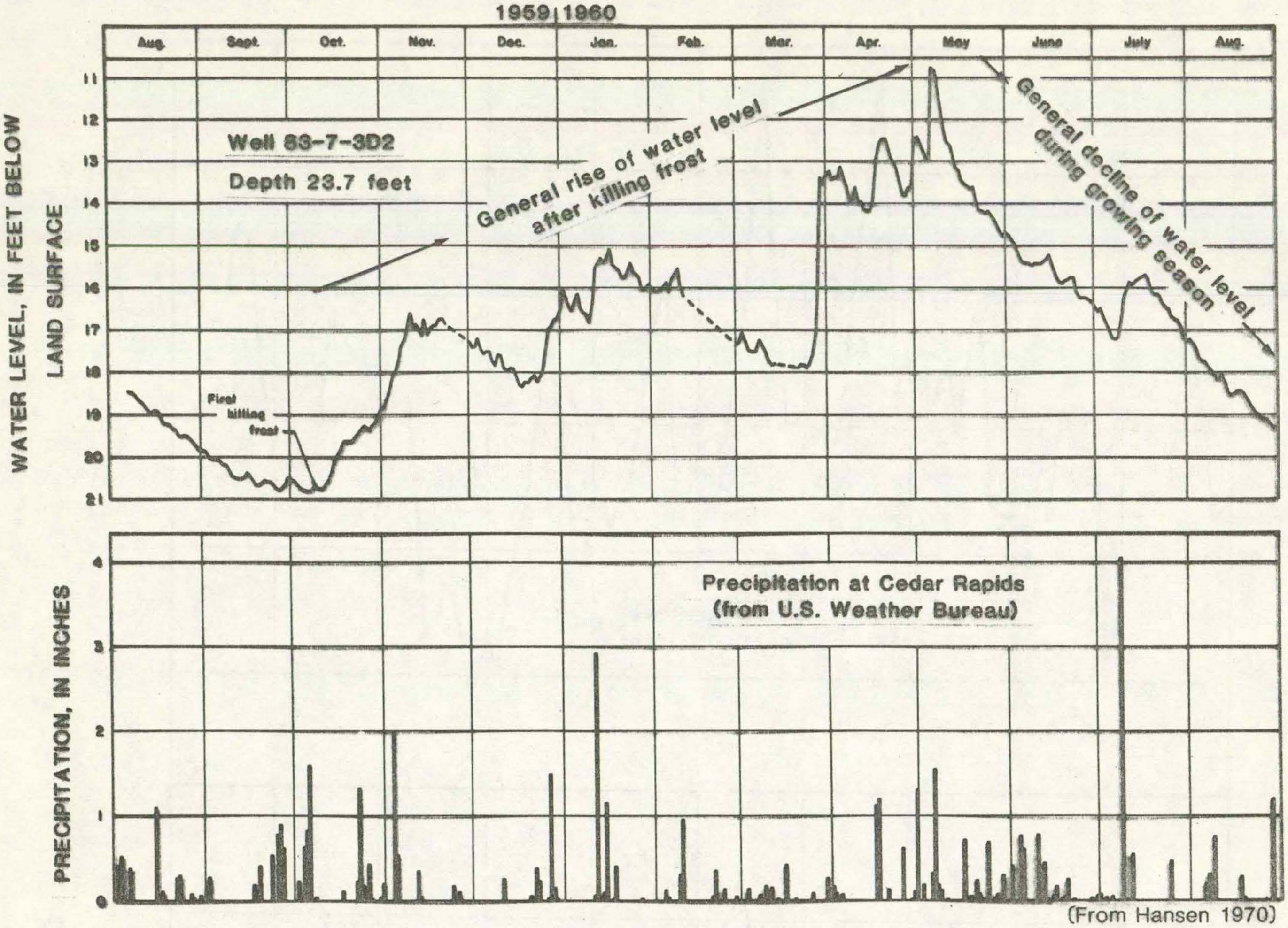


Figure 13.--Relation of water level to precipitation and to the growing season.

During times of drought, the water table generally will decline because natural discharge from the aquifer is a continuous process, while recharge is absent or decreased. Shallow wells may go dry during these periods because the water table is lowered below the bottom of the wells. At the end of the drought, when recharge increases and water levels rise, these "dry" wells will contain water again. Differences in aquifer response to precipitation in artesian and water-table aquifers are shown in figure 15.

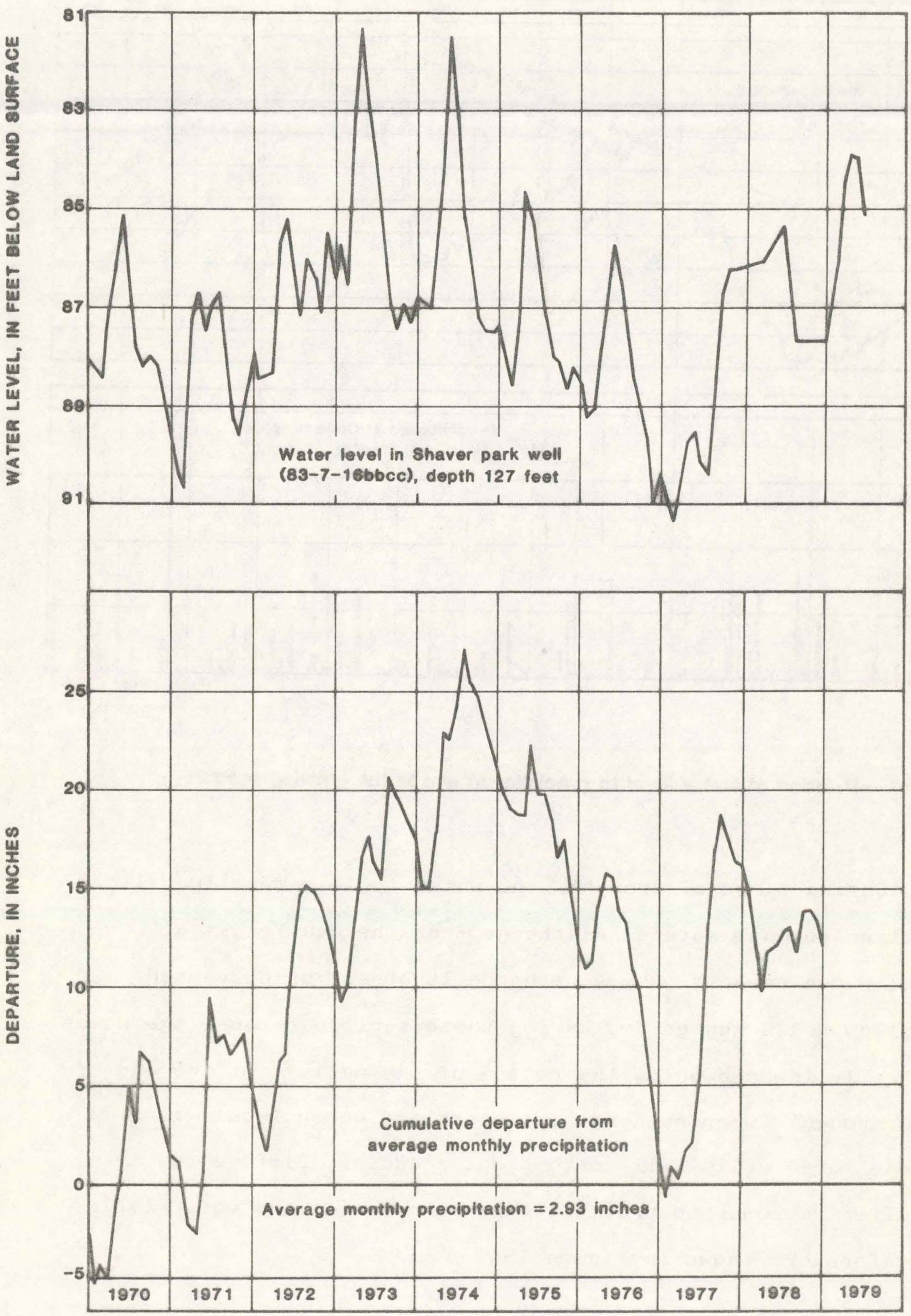


Figure 14.--Water levels and cumulative departure from average precipitation at Cedar Rapids.

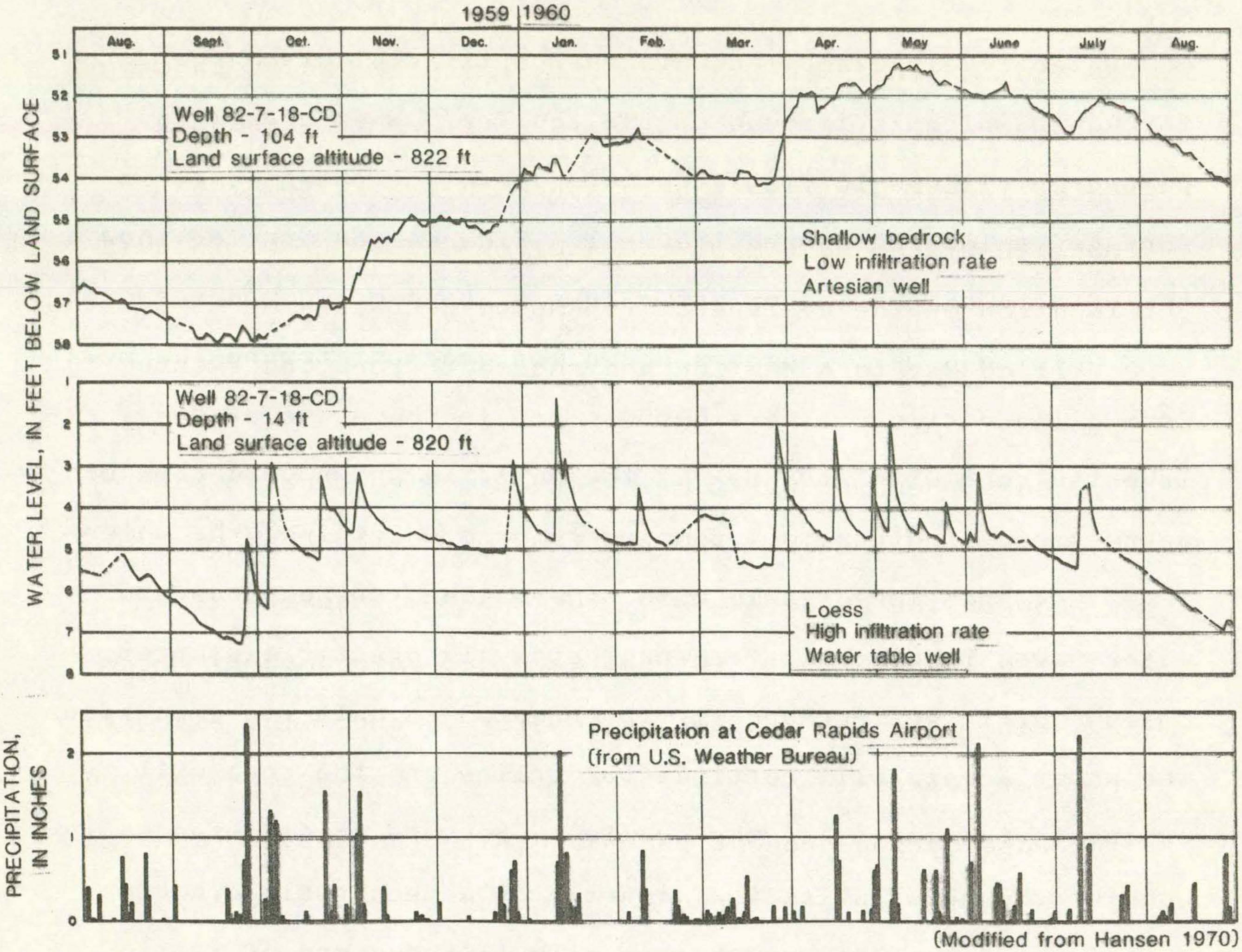


Figure 15.--Comparison between precipitation and effects in shallow (water table) and deep (artesian) wells.

Water levels in artesian aquifers, especially deeply buried aquifers, are only slightly affected by short-term changes in recharge. Primary recharge areas for these aquifers may be tens or even hundreds of miles away. The effects of any variations in precipitation and recharge on the potentiometric surface will be smoothed out because of the distance to the recharge area and the depth of the aquifer. Therefore seasonal and annual fluctuations in the potentiometric surface of deep artesian aquifers that are undisturbed by pumping are less pronounced than those in shallow water-table wells.

Water levels also fluctuate when artificial discharge through pumping is imposed on the aquifer. When a well is pumped or allowed to flow, the water level or potentiometric surface is lowered around the well. Figures 16A and 16B show the effects of pumping on water levels, both daily and seasonal.

Pumping a well causes a hydraulic gradient toward the well from all directions. This depression, in the shape of an inverted cone with its apex at the well, is known as a cone of depression. If a constant pumping rate is maintained the water level declines more slowly with time as the cone expands and water moves to the well from progressively greater distances. Unless sufficient recharge is intercepted to halt its expansion, the water levels will continue to decline and the cone will expand to the limits of the aquifer. Because of differences in aquifer characteristics the diameter of a measurable drawdown cone in an artesian aquifer generally is thousands of feet, whereas the diameter of a water-table cone is generally hundreds of feet.

When two or more pumping wells are located close to each other, their cones of depression are likely to overlap. This overlapping causes increased lowering of water levels due to the combined effects. For this reason, wells pumping large volumes of water from the same aquifer should be spaced some distance apart.

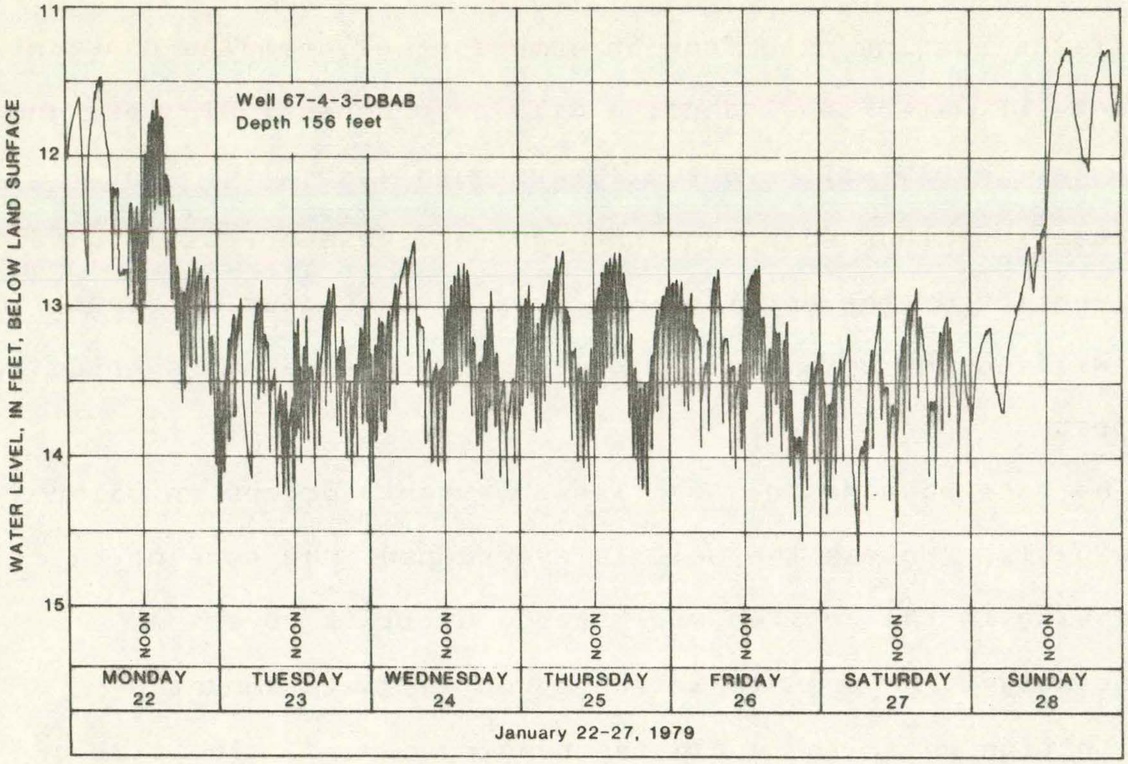


Figure 16a.--Short term water-level fluctuations caused by pumping.

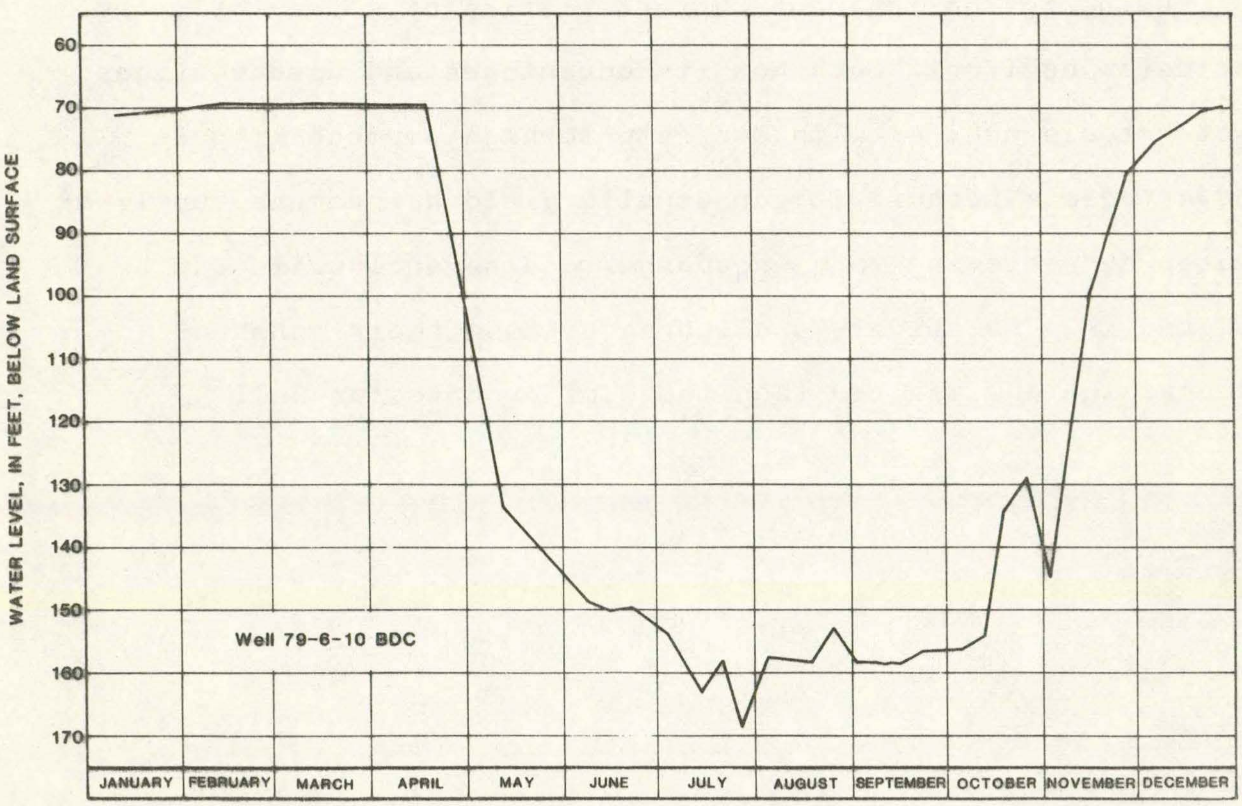


Figure 16b.—Long term water-level flucuations that correspond to the air conditioning season (1978).

If the pumping rate from an artesian well remains constant, the rate of water-level decline will be progressively less and the water levels will eventually approach stability. An increase in withdrawals from the aquifer, however, will cause acceleration of the decline. If pumping decreases or stops, the cone will adjust to a smaller and shallower cone and eventually disappear.

The same phenomenon, to a lesser extent, occurs in water-table wells. Unless the well is overpumped, the cone of depression in the aquifer will spread until it covers a sufficently large area to intercept an adequate amount of infiltrating water to supply the pumping demand. The size of the cone of depression will decrease during wet weather periods, and increase during drought periods due to changes in recharge.

Owing to the inherent characteristics of water-table and artesian aquifers, each has its advantages and disadvantages. A water-table aquifer with moderate-to-high permeability is advantageous because it can usually yield a moderate supply of water by recieving local recharge, and several wells can be placed in a relatively small area because their cones of depression are smaller than those of an artesian well.

One disadvantage is that a water-table aquifer is responsive to local short term changes in weather. In contrast, artesian aquifers have the advantage of not being greatly affected by short term trends in the weather but wells generally must be more widely spaced.

Earthquakes often have short term affects on water levels. Effects of Alaskan earthquakes have appeared on hydrographs in Iowa several times. An Alaskan earthquake of magnitude 8.6 on March 27, 1964 affected all major aquifers in the State. Coble (1965) noted; "Aquifers responded to the earthquake waves by 1) the seismic fluctuations on some recorder charts; 2) turbid water in some wells and springs, probably caused by the disturbance and movement of silts, clays, and colloidal particles within the aquifers; and 3) a permanent change; either a rise or a fall of the water level." Permanent water-level changes of up to 50 feet were noted.

On February 28, 1979 an Alaskan earthquake of magnitude 7.7 occurred. This event affected the water levels in Iowa with fluctuations of up to 1.42 feet (figure 17). No permanent changes in water levels were noted indicating that no long term deformation of the aquifer took place.

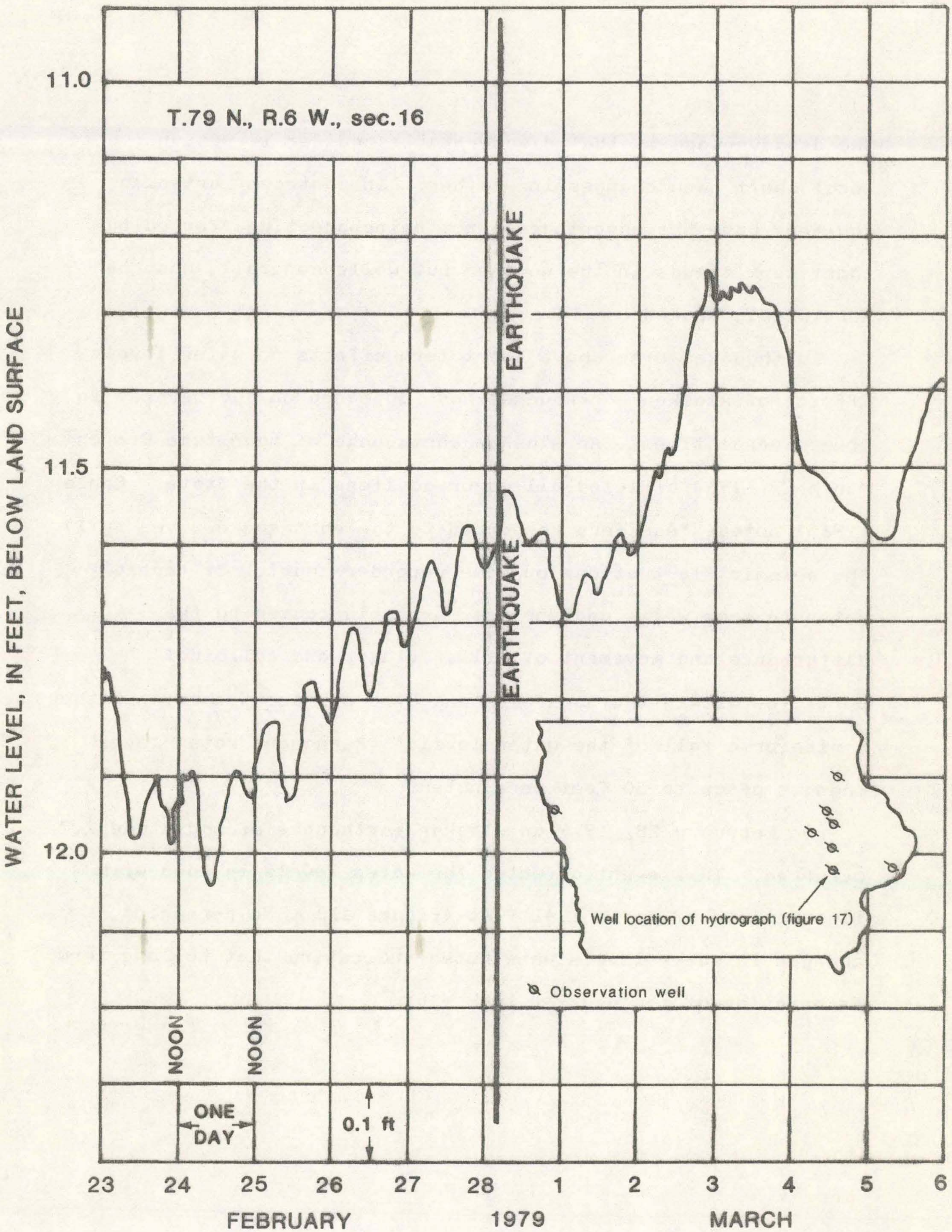


Figure 17.--Water-level fluctuation caused by Alaskan earthquake.

RECOMMENDATIONS

The addition and deletion of individual observation wells improves the efficiency of the water-level network. The wells presently being measured give a good portrayal of the potentiometric surface for most water-bearing systems, although some aquifer systems lack sufficent observation wells to give the total picture.

Only four wells penetrating alluvial aquifers are measured. All of these are in the southwestern corner of the State; three in the alluvium along the Missouri River and one in the alluvium along the East Nishnabotna River. Alluvial aquifers exist in many other areas throughout the State, suggesting the need for many more alluvial wells and a more even distribution.

The well network for the glacial drift aquifer presents the best distribution for an aquifer system in Iowa. Some wells in the drift aquifer that are presently being measured probably could be discontinued unless their location relative to other key observation wells warrant their continuation.

Seven observation wells in the Cretaceous System show the potentiometric surface of this confined aquifer system very well. A current detailed study of the system probably will result in a revised and enlarged observation well network.

The Mississippian aquifer network demands the most attention because of the lack of observation wells. Only two wells represent the aquifer which is present throughout two-thirds of the State. More wells should be added to this system for a more accurate depiction of the potentiometric surface.

The Silurian-Devonian aquifer system is not adequately covered in many parts of the State. Wells are needed in many areas where the Silurian-Devonian is not the first bedrock under the glacial drift. These wells would be deeper than average wells, thus, it is hard to find existing wells and expensive to drill new wells. The concentration of five wells in Linn County and four in Johnson County (figure 5) are necessary to define the cones of depression in the Cedar Rapids and Iowa City areas and these wells should be continued.

The St. Peter aquifer also needs more observation wells. Two additional observation wells in the western part of the State would probably suffice. Again availability of an existing well and the expense of drilling a new well is a problem.

Water users in many large pumping centers in the State depend on the Jordan aquifer. The southeast part of the State and the Mason City area have very good observation well coverage for the aquifer. An additional well should be added in the northwest at some distance from population centers so the aquifer can be monitored where it is unaffected by pumping.

The observation well network is relatively effective in its present condition in that it gives, in most cases, good quality data for a limited amount of effort. Additional wells will mean additional time and increased costs; however; additions should be considered. The addition of wells in key locations would benefit the network and enable the water resources of Iowa, on a broader scope, to be more accurately evaluated. Persons having knowledge of unused wells or wells about to be abandoned should contact the USGS regarding the use of these wells as possible observation wells.

SUMMARY AND CONCLUSION

Ground-water levels have been collected and recorded in Iowa since 1935. Between 1935 and 1979 water levels for about 450 different observation wells were collected.

Water levels for wells that have been or are being deleted from the active list of observation wells still could be useful to private individuals, government agencies, and private consultants dealing with specific ground-water problems. Future generations that face increasing depletions of ground-water resources will need historical records for management decisions. These are some of the reasons that a list of present and past observation wells needed to be compiled and maintained.

Sufficient water-level data is being collected in certain areas for certain aquifers. Many aquifers, however, do not have adequate observation wells to understand and monitor ground-water resources. The observation well network therefore should be reevaluated on a continuing basis and wells added or deleted to maintain the data base. The water-level information collected will allow a better understanding of a vital, dynamic resource that is often taken for granted.

SELECTED REFERENCES

Ground-water levels and artesian pressures have been published periodically in the U.S. Geological Survey Water Supply Papers series (WSP), since 1935 and in the Annual Water Resources Data for Iowa, since 1975 as indicated below.

Year	Publication
1935	WSP 777
1936	WSP 817
1937	WSP 840
1938	WSP 845
1939	WSP 886
1940	WSP 908
1941	WSP 939
1942	WSP 946
1943	WSP 988
1944	WSP 1018
1945	WSP 1025
1946	WSP 1073
1947	WSP 1098
1948	WSP 1128
1949	WSP 1158
1950	WSP 1167
1951	WSP 1193
1952	WSP 1223
1953	WSP 1267
1954	WSP 1323
1955	WSP 1406
1956	WSP 1456
1957-61	WSP 1781
1962-66	WSP 1976
1967-71	WSP 2090
1972-74	WSP 2163
1975	ANNUAL REPORT
1976	ANNUAL REPORT
1977	ANNUAL REPORT
1978	ANNUAL REPORT
1979	ANNUAL REPORT

Cagle, J. W., and Heintz, A. J., 1978, Water resources of south-central Iowa: Iowa Geological Survey Water Atlas no. 5, 97 p.

Coble, R, W., 1965, The effects of the Alaskan earthquake of March 27, 1964 on ground water in Iowa: Iowa Academy of Science, v. 72, p. 323-332.

Devaul, R. W., 1967, Trends in ground-water levels in Wisconsin through 1966: The University of Wisconsin Geological and Natural History Survey, Information Circular no. 9, 109 p.

Hansen, R. E., 1970, Geology and ground-water resources of Linn County, Iowa: Iowa Geological Survey Water Supply Bulletin no. 10, 66 p.

Russell, R. R., 1963, Ground water levels in Illinois through 1961: Illinois State Water Survey, Report of Investigation 45, 51 p.

Steinhilber, W. L., and Horick, P. J., 1970, Ground-water resources of Iowa: in Horick, P. J., ed., Water resources of Iowa, Iowa City, University Printing Service, p. 28-49.

Wahl, K. D., and others, 1978, Water resources of east-central Iowa: Iowa Geological Survey Water Atlas no. 6, 91 p.

Table 1--Present and Past Observation Wells in Iowa

Explanation

The first number (NO) is a list reference number. The county number (CO) is the standard number determined by it`s alphabetical position in the list of counties in the State. Numbers under (T, R, and S) are the township, range, and section of the well`s legal location within the State. The letters under (QQ) are the quarter section subdivisions of location as described on page 11. The name given (NAME) is that recorded when the well was measured and has not been updated for changes in ownership. The diameter of the well (DIAM) is in inches. The depth of the well (DEPTH) is in feet. The aquifer numbers and names (AQUIF) are those used by the USGS Watstore System consisting of a code number and key letters from the geologic unit name. A list of names may be obtained by contacting the U.S. Geological Survey. The years the well has been measured (YR MEAS) are inclusive of the two dates given. Those showing a second date of 99 are currently part of the water-level network.

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
2	1	75	30	3CC	PHILLIPS		73		42	43
3	1	75	30	8AA	SNETHEN		30	112DRFT	40	44
4	1	75	30	17BCB	ROBERT	12	26	110QRNR	41	76
5	1	75	31	15AB	SODERBERG		15	112DRFT	40	49
6	1	75	31	18AB	GILHAM		36	112DRFT	40	49
7	1	76	31	21DD	BREHENY		40	112DRFT	41	42
8	1	76	31	21DD	BREHENY	26	349	217DKOT	40	41
9	1	76	31	25DD	BOCHART		20	112DRFT	40	49
10	1	76	31	25CB	UNKNOWN	26	349	112	42	47
11	1	76	31	29BD	MUTUAL BENF LIFE	36	21	112DRFT	42	55
12	1	77	33	5BA	USGS	1	37	112DRFT	49	49
13	1	77	33	8BC	USGS	1	20	112DRFT	49	49
14	6	85	10	16CB	VINTON	16	1508	JRDN	40	55
15	11	90	37	3BC	SCHMIDT		15	QRNR	40	49
16	11	90	37	3CB	WATT		24	QRNR	40	48
17	11	90	37	11DA	USGS		6	QRNR	40	45
18	11	90	37	22DA	MONTEFUL		51	QRNR	40	45
19	11	90	37	23BB	BIGGINS BROS		29	QRNR	41	49
20	11	90	37	34ABB	ED ZINN	36	29	110QRNR	40	74
21	11	91	37	32BC	STORM LAKE		21	QRNR	40	47
22	13	88	33	1AB	KUTZ;VOSS	14	105	112DRFT	40	55
23	13	88	33	1BB	VOSS	8	105	112DRFT	40	55
24	13	89	32	28CC	LAIRD	15	11	112DRFT	40	74
25	13	89	32	31DD	LEGG		50	QRNR	40	44
26	13	89	32	33CC	BURNS	8	30	112DRFT	40	55
27	13	89	32	33BD	STATE CON COMM	8	53	112DRFT	48	99
28	14	84	34	25BD	CARROLL				40	40
29	14	84	35	25BDDB1	CITY OF CARROLL 1	8	120	217DKOT	39	99
30	14	85	35	7CCC	CITY OF BREDA	10	340	217DKOT	41	99
31	14	85	35	18BB	CITY OF BREDA	9	350	217DKOT	40	69
32	16	80	2	6BB	TIPTON	8	1000	3600DVC	49	52
33	17	94	19	3CC	UNKNOWN				42	44
34	17	94	19	16DD	KELSH				42	44
35	17	94	19	21CD	HOGAN ESTATE				42	44
36	17	94	19	25CC	UNKNOWN				42	44
37	17	94	20	3CA	CITY ROCKWELL				42	44
38	17	94	20	5CD	CONRIN				42	44
39	17	94	20	22AD	CURLEY				42	44
40	17	94	20	25DB	EQUITABLOF IA INS				42	44
41	17	94	20	25DB	EQUITABLOF IA INS				42	44
42	17	94	21	5DD	SCHONEMAN				42	44
43	17	94	21	10BB	UNKNOWN				42	44
44	17	94	21	24AA	TITUS MFG CO				42	44
45	17	94	21	28DD	SCHOOL DIST				42	44
46	17	94	22	8BB	DUGAN				42	44
47	17	94	22	20BB	WOHLER				42	44
48	17	94	22	24DB	UNKNOWN				42	47
49	17	94	22	24DB2	TOWN OF THORNTON	8	290	344CDVL	42	47
50	17	94	22	24DB3	BOWEN	4	120	DVNN	42	44
51	17	94	22	24DA	UNKNOWN	10	34	112DRFT	42	51
52	17	94	22	34CC	MESERVEY	6	125	330MSSP	58	61
53	17	95	19	9AD	UNKNOWN				42	44
54	17	95	19	18DA	UNKNOWN				42	44
55	17	95	19	26BB2	NATIONAL LF INS				42	44

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
56	17	95	19	30CD	UNKNOWN				42	44
57	17	95	19	30CD	UNKNOWN				42	44
58	17	95	20	3AB	FARM COOP SOC				42	44
59	17	95	20	5DB	HUNT				42	44
60	17	95	20	13CC	SCHOOL DISTRICT				42	44
61	17	95	20	20BA	UNKNOWN				42	44
62	17	95	20	27DC	UNKNOWN				42	44
63	17	95	20	33BA	IA ST COLLEGE				42	44
64	17	95	21	2AD	HOUCK				42	44
65	17	95	21	7BB	COMM OF INS OF IA				42	44
66	17	95	21	7CD	ENOBNIT				42	44
67	17	95	21	12BB	UNKNOWN				42	44
68	17	95	21	27DCDD	BLANKENSHIP;BONNER	5	115	341LMCK	41	99
69	17	95	22	3ABBA	KNUT OLSON	4	134	341LMCK	41	99
70	17	95	22	5DA	SCHOOL DIST				42	47
71	17	95	22	8BA	JURGENSEN BROS				42	47
72	17	95	22	19DD	UNKNOWN				42	45
73	17	95	22	22BA	MILES				42	44
74	17	95	22	34BC	LINDEN				42	44
75	17	96	19	3DA	UNKNOWN				42	44
76	17	96	19	18DD	CHIC MILW ST PL PAC				42	44
77	17	96	19	18DD	BILLINGS				42	44
78	17	96	19	27BC	INDEP ORDER FORESTER				42	44
79	17	96	19	31CD	THOMPSON				42	44
80	17	96	20	3CDBD	MINN+ST LOUIS RR	12	805	364STPR	42	77
81	17	96	20	3CB	MASON CITY	26	349	112DRFT	41	47
82	17	96	20	3CAB	MASON CITY 7	20	1230	371JRDN	69	99
83	17	96	20	3CAB	MASON CITY 8	12	1225	371JRDN	69	99
84	17	96	20	3CAB	MASON CITY 9	20	1281	371JRDN	69	99
85	17	96	20	3BDC	MASON CITY 10	20	1243	371JRDN	69	99
86	17	96	20	5DB	UNKNOWN				42	44
87	17	96	20	10CC	SWIFT+CO	36	815	364STPR	42	44
88	17	96	20	15AAA	MASON CITY 14	20	1297	371JRDN	68	99
89	17	96	20	16DAA	MASON CITY 11	20	1306	371JRDN	39	74
90	17	96	20	16ADA	MASON CITY 12	30	1539	371JRDN	69	99
91	17	96	20	17DAAD	STATE BRAND CREAMERY	20	1336	371JRDN	68	99
92	17	96	20	29AA	KIRK				42	44
93	17	96	20	33AA	MASON CITY				42	44
94	17	96	20	36CC	UNKNOWN				42	44
95	17	96	21	2AC	SKOVGAARD				42	44
96	17	96	21	5AC	FARM NAT LF INS				42	44
97	17	96	21	7CD	BATTLEMAN		20	QRNR	40	41
98	17	96	21	13BCCB1	MAS CITY CL LK RR	5	198	340DVNN	40	99
99	17	96	21	17BA	CLEAR LAKE SAND GVL	8	22	110QRNR	40	73
100	17	96	21	17CB	KENNEDY	24	5	112DRFT	40	53
101	17	96	21	18AD	KENNEDY	12	14	112DRFT	40	53
102	17	96	21	19CC	HARMS				42	44
103	17	96	21	22AA	MABB				42	44
104	17	96	21	23DD	THRAMS				42	44
105	17	96	21	33AA	TOFT				42	44
106	17	96	22	7DC	OVERGAARD			QRNR	42	47
107	17	96	22	7DC	OVERGAARD 2				42	47
108	17	96	22	12CD	DARC		53	QRNR	40	45
109	17	96	22	14AB	ADAMS		46	QRNR	40	45
110	17	96	22	14BA	STEPHENS	6	227	DVNN	40	47

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S	QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
111	17	96	22	20	CADC	BOINE+ELDER	5	130	112DRFT	40	99
112	17	96	22	20	BA	THE WILLOW INN		10	112DRFT	40	55
113	17	96	22	20	CADC	BSA; BAIN & ELDER	5	126	112DRFT	40	77
114	17	96	22	23	DC	ANDERSON		33	QRNR	40	49
115	17	96	22	25	BB	USGS	1	9	QRNR	40	54
116	17	96	22	30	AD	SKENE				42	44
117	17	96	22	30	AD	SKENE 2				42	44
118	17	97	19	5	CC	CHIC MILW ST PL PAC				42	44
119	17	97	19	16	AD	UNKNOWN				42	44
120	17	97	19	21	AD	ENGSTRON				42	44
121	17	97	19	23	AD	SENIOR				42	44
122	17	97	19	30	DD2	STEBENS	36	16	110QRNR	41	75
123	17	97	20	11	BB	SLOAN				42	44
124	17	97	20	17	CC	UNKNOWN				42	44
125	17	97	20	24	AD	SHANKS	36	79	112DRFT	42	54
126	17	97	20	27	BB	QUIMBY				42	44
127	17	97	20	28	CAAC	AMERICAN CRYSTAL SUG	20	1347	371JRDN	37	99
128	17	97	20	32	AD	UNKNOWN				42	42
129	17	97	21	9	BC	PHILLIPS	5	206	341SLCK	41	69
130	17	97	21	18	DA	HURD				42	44
131	17	97	21	18	DA	HURD 2				42	44
132	17	97	21	25	DD	ETNA LF INS				42	44
133	17	97	22	9	AD	ZOBEL				42	44
134	17	97	22	21	CC	FANKELL				42	44
135	17	97	22	21	CC2	FANKELL				42	44
136	17	97	22	22	CC	HENNIS				42	44
137	17	97	22	36	AD	KERN				42	44
138	17	97	22	36	AD	KERN 2				42	44
139	18	92	40	26	CD	CHEROKEE				40	47
140	21	96	35	2	CD	MONSELLE		48	QRNR	40	40
141	21	96	35	3	DD	WILSON	48	8	112DRFT	40	61
142	22	91	5	30	BBBB	KNIGHT	36	36	112DRFT	57	99
143	22	91	6	22	ACAC	STRAWBERRY PT 2	7	160	350SLRN	63	99
144	22	91	6	22	ACAB	BOWMAN	36	18	112DRFT	57	99
145	22	91	6	22	AC	STRAWBERRY POINT				57	63
146	22	94	4	4	CA	DRAHN		100	GLEN	41	43
147	22	95	4	22	BCBD	MIELKE	6	493	364STPR	57	99
148	22	95	4	32	DDDD	MEIER	6	380	264STPR	57	99
149	23	81	-7	6	DB	BURPEE		1180	SLRC	40	49
150	23	81	-7	7	AB	CLINTON	8	1763	370CMBR	45	55
151	23	81	-6	22	AB	DUPONT		2150	MSMN	40	49
152	25	81	28	8	AD	DAVISON CHEM	1	10	112DRFT	54	56
153	25	81	28	8	AC	DAVISON CHEM	1	10	112DRFT	54	56
154	25	81	28	9	BD	DAVISON CHEM	1	19	112DRFT	54	56
155	25	81	28	9	BC	DAVISON CHEM	1	11	112DRFT	54	56
156	27	69	25	29	DD	GASSET		30	QRNR	40	47
157	28	89	5	29	DB	MANCHESTER	12	197	350SLRN	49	55
158	29	69	3	6	AABA	IA ORDNCE PLT 3	16	1205	364STPR	50	99
159	29	69	3	6	DDCD	IA ORDNCE PLT 2	19	675	330MSSP	50	99
160	30	99	36	6	AC	MILLER	16	34	112DRFT	40	55
161	31	89	-3	7	DC	DUBUQUE	8	1306	370CMBR	47	55
162	32	99	31	31	DB	CHIC&NW RR	6	31	QRNR	42	42
163	32	99	32	10	BC	BIRNEY		28	QRNR	42	44
164	32	99	34	14	AB	CITY OF ESTERVILLE	20	408	217DKOT	40	47
165	32	100	32	11	DD	OKAMANPEDEN ST PK	6	277	217DKOT	39	99

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S	QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
166	34	95	15	7	CC	SALSBURY LABS	6	16	344CDVL	77	99
167	34	95	15	7	CC	SALSBURY LABS	6	65	344CDVL	77	99
168	34	95	15	7	CC	SALSBURY LABS	6	355	350SLRN	77	99
169	34	95	15	7	CC	SALSBURY LABS	1	80	344CDVL	77	99
170	37	83	30	8	CBB	CITY OF JEFFERSON	12	2307	371JRDN	60	76
171	38	88	18	15	DBBA	WELLSBURG		280	340DVNN	60	99
172	40	86	25	5	BC	STANHOPE	10	601	MSSP	39	39
173	40	86	25	5	BC2	STANHOPE		2200	PRDC	40	40
174	41	94	25	34	CBBB	WEBSTER EXP FARM		18	112DRFT	60	77
175	42	89	20	7	BC	GILBERT				42	44
176	43	78	42	11	DA	MUTUAL BENFT LFE INS		45	QRNR	39	47
177	43	78	42	12	DC	MUTUAL BENFT LFE INS	18	29	QRNR	39	47
178	43	79	41	34	CC	MUTUAL BENFT LFE INS	36	75	QRNR	39	47
179	43	80	41	20	CC	MUTUAL BENFT LFE INS		91	QRNR	39	40
180	43	80	42	11	DC	WOODBINE		92	QRNR	40	47
181	43	81	42	31	BB	MUTUAL BEFIT LFE INS		45	QRNR	39	40
182	44	71	6	9	CBB	MT PLEASANT 2	10	1820	371JRDN	45	77
183	44	71	6	9	CBB	MT PLEASANT 3	16	1896	371JRDN	45	99
184	44	71	6	9	ABA	MT PLEASANT 4	20	1860	371JRDN	46	99
185	44	73	7	4	AAB	WAYLAND	36	50	112DRFT	60	99
186	47	87	39	12	CA	KIETH LAUNDRY&CLEANI		219	217DKOT	39	40
187	47	89	40	35	BB	HOLSTIEN		645	217DKOT	40	50
188	48	80	9	3	CB	UNKNOWN				45	55
189	50	80	17	17	DB	ST CON COMM 8	8	151	325CHRK	47	67
190	50	80	17	17	DB	ST CON COMM 19	7	122	325CHRK	50	69
191	50	80	17	17	CA	ST CON COMM 1	7	94	325CHRK	51	69
192	50	80	17	17	CA	ST CON COMM 2	7	35	325CHRK	50	69
193	50	80	17	17	CA	ST CON COMM 3	7		325CHRK	50	69
194	50	80	17	17	CA	ST CON COMM 4	7	55	325CHRK	50	69
195	50	80	17	17	CA	ST CON COMM 24	7	122	325CHRK	50	69
196	50	80	17	17	CB	ST CON COMM 30	7		325CHRK	50	69
197	50	80	17	17	CB	ST CON COMM 31	7	189	325CHRK	50	69
198	50	80	17	20	BC	ST CON COMM 17	5	110	320PSLV	48	52
199	50	80	17	28	BB	ST CON COMM A2	5	55	325CHRK	48	56
200	50	80	18	31	ABBB	BEUKEMA	36	37	110QRNR	40	99
201	50	80	18	31	BA	UNION CENT LFE INS		38	QRNR	40	46
202	50	80	19	33	AC	HAMMERICK	8	2567	371JRDN	63	99
203	51	72	10	25	AA	FAIRFIELD 1	6	160	112DRFT	49	73
204	51	72	10	26	AA	CARTER				42	50
205	52	79	6	4	AAC	FOREST VIEW TR CT	6	280	350SLRN	71	99
206	52	79	6	7	DAB	SUI HAWK VILLAGE	18	400	350SLRN	71	99
207	52	79	6	9	DDBC	U OF I QUADRANGLE	12	431	350SLRN	75	99
208	52	79	6	10	CCCB	UNIV OF IOWA	26	1550	371JRDN	74	99
209	52	79	6	10	BDBC	U OF I CURRIER	12	425	350SLRN	76	99
210	52	79	6	16	DDAD	GE WAREHOUSE	6	363	350SLRN	72	99
211	52	80	5	9	DB	USGS		13	QRNR	40	47
212	52	80	5	9	CA	SNYDER	18	11	QRNR	40	40
213	52	80	5	9	DBBC	MILLER	1	15	112DRFT	50	99
214	52	80	5	22	CBB	CRI&PRR	48	19	112DRFT	41	99
215	52	80	5	22	CBCB	CRI&PRR	5	82	340DVNN	42	99
216	54	76	10	25		KEOTA		138	QRNR	39	39
217	56	67	4	3	DBAB	FT MADISON SHEAFFER		156	111ALVL	54	99
218	56	67	5	14	BAAD	USGS1	1	13	112DRFT	50	99
219	56	67	5	14	CAAA	USGS 2	1	13	111ALVL	50	74
220	57	82	7	3	AA	REA #2 SOUTH		446	350SLRN	50	64

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S	QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
221	57	82	7	3AA		REA #3 WEST			350SLRN	57	74
222	57	82	7	3AA		REA #1 NORTH		434	350SLRN	50	74
223	57	82	7	18CDCD		PETRAK		14	112DRFT	59	99
224	57	83	6	30ABBC		KATZ	6	77	DVNN	40	99
225	57	83	7	1AB		MARION	12	437	350SLRN	41	55
226	57	83	7	2CD		HOLLENBECK	6	52	340DVNN	40	63
227	57	83	7	6AB		SCHIMPER ESTATE				40	42
228	57	83	7	11BC		MARESH				42	49
229	57	83	7	11BC		MARESH 2				42	42
230	57	83	7	16BBDC		CEDER RAPIDS SHAVER	5	127	340DVNN	40	99
231	57	83	7	16DA		CEDAR RAPIDS DANIELS	5	163	340DVNN	40	55
232	57	83	7	17CADA		CEDER RAPIDS ELLIS	5	98	340DVNN	40	99
233	57	83	7	21DC		MERCHANT NAT BANK		400	350SLRN	69	76
234	57	83	7	21DC		CEDER RAPIDS GAZZETT		1450	371JRDN	68	78
235	57	83	7	21CB		CEDAR RAPIDS				42	47
236	57	83	7	21DC		KRESGE			350SLRN	42	53
237	57	83	7	21DC		IA THEATER	10	40	350SLRN	42	51
238	57	83	7	21DB		WAPSI VALLEY CREAM	8	156	350SLRN	43	61
239	57	83	7	21CA		CEDAR RAPIDS	10	1450	371JRDN	40	49
240	57	83	7	23AC		CEDAR RAPIDS BEVER P	5	81	340SLRN	40	54
241	57	83	7	24AA		ZRUDSKY	4	96	340DVNN	40	55
242	57	83	7	28AD		COLLINS		280	350SLRN	60	76
243	57	83	7	28AB		PARMOUNT THTER		428	350SLRN	69	74
244	57	83	7	28ADDA		KACENA		420	350SLRN	62	99
245	57	83	7	28AC		CEDAR RAPIDS GAS				40	47
246	57	83	7	28BA		IA ILL LT & PO CO			371JRDN	55	76
247	57	83	7	32ACDC		FELTER	5	282	350SLRN	40	99
248	57	83	7	33BD		MIELL	5	107	340DVNN	40	76
249	57	84	6	20CC		USGS	3	12	112DRFT	40	55
250	57	84	6	22BD		WISSLER	30	11	112DRFT	40	55
251	57	84	7	11DD		BURNS	12	29	112DRFT	48	54
252	57	84	7	13BCBB		USGS	3	17	112DRFT	40	99
253	57	84	7	13BC		RINDERKNECHT	6	140	350SLRN	40	45
254	57	85	6	19DB		USGS	3	9	112DRFT	40	55
255	57	85	6	26BB		USGS	3	14	112DRFT	40	76
256	57	85	6	29AB		BALDERSON	5	147	112DRFT	40	55
257	57	85	6	30BB		WITWER				40	49
258	58	75	4	18DA		RATH PACKING	12	1530	371JRDN	68	71
259	60	98	48	24CB		HANSON	24	25	QRNR	39	47
260	60	99	43	11AA		UNKNOWN	10	9	QRNR	42	47
261	60	99	44	26DDD		ST OF IOWA	20	38	112DRFT	40	99
262	60	99	44	26DD		UNKNOWN				40	43
263	60	99	45	5ABAC		ROCK RAPIDS		375	217DKOT	60	99
264	61	75	26	23AAA		ST. CHARLES		1058	330MSSP	62	99
265	61	75	28	2ABB		NEWTON	24	32	112PLSC	40	76
266	61	76	26	26BD		UNKNOWN				42	43
267	62	74	14	14AD		FREMONT		140	MSSP	39	39
268	63	74	20	2DA		UNKNOWN				42	45
269	63	74	20	16DA		WENDALL				42	47
270	63	74	20	22BA		DEWITT	48	32	112DRFT	42	73
271	63	74	20	33BB		BEEBOUT	24	29	112DRFT	40	76
272	63	74	21	11BD		MELCHER	18	25	112DRFT	45	57
273	63	74	21	11DA		MELCHER	10	95	112DRFT	45	67
274	63	74	21	11AA		RIDDEL	12	26	112DRFT	42	47
275	63	74	21	11DBCC		MELCHER 2	18	25	112DRFT	50	99

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
276	63	74	21	11DBCC	MELCHER 3	6	119	112DRFT	45	99
277	63	74	21	11CAA	MELCHER 5	6	101	112DRFT	53	99
278	63	74	21	15AD	UNKNOWN				42	47
279	63	74	21	26BC	GRIESBAUM ESTATE				42	42
280	63	75	20	22AD	UNION CEN LF INS	60	15	112DRFT	42	47
281	63	75	20	31BBAD	ELLIOTT	15	28	112PLSC	40	77
282	63	76	19	5CC	KNOXVILLE 4	40	47	111ALVL	49	55
283	63	77	18	34BA	LAUNPBAUGH		119	MSSP	39	39
284	64	82	17	24BB	GILLMAN	2	23	112PLSC	52	55
285	64	84	18	24CDCA	MARSHALLTOWN	8	200	112PLSC	49	99
286	69	71	36	6DAD	TEMPLETON	1	38	112DRFT	50	99
287	69	71	36	6DB	ST OF IOWA	1	38	112DRFT	50	74
288	69	71	36	21DD	CITY VILLISCA				42	45
289	69	71	37	8DB	OAKLEAF	12	49	QRNR	36	46
290	69	71	38	11DD	HOLQUIST	36	28	112DRFT	34	53
291	69	71	38	24BA	BERGREN		17	QRNR	37	47
292	69	71	38	27AC	SWANSON		31	QRNR	37	37
293	69	71	38	35BC	USGS # 79	3	29	112DRFT	37	55
294	69	71	38	35AB	MAINQUIST	3	18	112DRFT	37	55
295	69	71	38	35AB	UNKNOWN				37	64
296	69	72	37	4CC	STONELLING	12	22	QRNR	35	45
297	69	72	37	29BA	USGS # 82	3	40	QRNR	37	99
298	69	72	38	24DC	MILNER	3	25	112DRFT	37	52
299	69	72	38	25BB	#73		27	QRNR	37	47
300	70	76	2	10BC	USGS BDR#2	6	154	344CDVL	66	73
301	70	76	2	10DA	GRAIN PROCESSING COR	1	45	110QRNR	49	73
302	70	76	2	14BBCB	USGS	6	154	344CDVL	66	99
303	70	76	2	14BB	MUSCATINE #4	2	39	111ALVL	39	55
304	70	76	2	15AA	MUSCATINE #5	2	32	111ALVL	40	56
305	70	76	2	30CBAA	USGS X-FARM	6	29	111ALVL	66	76
306	71	94	40	22AC	MEIER				42	44
307	71	94	40	22DB	ILL CENTRAL RR				42	43
308	72	99	41	18BA	SIBLEY		18	QRNR	39	47
309	73	67	38	20DC	NORDHOLM	36	20	112DRFT	34	66
310	73	67	38	21BA	METROPOLITAN LF INS	12	29	112DRFT	34	99
311	73	68	38	7CCA	TOFT 5	12	44	112DRFT	34	78
312	73	68	38	17DB	RUNYON				37	37
313	73	68	38	19DD	HASKINS	36	33	QRNR	35	47
314	73	68	38	29BA	METROPOLITAN LF INS	3	18	112DRFT	37	76
315	73	68	39	35DA	SMITH	12	50	112DRFT	35	35
316	73	69	36	31CA	CITY CLARINDA				42	47
317	73	69	37	20CB	WINDHORST	36	63	112DRFT	34	64
318	73	69	37	20CB	WINDHORST	12	58	112DRFT	34	76
319	73	69	38	18CC	SLICKERVEER	12	50	112DRFT	34	76
320	73	69	38	30AC	SNYDER	3	20	112DRFT	37	55
321	73	69	38	30AD	SNYDER	30	23	112DRFT	37	55
322	73	69	38	33BD	MILLER				37	38
323	73	69	38	34AB	BURTON	1	35	112PLSC	37	76
324	73	69	39	25DD	GOODNER		27	QRNR	37	38
325	73	69	39	25DD	GOODNER 61		23	QRNR	37	38
326	73	69	39	25DD	GOODNER 60		32	QRNR	37	38
327	73	69	39	25DD	DO 68		27	QRNR	37	38
328	73	69	39	25DD	DO 67		27	QRNR	37	38
329	73	69	39	25DD	DO 66		16	QRNR	37	38
330	73	69	39	25DD	DO 65		16	QRNR	37	38

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S QQ	NAME	DIAM	DEPTH	AQUIF	YR MEAS
331	73	69	39	25DD	GOODNER 64		20	QRNR	37 38
332	73	69	39	25DD	DO 63		21	QRNR	37 38
333	73	69	39	35AC	NORDSTROM 58				37 49
334	73	69	39	35AC	NORDSTROM 57				37 49
335	73	69	39	35AC	NORDSTROM 56		39	QRNR	37 43
336	73	69	39	35AC	DO 55		37	QRNR	37 43
337	73	69	39	35AC	DO 54		39	QRNR	37 43
338	73	69	39	35AC	DO 52		39	QRNR	37 45
339	73	69	39	35AC	DO 51				37 55
340	73	69	39	35AC	DO50		35	QRNR	37 43
341	73	69	39	35AC	DO 49		38	QRNR	37 43
342	73	69	39	35AC	DO 48		78	QRNR	37 39
343	73	69	39	35AC	DO 46		27	QRNR	37 39
344	73	69	39	35AC	DO 45		34	QRNR	37 53
345	73	69	39	35AC	DO 44	6	30	112DRFT	38 67
346	73	69	39	35AC	DO 43		31	QRNR	37 45
347	73	69	39	35AC	DO 42		38	QRNR	37 45
348	73	69	39	35AC	DO 41		34	QRNR	37 39
349	73	69	39	35AC	DO 40		38	QRNR	37 39
350	73	69	39	35AC	DO 39		42	QRNR	37 45
351	73	69	39	35AC	DO 38		40	QRNR	37 45
352	73	69	39	35BB	DO 87	3	25	110QRNR	38 76
353	73	69	39	35BB	DO 86	3	27	112DRFT	38 76
354	73	69	39	35BB	DO 84	3	28	112DRFT	38 75
355	73	69	39	35BB	DO 83	3	33	112DRFT	38 76
356	73	69	39	35AB	NORDSTROM #47	3	27	112DRFT	37 65
357	73	70	37	17DD	PALMQUIST 11	12	26	112DRFT	34 76
358	73	70	37	17DA	DO 10	12	40	112DRFT	34 71
359	74	96	34	6DA	ELECTRIC PK	18	20	112DRFT	43 70
360	74	97	34	29CC	UNKNOWN	20	8	112DRFT	42 51
361	74	97	34	29CC2	UNKNOWN	4	11	112DRFT	42 49
362	74	97	34	30DC	BROADWELL	48	25	112DRFT	40 59
363	74	97	34	32CD	ZORT ISLAND ST PK				42 43
364	75	91	48	19CB	TRACY	4	352	217DKOT	39 47
365	77	78	22	6BB	SE POLK SCH		2557	371JRDN	64 74
366	77	78	24	4CD	KRESGE	12	58	111ALVL	43 76
367	77	78	25	10CC	WEST DES MOINES	12	33	112DRFT	51 55
368	77	78	25	10CDDD	W DES MOINS 1		2460	371JRDN	73 74
369	77	78	25	15B	W DES MOINS 2		2482	371JRDN	71 74
370	77	79	22	22AA	REED	36	39	112PLSC	40 76
371	77	79	24	24AC	FORD MOTOR		2424	371JRDN	63 76
372	77	80	24	14CDD	ANKENY CITY 5		2580	371JRDN	73 74
373	77	80	24	23BAA	ANKENY CITY 4		2175	371JRDN	73 74
374	78	74	43	18BCCC	USGS 18EI	1	16	111ALVL	51 99
375	78	74	44	13DA	MANAWA	1	13	111ALVL	51 70
376	78	74	44	16CBCD	CORP OF ENGERS	6	37	111ALVL	51 99
377	78	74	44	23DAAB	USGS 23JI	1	14	111ALVL	51 99
378	78	74	44	23CD	CORP OF ENGERS				51 69
379	78	75	39	11BABA	NORTHERN NAT GAS	24	3183	371JRDN	76 99
380	79	78	15	1DD	HARDING				43 55
381	81	86	36	2BA	CHRISTIAN				42 55
382	81	86	36	2BD	CULVER				42 51
383	81	86	36	3AD	BLACKHAWK LK PRSVE				42 43
384	81	86	36	4CCD	ST CON COMM	36	10	111ALVL	40 76
385	81	87	37	21AA	OGREN	5	13	112DRFT	42 55

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
386	81	89	38	11DB	UNKNOWN	27	39	112DRFT	42	47
387	81	89	38	26AA	SCHALLER	10	352	217DKOT	40	99
388	82	78	-5	3AADA	LECLAIR	12	1607	371JRDN	79	99
389	84	95	45	5AA	CITY SIOUX CENTER	5	456	217DKOT	42	66
390	84	95	45	17AA	CITY MAURICE				42	42
391	85	83	24	2DCA	AMES	20	110	112DRFT	54	99
392	85	83	24	4DC	ISU	12	2250	371JRDN	39	55
393	85	83	24	4DD	IOWA ST COLLEGE	36	33	112DRFT	42	55
394	85	83	24	17DD	AGRONOMY FARM		229	PSLV	39	39
395	85	83	24	20DAD	AG ENG EXP	36	38	112DRFT	39	76
396	86	82	13	13DD	BELLE PLANE	8	29	112DRFT	45	55
397	86	85	15	3BA	FOUR MILE CR 1				66	69
398	86	86	15	33BA	FOUR MILE CREEK	4	28	112DRFT	66	69
399	86	86	15	33BA	DO 2	4	317	340DVNN	66	69
400	90	72	13	29CBCC	MORELL 9		1900	371JRDN	74	78
401	90	72	13	30DDBA	MORELL 6	20	1930	371JRDN	75	78
402	90	72	13	30DDBA	MORELL 7	20	1906	371JRDN	75	77
403	90	72	13	30DADB	MORELL 8	20	1900	371JRDN	75	99
404	90	72	14	24DC	IGS	1	23	112DRFT	55	55
405	90	72	14	25BA	OTTUMWA	1	17	112DRFT	51	55
406	91	76	25	8DC	IOWA ST COLLEGE	36	30	112DRFT	42	56
407	91	76	25	17AABA	KELLY	30	40	QRNR	58	76
408	91	77	25	12DD	UNK				42	49
409	92	76	9	31CBB	PEPPER QUARRY	5	136	330MSSP	79	99
410	92	77	9	24AAD	WELLMAN		110	340DVNN	63	99
411	93	67	23	20DC	BRYAN				42	49
412	94	86	27	4BB	DAVIS	5	225	320PSLV	42	55
413	94	86	28	9DD	VAN BLOOM				42	44
414	94	86	28	14ADAB	TOWN DAYTON	13	1240	340DVNN	42	99
415	94	86	29	14AA	CASTENSON	12	39	112DRFT	42	76
416	94	86	30	5BA	MONSON	6	225	320PSLV	42	55
417	94	86	30	12AB	SCHWARTZ				42	44
418	94	87	27	4CC	GOODRICH				42	44
419	94	87	27	18DA	MARSH	6	356	320PSLV	42	53
420	94	87	28	5DC	UNKNOWN	36	27	112DRFT	42	49
421	94	87	28	12AD	UNKNOWN				42	44
422	94	87	28	12DC	TIMMONS				42	47
423	94	87	28	29CC	RYDMAN				59	76
424	94	87	28	29CCCD	SPLANGLER;HELMS	12	42	112DRFT	54	99
425	94	87	29	2CD	BLOMQUIST				42	44
426	94	87	29	24BB	SCHOOL DIST 9				42	44
427	94	87	29	30BB	NORBERG				42	44
428	94	87	30	9AA	CLICK				42	44
429	94	87	30	12CB	TOWN CALLENDER				42	44
430	94	87	30	30DD	SCHOOL DIST 9	14	42	112DRFT	42	49
431	94	88	27	4AA	JONES				42	44
432	94	88	28	12BB	HIVELAY				42	44
433	94	88	29	6AD	UNKNOWN				42	44
434	94	88	29	11BA	MADSON	14	55	112DRFT	42	55
435	94	88	29	23AA	UNKNOWN				42	42
436	94	88	30	5DD	KUSTERER				42	45
437	94	89	27	19CC	SCHARF				42	44
438	94	89	28	16CC	STROMBERG				42	44
439	94	89	28	21DC	LIETCHFRIED	5	150	330MSSP	42	49
440	94	89	28	21DC	DO 2				42	44

Table 1. Present and past observation wells in Iowa (Cont).

NO	CO	T	R	S QQ	NAME	DIAM	DEPTH	AQUIF	YR	MEAS
441	94	89	30	18DB	CAIN	15	35	112DRFT	42	51
442	94	89	30	22DDAA	JOHNSON TWP SCHL	4	208	DKOT	42	99
443	94	90	27	4BB	OLE MAAGE				42	44
444	94	90	27	22CA	RIECHERT				42	44
445	94	90	27	31CCB	KNUDSON		53	112PLSC	42	76
446	94	90	28	1AB	ASKLAND	18	43	112DRFT	42	55
447	94	90	28	8DC	HOVEY		32	112PLSC	42	74
448	94	90	28	15BB	MYRLAND				42	44
449	94	90	28	34DC	MCGILL				42	44
450	94	90	29	25BC	SCHOOL DIST				42	43
451	94	90	30	26AA	CLARE		37	112DRFT	42	56
452	94	90	30	32BB	JONDLE				42	44
453	97	89	47	22BADC	SIOUX CITY	26	343	217DKOT	39	99
454	97	89	48	23AB	SIOUX CITY	21	260	217DKOT	39	45

Table 2

COUNTY CODES

1	Adair	34	Floyd	67	Monona
2	Adams	35	Franklin	68	Monroe
3	Allamakee	36	Fremont	69	Montgomery
4	Appanoose	37	Greene	70	Muscatine
5	Audubon	38	Grundy	71	O'Brien
6	Benton	39	Guthrie	72	Osceola
7	Blackhawk	40	Hamilton	73	Page
8	Boone	41	Hancock	74	Palo Alto
9	Bremer	42	Hardin	75	Plymouth
10	Buchanan	43	Harrison	76	Pocahontas
11	Buena Vista	44	Henry	77	Polk
12	Butler	45	Howard	78	Pottawattamie
13	Calhoun	46	Humboldt	79	Poweshiek
14	Carroll	47	Ida	80	Ringgold
15	Cass	48	Iowa	81	Sac
16	Cedar	49	Jackson	82	Scott
17	Cerro Gordo	50	Jasper	83	Shelby
18	Cherokee	51	Jefferson	84	Sioux
19	Chickasaw	52	Johnson	85	Story
20	Clarke	53	Jones	86	Tama
21	Clay	54	Keokuk	87	Taylor
22	Clayton	55	Kossuth	88	Union
23	Clinton	56	Lee	89	Van Buren
24	Crawford	57	Linn	90	Wapello
25	Dallas	58	Louisa	91	Warren
26	Davis	59	Lucas	92	Washington
27	Decatur	60	Lyon	93	Wayne
28	Delaware	61	Madison	94	Webster
29	Des Moines	62	Mahaska	95	Winnebago
30	Dickinson	63	Marion	96	Winneshiek
31	Dubuque	64	Marshall	97	Woodbury
32	Emmet	65	Mills	98	Worth
33	Fayette	66	Mitchell	99	Wright

Table 3--Geologic and hydrogeologic units in Iowa*

	AGE	ROCK UNIT	DESCRIPTION	HYDROGEOLOGIC UNIT	WATER-BEARING CHARACTERISTICS
Cenozoic	Quaternary	Alluvium	Sand, gravel, silt and clay	Surficial aquifer	Fair to large yields
		Glacial drift (undifferentiated)	Predominantly till containing scattered irregular bodies of sand and gravel		Low yields
		Buried channel deposits	Sand,gravel,silt & clay		Small to large yields
Mesozoic	Cretaceous	Carlile Formation Graneros Formation	Shale	Aquiclude	Does not yield water
		Dakota Sandstone	Sandstone & shale	Dakota aquifer	High to fair yields
Paleozoic	Pennsylvanian	Virgilian Series Missourian Series	Shale & limestone	Aquiclude	Low yields only from limestone & sandstone
		Des Moinesian Series	Shale;sandstones, mostly thin		
	Mississippian	Meramecian Series	Limestone, sandy	Mississippian aquifer	Fair to low yields
		Osagian Series	Limestone & dolomite, cherty		
		Kinderhookian Series	Limestone, oolitic, & dolomite, cherty		
	Devonian	Maple Mill Shale Sheffield Formation Lime Creek Formation	Shale; limestone in lower part	Devonian aquiclude	Does not yield water
		Cedar Valley Limestone Wapsipinicon Limestone	Limestone & dolomite; contains evaporites in southern half of Iowa	Silurian-Devonian aquifer	High to fair yields
	Silurian	Niagaran Series Alexandrian Series	Dolomite, locally cherty		
	Ordovician	Maquoketa Formation	Shale & dolomite	Maquoketa aquiclude	Does not yield water, except locally in northwest Iowa
		Galena Formation	Limestone & dolomite	Minor aquifer	Low yields
		Decorah Formation Platteville Formation	Limestone & thin shales;includes sandstone in SE Iowa	Aquiclude	Generally does not yield water;fair yields locally in SE Iowa
		St. Peter Sandstone	Sandstone	Cambrian-Ordovician aquifer	Fair yields
		Prairie du Chien Formation	Dolomite, sandy and cherty		High yields
	Cambrian	Jordan Sandstone	Sandstone		
		St. Lawrence Formation	Dolomite	Aquiclude (wedges out in NW Iowa)	Does not yield water
		Franconia Sandstone	Sandstone & shale		
		Dresbach Group	Sandstone	Dresbach aquifer	High to low yields
	Precambrian	Sioux Quartzite	Quartzite	Base of ground-water reservoir	Not known to yield water except at Manson cryptovolcanic area
		Undifferentiated	Coarse sandstones; crystalline rocks		

*-The nomenclature and rock classification are those of the Iowa Geological Survey and differ slightly from those of the U.S. Geological Survey.

(modified from Steinhilber and Horick 1970)