ness of the Ordovician above the Saint Peter sandstone be given a minimum of 300 feet, the Saint Peter sandstone would lie at 2755 feet from the surface or 1385 feet below sea level.

Driller's log

	Depth in Feet		Depth in Feet
Yellow clay	0–120	Limestone	895–905
Black mud	120–140	Gray shale	905–920
Blue shale	140–180	Mottled shale	920–1020
Yellow clay	180–200	Gray shale	1020–1080
White limestone, medium soft	200–220	Pink shale	1080–1100
Black shale	220–230	Black shale	1100–1138
Mottled clay	230–250	Sandstone	1138–1163
Red shale	250–270	Black shale	1163–1235
Blue shale	270–290	Sandstone, soft	1235–1265
Blue shale and lime-shells, soft	290–310	Black shale	1265–1280
Red shale	310–330	Soft sandstone	1280–1295
White limestone	330–340	Black shale	1295–1310
Blue shale	340–380	Shale and sand	1310–1330
Gray shale	380–425	Lime	1330–1350
Gray limestone	425–460	Gray shale	1350–1390
Green shale	460–465	Lime	1390–1395
White limestone	465–475	Sandy shale	1395–1465
Blue shale	475–500	Lime	1465–1500
White limestone	500–515	Shale	1500–1510
Black shale	515–525	Lime	1510–1570
White limestone	525–542	Gray shale	1570–1640
Black shale	542–545	Lime	1640–1720
Red shale	545–580	Shale	1720–1785
Blue shale	580–600	Brown lime	1785–1790
Red shale	600–620	Shale	1790–1800
Blue shale	620–640	Hard lime	1800–1880
Limestone	640–645	Lime	1880–1890
Blue shale	645–700	Sandy lime	1890–1900
Mottled shale	700–750	Brown lime	1900–1930
Gray limestone	750–755	Hard lime	1930–2080
Mottled shale	755–780	Brown lime	2080–2108
Blue shale	780–820	No record, except about 4 feet of shale at 2445	2108–2505
Gray shale	820–875		
Mottled shale	875–895		

GRINNELL

(Altitude 1007 feet, C., R. I. & P. Ry)

CITY WELL NO. 5

This well, drilled in 1920 by the Thorpe Brothers Well Company of Des Moines, is 2000 feet deep and its diameters are from 16 to 8 inches. The principal supply was found at 1800 feet in the Shakopee dolomite; other water beds were encountered at 1500 feet in the Galena and at 1900 feet in the New Richmond.

The static level is 250 feet below the surface. The capacity under the air lift is 120 gallons per minute but continuous pump-

ing draws down the head 100 feet. The cost of the well was $32,692.

Samples of the cuttings were carefully saved and the following description by Lees (somewhat abridged) corroborates the records of the earlier city wells.[53]

Record of Strata

	Depth in Feet
Pleistocene:	
Sand and gravel, some limestone fragments, to one-half inch diameter; some quartz and greenstone grains. Possibly represents both glacial gravel and bed rock	200–210
Mississippian:	
Saint Louis limestone and Osage shale—	
Limestone, gray, in fine powder concreted in sample; some clayey residue; 2 samples	210–230
Limestone, light gray, finely crystalline, sugary texture	230–240
Limestone, dark gray, in fragments and powder	240–250
Limestone, dark gray, in fragments and powder, some dark clay	250–260
Limestone, similar to above; 5 samples	260–310
Limestone, fragments of both light and dark gray, finely sugary texture	310–320
Limestone, medium and light gray, in fine powder (at 370 also in small chips); 7 samples	320–390
Kinderhook shale—	
Shale, limy, darker gray than sample above, in very fine powder concreted into lumps	390–400
Shale, in finely gritty blue-gray powder, ready response to acid, but large residue of clay; 5 samples	400–450
Shale, darker gray, in powder and chips	450–460
Shale, rather dark gray, hard, very little or no response to HCl; 9 samples	460–540
Shale, limy, or shaly limestone, medium dark gray, ready response to acid, but large clay residue	550–560
Shale, medium dark gray, no response to acid	560–570
Devonian:	
Limestone, medium dark gray, shaly, finely gritty, large clayey residue; 4 samples	570–610
Limestone, shaly, gritty, dark bluish gray, brisk response to acid, some clayey residue; 8 samples	610–690
Limestone, dark gray, some hard chips, response to acid more brisk than above	690, 700
Limestone, dark gray, in coarse powder and hard, fine-grained chips; 9 samples (in finer powder at 770)	700–790
Silurian:	
Limestone, light gray, in fine gritty powder, concreted	790–800
Limestone, rather dark gray, in coarse powder; 8 samples (some chips at 810, 860 and 870, some fine powder at 840)	800–880
Limestone, gray, small chips, coarse powder; 3 samples	880–920
Limestone, similar to above; some soft white grains; 6 samples	920–980
Limestone, dark gray, some light gray chips; 3 samples	980–1010
Limestone, lighter gray, much powder; gypsum in light blue-gray chips	1010–1020
Limestone, light gray, rather fine powder, and small chips; gypsum in light blue-gray chips	1020–1030
Limestone, light gray, in fine powder, concreted, brisk effervescence in cold acid; some small grains of white and bluish chert	1030–1040

53 Underground Water Resources of Iowa, Iowa Geol. Survey, vol. XXI, pp. 580-582.

Limestone, similar to above, powder quite fine 1040–1050
Limestone, similar to above, considerable clayey residue 1050–1060
Limestone, light gray, with some chips of dark green shale, sample chiefly small chips; 5 samples 1060–1110
Limestone, reddish, very fine-grained, much residue 1110–1120
Limestone, mixed light and dark gray chips, not so much reaction with acid 1120–1130
Limestone, similar to above, brisk reaction to acid; 3 samples 1130–1160
Limestone, dolomitic, fragments light gray, finely crystalline; 3 samples 1160–1190

Ordovician:

Maquoketa shale—

Shale, dark gray, slightly limy; 24 samples (small fragments of pyrite at 1210, no response to acid at 1260, 1270, 1340, 1360, very limy at 1430, with lighter gray lime fragments at 1400-1420) 1190–1430

Galena-Platteville limestone—

Limestone, dolomitic, brownish gray, finely granular powder, almost completely soluble in hot acid; 6 samples 1430–1490
Limestone, ready response to acid, light brownish gray and medium gray; 3 samples 1490–1520
Limestone, gray, dolomitic, considerable residue; 4 samples 1520–1560
Limestone, medium gray, ready response to cold acid; 3 samples 1560–1590
Limestone or dolomite, no response in cold acid 1590–1600
Limestone, dolomitic, similar to above 1600–1610
Limestone, dolomitic, gray, granular texture 1610–1620
Limestone, mingled light and dark fragments, fairly ready response to cold acid 1620–1630
Limestone, dark gray, in small chips and powder, very ready effervescence in cold acid 1630–1640
Shale, greenish, limy, fairly fine texture; some pyrite grains 1640–1650
Limestone, dark gray, in small chips and powder, ready response to acid; 2 samples 1650–1670
Limestone, lighter gray, finer texture than above 1670–1680
Limestone, similar to above, powder a little more gritty 1680–1690
Shale, green, not limy, fine texture 1690–1700
Limestone, gray, in rather fine powder, ready effervescence in cold acid 1700–1710

Saint Peter sandstone—

Sandstone, light gray, almost white, very fine grains, reaction with acid slight, not increased with boiling; 2 samples 1710–1730

Prairie du Chien—

Shakopee dolomite—

Limestone, dolomitic, dark gray, slight reaction in cold acid, vigorous in hot acid; 5 samples 1730–1780
Limestone, dolomitic, light gray, very fine-grained, considerable fine sandy residue; 4 samples 1780–1820
Limestone, dolomitic, light gray, fine powder; 5 samples 1820–1870
Limestone, dolomitic, medium gray, coarser grained than above, considerable white sandy residue, sample in subrounded sparkling granules; 2 samples 1870–1890
Limestone, light gray, ready effervescence in cold acid, large sandy residue 1890–1900

New Richmond sandstone—

Sandstone, coarser and somewhat darker than sample above 1900–1910
Limestone, cream colored, ready response to cold acid; sample similar to 1890-1900 1910–1920
Sandstone, similar to sample at 1900 (*This and the last sample may be reversed*) 1920–1930
Sandstone, small light gray sparkling grains 1930–1940
Sandstone, in fine sparkling grains, mixed light and dark gray; 2 samples 1940–1960

Sandstone, light gray, larger grains than above 1960–1970
Limestone, dolomitic, sandy, lighter colored than sample above; no response to cold acid; some fine sandy residue after treating with hot acid 1970–1980
Oneota dolomite—
Limestone, darker gray than sample above, fine sparkling grains, considerable response to cold acid, increased on heating, some sandy residue 1980–1990
Limestone, similar to sample at 1970-1980, small sandy residue 1990–2006

*Driller's Log**

	Depth in Feet
Pleistocene:	
Black soil	0–2
Yellow clay	2–25
Blue clay	25–41
Yellow sandy clay	41–90
Blue clay, some gravel	90–180
Yellow clay and sand	180–209
Mississippian:	
Saint Louis and Osage—	
Broken limestone	209–214
Shaly limestone	214–240
Limestone, harder	240–246
Shale	246–248
Limestone	248–256
Shale	256–268
Hard limestone	268–400
Limestone, sandy	400–411
Shale	411–425
Kinderhook shale—	
Light blue shale	425–490
Shale, darker	490–530
Shale, light green	530–567
Devonian:	
Limestone, and shale streak	567–594
Shale	594–601
Limestone	601–630
Shale, streak of lime	630–698
Limestone	698–713
Shale and lime	713–734
Hard lime	734–750
Very hard lime	750–774
Hard shale and lime	774–792
Silurian:	
Limestone, light color	792–862
Limestone, brown	862–875
Limestone, light color	875–889
Sandy shale, mixed lime	889–915
Limestone	915–1112
Shale, reddish	1112–1120
Limestone, sandy	1120–1151
Limestone	1151–1197
Ordovician:	
Maquoketa shale—	
Green shale	1197–1220
Shale, light	1220–1233
Chocolate shale	1233–1260
Lime, dark	1260–1263
Shale, dark	1263–1283

* Geological interpretation by Dr. James H. Lees, Asst. State Geologist.

Lime, black	1283–1289
Lime rock, shale streak	1289–1350
Shale and lime	1350–1361
Limestone, some shale	1361–1407
Galena-Platteville—	
Limestone	1407–1560
Limestone, sandy, cuttings washed	1560–1595
Limestone	1595–1649
Shale, green	1649–1652
Limestone, sandy	1652–1690
Shale, green	1690–1696
Sandy lime	1696–1698
Saint Peter—	
Sandstone	1698–1730
Prairie du Chien—	
Shakopee—	
Hard lime, sandy, cutting washed away	1730–1769
Limestone	1769–1839
Sandy lime and sandstone	1839–1860
Sandstone, cuttings washed away	1860–1868
Limestone	1868–1902
New Richmond—	
Sandstone	1902–1979
Oneota—	
Limestone, sandy	1979–1982
Sandstone	1982–1986
Sandy limestone	1986–2006

CITY WELL NO. 6, GRINNELL

This well was completed in 1926 by Thorpe Bros. of Des Moines. The depth is 2500 feet, the diameters from 16 to 10 inches, the latter diameter carried from 444 feet. The principal supply was found at 1700 feet and other water beds were struck at 1900 and 2190 feet. The static level is 258 feet below the curb. Continuous pumping with the air line at 635 feet lowers the water 35 feet. The capacity of the well is 500 gallons or more per minute. Casing is placed as follows: 16 inch to 300 feet, 12 inch from 300 to 444 feet, 9 inch from 444 feet to 1700 feet. The cost of the well was about $50,000.

Record of strata, City well no. 6, Grinnell

As the section of this well parallels that of well no. 5, given above, to the depth of 2006 feet, the footing of the latter well, only the cuttings below that depth are described.

	Depth in Feet
Oneota (120 feet thick; top (at 1970 feet) 942 feet below sea level):	
Dolomite, light cream color, vesicular, in chips	2000–2010
Dolomite, whitish, in fine meal	2010–2020
Dolomite, light cream color, in chips	2020–2030
Dolomite, brown, gray, yellow-gray and buff, cherty; 4 samples	2030–2080

Dolomite, light gray and light buff, in meal, cherty at 2080, and from 2110 to 2150; 10 samples 2080–2190
Jordan sandstone (60 feet thick; top 1162 feet below sea level):
Sandstone, white, moderately well rounded grains, up to 0.7 mm. diameter, with considerable dolomitic meal 2190–2200
Sandstone, light yellow-gray, dolomitic cement, larger grains 1 mm. diameter; in chips and sand 2200–2210
Sandstone, white, larger grains 1.3 mm. diameter, well rounded, dolomitic cement 2210–2220
Sandstone, light yellow-gray, dolomitic cement, fine, rounded grains 2220–2230
Sandstone, whitish, fine, grains well rounded 2230–2240
Sandstone, whitish, somewhat dolomitic, grains minute, ill-rounded, larger grains well rounded 2240–2248
Sandstone, gray, dolomitic, finely arenaceous and quartzose; some rounded grains in cuttings, perhaps from above 2248–2250
Saint Lawrence, Trempealeau beds (110 feet thick; top 1222 feet below sea level):
Dolomite, whitish, soft, minutely arenaceous and quartzose; some fine grains of well rounded quartz sand perhaps from above 2250–2254
Dolomite, as above; dolomite, brown, hard, minutely quartzose 2254–2261
Dolomite, whitish, soft and gray; minutely quartzose 2261–2263
Dolomite, brown in mass, rusted; some highly arenaceous with fine well rounded imbedded grains 2260–2270
Sandstone, dark gray, minute, ill-rounded grains, dolomitic, argillaceous, pyritiferous, in chips 2280–2290
Dolomite, light yellow-gray, in fine sand 2290–2300
Sandstone, gray, minute grains, dolomitic, in chips 2310–2320
Dolomite, light yellow-gray, in powder and meal, minutely arenaceous and quartzose, with some larger grains, argillaceous 2330–2340
No samples 2340–2350
Saint Lawrence, Franconia beds (penetrated 140 feet; top 1332 feet below sea level):
Dolomite, gray, minutely quartzose; sandstone, gray, glauconitic, dolomitic 2350–2360
Dolomite, yellow-gray and whitish, minutely quartzose, glauconitic; 2 samples 2370–2390
Marl, light blue-green, dolomitic, argillaceous, highly quartzose, some fine ill-rounded grains, some with secondary enlargements, glauconitic 2390–2400
Dolomite, gray and whitish, in small chips, minutely quartzose, glauconitic at 2410; 2 samples 2400–2420
Dolomite, buff, minutely quartzose, quartz grains, as those of samples above, too small generally to polarize in strong colors 2420–2430
Dolomite, gray, finely arenaceous, glauconitic 2430–2440
Sandstone, minutely quartzose, dolomitic, glauconitic; shale light green, noncalcareous 2460–2470
Sandstone, drab and gray in mass, minutely quartzose, dolomitic, glauconitic, argillaceous at 2495; 4 samples 2470–2500

Driller's log, City well no. 6, Grinnell

	Depth in Feet
Soil and clay	0–48
Sand	48–53
Clay, blue	53–197
Shale	197–199
Hard lime	199–220
Lime and shale	220–248
Shale, blue	248–258
Shale with lime	258–268
Lime rock	268–399
Lime and shale	399–414

Shale, light colored	414–490
Shale, dark	490–530
Shale, gray	530–566
Lime, some shale	566–592
Limestone	592–620
Shale with a little lime	620–706
Lime, hard	706–761
Shale	761–782
Lime, white	782–848
Lime, brown	848–863
Lime, white	863–873
Sand, shale and lime	873–903
Lime with small streaks of shale	903–1026
Shale, light	1026–1030
Lime, sharp	1030–1077
Shale, red	1077–1079
Lime with streaks of shale	1079–1108
Lime, sharp	1108–1169
Cherty lime, very hard	1169–1186
Shale, green and light	1186–1221
Shale, chocolate brown	1221–1264
Shale, light and real hard	1264–1321
Shale, chocolate brown	1321–1363
Shale, light and hard	1363–1391
Lime	1391–1638
Shale	1638–1643
Lime, hard	1643–1676
Shale	1676–1681
Sandstone	1681–1714
Lime, hard	1714–1768
Lime rock, some sand	1768–1914
Sandstone, New Richmond	1914–1968
Dolomite	1968–2181
Sandstone	2181–2233
Dolomite with streaks of shale	2233–2438
Shale, light	2438–2443
Dolomite	2443–2486

GRUNDY CENTER

(Altitude 983 feet)

A well 255 feet deep and 10 inches in diameter was completed for Grundy Center in 1917 by E. A. Ford of Marshalltown and pumped in 1922 80 g.p.m. The town also has installed an 8 inch well 360 feet in depth yielding 65,000 g.p.d.

Driller's Log

	Depth in Feet
Clay	0–161
Shale	161–171
Rock	171–255

GRUNDY COUNTY POOR FARM (Four miles southwest of Grundy Center)

In 1925 a well was drilled for this institution by E. A. Ford of Marshalltown and tested 25 g.p.m. The depth is 507 feet and the diameters are 8 and 6 inches.

Driller's Log

	Depth in Feet.
Clay	0-253
Shale	253–353
Rock	353–507

GRUNDY CANNING COMPANY, GRUNDY CENTER

This well, 428 feet deep and 8 inches in diameter, was completed in 1919 by E. A. Ford of Marshalltown. The tested capacity of the well is 125 g.p.m. The cost was $1805.

Driller's Log

	Depth in Feet
Clay (Pleistocene)	0–113
Shale (Mississippian)	113–270
Rock (Devonian)	270–428

WELL OF H. F. SPRAGUE, GRUNDY CENTER

The well at the Sprague Ice Factory is 509 feet in depth, with diameters from 8 to 6 inches. It was completed in 1917 by E. A. Ford of Marshalltown. The principal supply was found at 506 feet. The well supplies 35 g.p.m. under the air lift. There are 156 feet of 8 inch casing and 175 feet of 6 inch. The cost of the well was $1313.

The owner states an interesting fact in the operation of the well. "I use the Sullivan air lift for pumping and we pump enough so that I have a small stream overflowing from the tank. But with the same air pressure and other conditions the same, if the wind blows from the southeast for about 24 hours there will be a smaller amount of water pumped, for the overflow will stop. As soon as the wind gets out of that quarter, we will have the overflow stream again. I have heard of this in shallow wells, but not in deep wells before."

The log of the city well, given in the water report of 1912, indicates that the well foots in the Devonian limestone, possibly reaching the Silurian.

HAMBURG, FREMONT COUNTY

(Altitude of C., B. & Q. R. R. Sta., 911 feet)

Driller's record of oil prospect on Spicer Farm, spudded in June 20, 1925. Located on the NE¼ of the NE¼ of section 3, township 67, range 42, Fremont county, three miles north and one-half mile east of Hamburg

	Thickness, feet	Depth, feet
Loess and glacial drift		90
Shale and gravel, light colored, soft	10	100

Shale, light colored, soft	100	200
Lime, white, hard	10	210
Shale, white, hard	80	290
Lime, white, hard	5	295
Slate, black, soft	135	430
Lime, white, hard	55	485
Shale, white, soft	10	495
Lime, white, hard	5	500
Red rock, soft	5	505
Shale, white, soft	90	595
Lime, white, firm	20	615
Shale, white, soft	5	620
Lime, white, hard	35	655
Shale, gray, soft	5	660
Lime	15	675
Shale, gray, soft	10	685
Lime	40	725
Slate, black	5	730
Lime, broken, firm	70	800
Slate, black	10	810
Lime	80	890
Shale, light	50	940
Shale, black	5	945
Shale, gray	5	950
Lime, white, hard	5	955
Shale, white	50	1005
Slate, black	5	1010
Slate, white, soft	50	1060
Slate, black	5	1065
Lime, white	5	1070

Some oil was found at the bottom of the well.

HAMPTON

(Altitude 1140, C. G. W. R. R.)

WATERWORKS WELL NO. 2, 1926

This well, 1700 feet deep, was completed in February, 1926, by the Thorpe Bros. Well Company of Des Moines. The diameters are from 20 inches to 8 inches. The principal supply was found at 1700 feet in the Jordan standstone. Water found in the Saint Peter sandstone at 1200 feet was cased out. The static level is 153 feet below the surface. With the cylinder at 200 feet the well delivers 1000 g.p.m. with a draw down of 23 feet. The cost of the well was $23,000 and of the pumping machinery $5,000.

The normal static level of well no. 1, drilled in 1900,[54] was 50 feet below the surface with a draw down to 160 feet. The static level is now the same as that of well no. 2, which is only 30 feet distant. The capacity originally was 160 g.p.m., but after well no. 2 was drilled it was reported at 366 g.p.m.

[54] Norton, Underground Water Resources of Iowa, Iowa Geol. Survey, vol. XXI, pp. 777-779.

Record of strata, Hampton city well no. 2

	Depth in Feet
Pleistocene and Recent:	
No samples	0–10
Mississippian, Kinderhook (140 feet thick, top 1106 feet above sea level):	
Limestone, ocher-yellow, effervescence in cold dilute HCl rather slow, much rusted and decayed	10
Sandstone, gray, argillaceous, highly calcareous, grains of quartz minute and ill-rounded; in easily friable masses	20, 30
Shale, gray, slightly calcareous, minutely arenaceous	40
Sandstone, as at 20 and 30 feet	50
Limestone, blue	60
Limestone, gray	70
Shale, blue; 7 samples	80–140
Devonian and Silurian (?) (450 feet thick, top 966 feet above sea level):	
Limestone, brown, crystalline-granular, effervescence moderately rapid, in large chips	150
Limestone, drab; powder of shale	160
Limestone, drab, fine crystalline-granular; whitish, same texture	170, 180
Shale, blue-green, in concreted masses	190
Limestone, varicolored	200
Shale, greenish gray, in concreted masses	210
Limestone, drab, fine crystalline-granular; calcite	220, 230
Shale, blue and green-gray; 6 samples	240–290
Limestone, whitish, in large chips	300, 310
Limestone, cream colored and gray, fine grained; 4 samples	320–350
Limestone, brown-drab	360
Limestone, cream color and gray, with much powder of shale	370
Limestone, gray, buff and brown, effervescence generally rather slow, some brisk; 11 samples	380–480
Limestone, light brown, compact, cryptocrystalline, slow effervescence	490
Limestone, whitish and light yellow-gray and buff, rapid reaction	500
Limestone, blue-gray and yellow-gray, reaction rather slow, some rapid; 5 samples	510–550
Limestone, yellow-gray, moderately rapid	560
Limestone, whitish, soft, response rapid; 3 samples	570–590
Maquoketa shale (140 feet thick; top 516 feet above sea level):	
Shale, light brown, calcareous	600, 610
Shale, light reddish brown; some greenish yellow	620
Shale, blue; 3 samples	630–650
Limestone, yellow-gray, slow effervescence	660
Chert, gray, and shale, some limestone; some red shale at 700; 4 samples	670–700
Shale, gray; 3 samples	710–730
Galena and Platteville limestones (400 feet thick; top 376 feet above sea level):	
Limestone, drab and light buff, reaction rapid; chips of shale	740, 750
Shale, blue-gray	760
Limestone, gray and yellow-gray, slow and moderately slow effervescence	770, 780
Limestone, whitish, rapid reaction	790, 800
Limestone, gray in mass; 25 samples	810–1050
Shale, blue-green	1060
Limestone, gray in mass; 7 samples	1070–1130
Glenwood shale (30 feet thick):	
Shale, hard, blue-green	1140
Shale, drab and brown	1150
Shale, green, fissile	1160
Saint Peter sandstone (70 feet thick; top 54 feet below sea level):	
Sandstone, whitish, of Saint Peter facies; with much yellow-gray limestone of rapid effervescence in small chips	1170

Sandstone, white, grains up three-fourths mm. in diameter; considerable shale in flakes 1180
Sandstone, white, clean except for a little shale 1190, 1200
Shale, blue-green, noncalcareous; a large chip of sandstone, dark gray, of well cemented rounded grains 1210
Sandstone, white, rusted yellow at 1230 ..... 1220, 1230
Prairie du Chien (410 feet thick; top 124 feet below sea level):
Dolomite, light gray, in fine chips; most of sample consists of quartz sand 1240, 1250
Dolomite, gray, buff and whitish; highly arenaceous from 1300 to 1480, sandstone at 1460 (New Richmond); 37 samples 1260–1620
Dolomite, highly arenaceous 1630
Dolomite, clean of sand 1640
Jordan sandstone (penetrated 50 feet; top 534 feet below sea level):
Sandstone, white, clean, grains well rounded, up to about 1 mm. diameter; 6 samples 1650–1700

HAWKEYE, FAYETTE COUNTY

(Altitude 1176 feet)

A well 835 feet deep and 8 and 6 inches in diameter was drilled for this town by Thomas James of Shullsberg, Wisconsin.

At 600 feet a water bed was struck, when the water in the well dropped to 90 feet from its previous head of 30 feet below the curb. The main supply was found at 835 feet, when the water fell to the static level of 265 feet.

The well now delivers 100 gallons per minute under air. The cost of the well was $5,200.

HOLSTEIN, IDA COUNTY

CITY WELL NO. 2, 1924

This well was drilled by Thorpe Brothers of Des Moines. Its depth is 2040 feet and the diameters are 12 inches to 6 inches. With the cylinder of the pump placed at 600 feet, the well has a pumping capacity of 200 gallons per minute.

The static level of the water is about 290 feet below the curb. The chief water beds reported are the Pleistocene at 275 feet, undifferentiated Paleozoic at 750 feet in dolomite and the Prairie du Chien at 1550 feet. Water is also said to have been found in the Cambrian at 1900 feet. The cost of the well was $34,000 and that of the pumping machinery $4,000. In city well no. 1 (1897) water was found in quicksand at 390 feet, at 1200 feet in Galena dolomite and "below 1500 feet", i.e. in the Prairie du Chien and possibly the subjacent beds.

Record of strata in City well no. 2, Holstein

	Depth in Feet
Pleistocene and Recent (420 feet thick; top 1457 feet above sea level):	
Till, drab, clayey, calcareous, small pebbles of dolomite	20
Clay, blue, gritty, calcareous	30
Clay, light greenish drab, hard, concreted, calcareous, gritty	40
Till, clayey, pale yellow, calcareous, small pebbles of igneous rocks and limestone	50
Clay, as at 40 feet	60
Till, drab, clayey, with small pebbles; 5 samples	70–110
Clay, as at 40 feet, gritty with coarse sand	120
Clay, drab, hard, noncalcareous, with rare grains of siliceous limestone	130
Clay, gray-buff, calcareous, gritty with coarse sand of quartz and some of limestone	140
Till, gray-buff, clayey, with small pebbles; 2 samples	150, 160
Till, drab, clayey, with small pebbles; 3 samples	180–200
Till, drab, sandy, friable, pebbly	210
Till, drab, clayey, with pebbles, many of chert and limestone, 7 samples	220–280
Clay, reddish buff, noncalcareous, with small ironstone brownish concretions	290
Till, light drab, clayey, gritty, calcareous	300
Clay, friable, sandy, brownish drab	310
Clay, as at 290	330
Clay, dark gray, noncalcareous, gritty; 4 samples	340–370
Till, clayey, dark gray, calcareous, gritty, with many pebbles of limestone, greenstone, quartz, etc.	380
Pennsylvanian (?) (170 feet thick; top 1037 feet above sea level):	
Shales, drab, gray and red, plastic, noncalcareous; 15 samples	420–580
Mississippian (140 (?) feet thick; top 867 feet above tide):	
Sandstone, light yellow-gray, grains imperfectly rounded, of pure quartz, largest up to 1 mm. and 1.5 mm. diameter; 3 samples	590–610
Limestone, light yellow-gray, crystalline-granular, rapid effervescence in cold dilute HCl	620
Sandstone, as at 590	630
Limestone, as at 620	640, 650
Limestone, as above, in thin chips, cherty; with much quartz sand of highly irregular grains; 3 samples	660–680
Limestone, drab, effervescence rapid; with a little quartz sand	690
Limestone, magnesian, or dolomite, light buff, fine crystalline-granular, moderately slow effervescence	700
Limestone, as above; with much white fossiliferous chert, and much quartz sand, irregular grains varying much in size, some pinkish	710
Limestone, gray and light yellow, compact, rapid reaction, with much sand as above	720
Undifferentiated Paleozoic, lower portion Galena and Platteville (700 feet thick; top 727 feet above tide):	
Shale, hard, blue-green, fissile; and sandstone, gray, fine, of pure quartz, moderately well rounded, apparently from horizon of Saint Peter, and out of place, as no like shale and sand appears in cuttings of immediately underlying beds	730
Dolomite, or magnesian limestone, blue-gray, and yellow-gray, earthy, laminated, in flaky chips	740, 750
Dolomite, drab, subcrystalline, hard, compact, in chips; with some large chips of buff limestone at 770; 3 samples	760–780
Dolomite, as above; with considerable quartz sand of vari-colored and ill-rounded grains probably from above	790
Dolomite, drab, chiefly in sand, some blue shale	800
Dolomite, blue, drab and light yellow-gray; with some blue and green hard fissile shale, and some irregular grains of quartz	810
Dolomite, blue and yellow-gray, pyritiferous; with much quartz sand of well rounded grains and dark green-gray hard, finely laminated shale	820

Dolomite, light gray, with a little green shale and sand 830, 840
Dolomite, drab, hard 850
Dolomite, light yellow-gray, in sand; with much green shale, some with *cone-in-cone* structure, and well rounded quartz sand up to 1 mm. diameter 860
Dolomite, gray and blue-gray, in crystalline sand and small chips, argillaceous, and with some blue shale at 1040-50, a little white chert at 1080-90, highly cherty 1100-30; 23 samples 900–1130
Shale, greenish drab, hard, fissile; and sandstone, rounded grains up to 1.3 mm. diameter; much white chert 1140
Dolomite, light gray and yellow-gray, cherty 1150, 1160
Dolomite, blue and yellow-gray, in crystalline sand, at 1170 dark drab in chips, cherty at 1250; 16 samples 1170–1310
Dolomite, yellow-gray, with some drab shale 1320, 1330
Dolomite, blue, argillaceous; with some sandstone, blue, argillaceous, of minute grains 1340
Shale, light green-gray, calcareous, arenaceous with minute grains 1350
Sandstone, rounded grains, a few reaching 1.8 mm. in diameter; much green fissile shale, a little gray dolomite 1360
Shale, bright green and blue-gray, calcareous; 3 samples 1370–1390
Limestone, response rapid, gray, with shale 1400
Shale, green and light brown 1410
Limestone, gray, rapid reaction, with much shale, all in small chips 1420

Ordovician:

Saint Peter sandstone (20 feet thick; top 27 feet above sea level)—
Sandstone, white, fine, grains well rounded, with some chips of green shale 1430, 1440
Prairie du Chien (180 feet thick; top 7 feet above sea level):
Dolomite, light yellow-gray 1450
Dolomite, drab, sparse floating grains of sand, oölitic, with much quartz sand and drab shale 1470
Sandstone, clean, white, well rounded grains up to about 0.5 mm. diameter; some green, fissile shale 1480
Dolomite, gray, in sand; much shale at 1510 1490–1510
Dolomite, gray, oölitic 1540
Dolomite, light yellow-gray, cherty (duplicate sample: sandstone, white, well rounded grains) 1550
Dolomite, gray and buff, in fine crystalline sand; 6 samples 1560–1620

Cambrian:

Jordan sandstone (?)
Sandstone, white, well rounded grains, up to 1.2 mm. diameter 1630
Saint Lawrence dolomite and shales and undifferentiated Cambrian (340 feet thick; top 183 feet below sea level)—
Dolomite, gray, highly arenaceous with minute quartz grains and particles, somewhat argillaceous; 5 samples 1640–1680
Shale, green-gray, calcareous, minutely quartzose, glauconitic, in powder and friable masses 1690
Dolomite, highly arenaceous, grains minute, at 1740 argillaceous; 4 samples 1700–1740
Shale, gray, highly calcareous, minutely quartzose 1750, 1760
Sandstone, grains minute, dolomitic, glauconitic 1770
Shale, green-gray, as at 1750 ..... 1780, 1790
Sandstone, as at 1770 1800
Shale, as at 1780, in powder 1810
Sandstone, gray, calcareous, argillaceous 1820
Shale, greenish and blue-gray, plastic, hard, in splintery chips, slightly calcareous; 4 samples 1830–1880
Dolomite, buff, arenaceous, glauconitic 1890
Shale, greenish, in hard splintery chips 1900
Dolomite, gray, highly quartzose, glauconitic, in chips, with much shale 1910, 1920
Shale, drab, hard, noncalcareous, with dolomite as above 1930, 1940

Shale, calcareous, quartzose 1950
Shale, hard, green gray, plastic 1960, 1970
Red Clastic beds (40 feet thick; top 523 feet below sea level):
Sandstone, red, grains of clear uncolored quartz well rounded, little broken, with surface before washing reddened with ochreous interstitial material, with balls, dark red, ochreous, ellipsoidal and globular, up to 2.7 mm. diameter, concentric structure, outer coating dark red, inner reddish yellow, noncalcareous; 3 samples 1980–2000
Sandstone, cuttings flesh colored, grains of clear quartz with a light surface stain, grains well rounded, up to 1.5 mm. diameter, in sand; with some chips of flesh colored sandstone, noncalcareous, of minute grains of clear uncolored quartz 2010
Archean (?) (penetrated 20 feet; top 563 feet below sea level):
Granite, pink; with much quartz sand in rounded grains and a little shale; components of granite; orthoclase feldspar, quartz in small grains, white mica (muscovite?), and a black ferro-magnesian mineral, yellow brown when pulverized, with no noticeable pleochroism; in chips and sand; 3 samples 2020–2040

Notes.—While the samples of the cuttings of this well, on the whole, have evidently been taken with care, yet some obvious misplacements have taken place. The city officials who packed them for shipment to this office called attention to this fact, and in copying labels other errors could happen. Thus a Pleistocene clay is labelled with a depth of 890 feet. The sandstone of Saint Peter facies at 730 feet also is very probably out of place.

The drift is of exceptional thickness, and the shales beneath it carry no very convincing evidence as to whether they are Cretaceous or Pennsylvanian. Comparing this section with that of the deep well at Cherokee, eighteen miles north, it will be seen that the nondolomitic limestones and sandstones assigned to the Mississippian have thinned greatly to the south, while the underlying dolomites have correspondingly thickened. Probably the larger portion of these dolomites belongs to the Galena and Platteville. The gray and blue-gray argillaceous and in part cherty dolomites from 900 to 1130 feet probably include the Maquoketa. A thin sandstone of Saint Peter facies occurs at Holstein, according to the samples, at 1360 feet and is associated with the green shale so common at this horizon. The top of the Saint Peter, however, is placed at 1430 feet, where a white sandstone occurs in greater thickness, at near the level of the Saint Peter in well no. 1, and where it is underlain by the usual dolomites of the Shakopee.

The white sandstone at 1630 feet is too thin to be assigned with any certainty to the Jordan, but the underlying thick series of

dolomitic, argillaceous quartzose beds, in places glauconitic, with some shales, are typically Saint Lawrence and EauClaire. No well defined Cambrian water bearing sandstones, such as the Dresbach and Mount Simon of northeastern Iowa deep well sections, are found here below the Saint Lawrence—a fact of major importance in well drilling. The beds of the lithologic facies of the Franconia or EauClaire rest directly on a red ochreous sandstone, tentatively correlated with the Red Clastics of southern Minnesota, as its loosely cemented grains show no evidence that it had ever been quartzitic.

The importance of the granite floor reached at 2020 feet has been set forth by Lees,[55] who was consulted by the drillers and after visiting the town and examining the cuttings identified the rock as granite in which the drill was working and advised stopping the work immediately.

From Cherokee to Holstein the south dip of the Saint Peter sandstone is about sixteen feet per mile. The Cherokee well did not go below the Saint Peter, and while additional water might have been found in the Prairie du Chien, the Holstein section shows that it would have been unadvisable to enter the Saint Lawrence. Indeed, if the Archean surface is of slight relief and the Cambrian formations above it thicken to the south, it might easily have been reached at Cherokee from 300 to 500 feet below the bottom of the well.

It is worth remark that the red sandy, cherty, caving shale found in the first city well at Holstein at 1520 feet, not far below the base of the Saint Peter, where such residual formations are not uncommon, is entirely absent in the second well.

*Mineral Content of City well, no. 2, Holstein**

	P.P.M.
Bicarbonate	236.7
Chloride	13.
Sulfate	757.8
Silica	24.4
$Fe_2O_3+Al_2O_3$	10.0
Calcium	139.5
Magnesium	77.8
Na + K as Na	109.6
Total solids	1250.4

55 Proc. Iowa Acad. Sci., vol. XXX, pp. 445-450.

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

HUXLEY, STORY COUNTY

(Altitude 1046 feet, Ft. D., D. M. & S. E. R.)

The well which furnishes the public supply for Huxley is 892 feet deep and was completed in 1921 by Thorpe Brothers of Des Moines. The diameters are from 10 to 5 inches. The main supply was found at 891 feet and small veins were struck between 125 and 325 feet. The original static level of 125 feet below the curb and the pumping capacity of 75 g.p.m. are both maintained. The consumption of the village averages 5,000 g.p.d. with a maximum of twice that amount. The pumping cylinder is hung at 160 feet and continuous pumping has no effect on the level of the water. The water is reported as rather hard on boilers. The cost of the well was $10,000.

Driller's log of town well at Huxley

	Thickness, feet	Depth, feet
Black dirt	8	8
Yellow clay	40	48
Blue clay	72	120
Shale	120	240
Limerock	40	280
Shale	80	360
Limerock	60	420
Shale	120	540
Limerock	180	720
Shale	40	760
Lime	110	870
Shale	22	892

Hole started 10 inches in diameter. 8 inch pipe from surface to solid formation. 120 feet of 6 inch pipe from 500 feet to 620 feet, 4 inch pipe to bottom.

INWOOD, LYON COUNTY

(Altitude 1466 feet)

The city well of Inwood was drilled in 1917 by the McCarthy Well Company of Saint Paul. The depth is 914 feet; the diameters are 12 and 10 inches. The principal supply was found in the "fine sand" from 290 to 300 feet. A "light vein" was struck at 450 feet in the "shale" of the driller's log, yielding soft water. About 5 gallons per minute were obtained from the Sioux quartzite.

The static level is 275 feet below the curb and is not drawn down by pumping. The pumping capacity is named at 23 gallons of clear water. The pump, whose cylinder is set at 297 feet below the curb, will lift 60 gallons, but the water is then turbid.

The cost of the well was $10,000 and of the pumping machinery $2,000.

Driller's Log

	Depth in Feet
Clay	0–290
Fine sand	290–300
Shale	300–475
Granite	475–915

A few samples of the cuttings of this well were obtained. The first, stated to represent the material from the surface to 300 feet, is a blue clay with pebbles of the northern drift. That labeled 300 to 475 feet is shale, drab, noncalcareous, with much quartz in fine angular particles. The sample at 475 feet and three others to and including 500 feet are of Sioux quartzite, in clear pinkish grains, coarse, up to 2.5 mm. in diameter, and at 500 feet showing greater induration by more complete fractures. The top of the Sioux quartzite lies about 1000 feet above sea level. The shale above it may be Cambrian. The fact that the drillers noticed no difference of material from 475 feet to 915 feet gives a shade of probability to the supposition that the quartzite extends to the bottom of the well.

While the drilling was in progress Assistant State Geologist Lees gave the advice not to drill into the quartzite "as it is in most places very hard and close-grained and yields very little water"—advice which if followed would have saved the town several thousand dollars.

*Mineral Content of City Well, Inwood**

	P.P.M.
Bicarbonate	380.6
Chloride	9.0
Sulfate	957.8
Silica	20.0
$Fe_2O_3+Al_2O_3$	10.1
Calcium	250.9
Magnesium	162.5
Na + K as Na	63.1
Total solids	1663.7

IOWA CITY

WELL OF THE STATE UNIVERSITY OF IOWA, 1927

This well is located just north of the east end of the Burlington Street bridge on the bank of Iowa river at an elevation above

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

sea level of 672 feet. The depth of the well is 840 feet. A 10 inch pipe extends to 499 feet; an 8 inch pipe, from this point to the bottom, is perforated at the water beds. Flowing water was struck in the Galena limestone at 755 feet, with a natural discharge of 100 g.p.m.

The pumping capacity on completion was found to be 210 g.p.m. with a draw down of 20 feet. An air lift now raises 300 g.p.m. with a draw down of 70 feet. The well was drilled by the Thorpe Bros. Well Company of Des Moines at a cost of $9700.

Chemical analysis of water of University well, Iowa City, done by the Cochrane Engineering Co.

	Grains per U. S. Gallon
Magnesium carbonate	5.98
Magnesium sulphate	1.79
Calcium sulphate	10.85
Sodium sulphate	21.00
Sodium chloride	4.55
Silica	0.44
Iron oxide and alumina	0.02

Record of strata, State University well, Iowa City, 1927

	Depth in Feet
Cedar Valley limestone:	
Limestone, light cream yellow, soft, earthy, fine-grained, compact, laminated, rapid effervescence in cold dilute HCl, in thin flakes	55–65
Wapsipinicon limestone (140 feet thick):	
Limestone, light yellow-gray, soft, earthy, rapid reaction; chip of same texture shows fragment of small brachiopod shell with plications, another chip a fragment of a larger plicated brachiopod shell; some light gray limestone	65–75
Limestone, light yellow-gray, calcilutite, conchoidal fracture; also buff-gray, crystalline-earthy; buff, laminated; and buff with brown crusts	75–80
Limestone, light yellow-gray, and light gray, calcilutite; some chips show crystalline-earthy gray limestone inclosing minute fragments of calcilutite	80–90 (?)
No samples	90–110
Limestone, yellow-gray, earthy, argillaceous, rather slow effervescence	110–120
Limestone, dark buff, fine crystalline-granular, in large chips of rough surface and irregular fracture; slight quartzose and argillaceous residue	120–130
Limestone, gray, crystalline-earthy, soft, rapid effervescence; some buff dolomite or magnesian limestone, slow reaction; some silica, whitish, translucent	130–140
Shale, light gray, in clean large flaky dolomitic chips, and earthy argillaceous limestone of same color	148
Dolomite, gray, crystalline-granular, in chips	150–160
No samples	160–185
Dolomite, gray and yellow-gray, cryptocrystalline	185–190
Shale, dark greenish gray, noncalcareous, unctuous, pyritic, highly arenaceous, grains fine, of clear quartz and many of larger grains well rounded	201–205
Niagaran (150 feet thick; top 462 feet above sea level):	

Dolomite, light yellow-gray, cryptocrystalline, vesicular, rough fracture; 3 samples	210–240
Dolomite, light blue-gray and yellow-gray, cherty at 340; 12 samples; no samples from 280-320	240–360
Maquoketa (top 312 feet above sea level):	
Shale, light blue-gray and green-gray, plastic, dolomitic; 2 samples	360–380
No sample	380–390
Dolomite, blue-gray and yellow-gray, crystalline; shale, hard, drab	390–400
Shale, light blue-gray, plastic; 3 samples	400–430
Dolomite, gray, hard; much gray chert	430–440
Dolomite as above, earthy; some chert	440–450
Dolomite, gray, earthy	450–460
Shale, light blue-gray, plastic; 2 samples	460–478
Shale, hard, drab and greenish drab; gray shale, noncalcareous, arenaceous with fine well rounded grains of clear quartz; dolomite, greenish drab, earthy; lumps of decayed chert; 2 samples	478–490

Notes on this section will be found under Oakdale sanatorium well, 1928.

*Driller's log, well of State University of Iowa, 1927**

	Depth in Feet
Pleistocene and Recent (50 feet thick; top 672 feet above sea level):	
Soil and clay	0–15
Sand	15–50
Devonian limestones and shales (155 feet thick; top 622 feet above sea level):	
Sandy limestone	50–60
Limestone	60–95
Broken lime rock	95–105
Limestone; water, 25 g.p.m.	105–128
Shale	128–136
Lime	136–164
Shale	164–172
Lime	172–179
Shale	179–185
Limestone	185–201
Shale	201–205
Niagaran limestone (155 feet thick; top 467 feet above sea level):	
Lime	205–250
Lime	250–360
Maquoketa shale (193 feet thick; top 312 feet above sea level):	
Shale	360–390
Lime	390–406
Shale	406–432
Lime; more water	432–465
Shale	465–478
Lime	478–499
Lime	499–504
Shale	504–553
Galena-Platteville (287 feet thick; top 119 feet above sea level):	
Lime	553–563
Sand rock	563–568
Lime rock	568–580
Shale	580–585
Lime	585–755
Magnesia lime; more water	755–770
Magnesia lime	770–812
Hard lime	812–828
Green mud (Glenwood shale?)	828–835
Mud, blue (Glenwood shale?)	835–840

* Assignment of formations by W. H. Norton.

KEOKUK

(Altitude 504 feet)

WELL OF ELECTRO-METALS CO.

This well was drilled by S. B. Geiger and Co. of Chicago, and was completed in 1928. It is 888 feet in depth and from 12 to 8 inches in diameter. There are 40 feet of 12 inch casing at top and an 8 inch pipe from 245 to 470 feet cases out the Kinderhook shales.

The natural flow is 294 g.p.m. A small flow was obtained from the Galena-Platteville limestone at 625 feet and one of 125 g.p.m. at about 730 feet in the same formation. The Saint Peter gave a flow of 275 g.p.m. at about 820 feet and this had increased to 294 g.p.m. at the bottom of the well. The temperature of the water is 63° F. The curb is 513 feet above sea level.

Driller's log and record of strata

	Depth in Feet
"Fill and white sand"	0–58
Clay, gray and buff, with a few pebbles, some rolled	10–37
Sand and gravel	37–40
Mississippian, undifferentiated (222 feet thick; top 475 feet above sea level):	
"White lime"	58–150
Limestone, white, soft, earthy, in flaky chips, rapid effervescence in cold dilute HCl	40–137
Limestone, dark gray and yellow-gray, soft, crystalline-earthy; in chips and argillaceous powder	137–150
"Shale"	150–155
Shale, blue-gray, somewhat calcareous; a little white chalcedonic silica	150–155
"Gray lime"	155–170
Sandstone, dark blue-gray, calcareous, highly argillaceous, grains irregular, microscopic; a little chalcedony	155–170
"Shale"	170–180
"White lime"	180–260
Limestone, yellow-gray, fine-grained, earthy, rapid effervescence	180–250
Limestone, drab, in sand, rapid effervescence	250–260
Kinderhook shale (200 feet thick; top 253 feet above sea level):	
"Shale"	260–460
Devonian? Silurian? Maquoketa? Galena-Platteville (322 feet thick; top 53 feet above sea level):	
"Brown lime"	460–590
"Sand"	590–755
Dolomite, light buff gray in mass; in sand	590–595
Dolomite, as above	595–605
Dolomite, brownish buff in mass, in coarser sand; a little white chert	605–625
"Lime"	755–782
Dolomite, grayish buff	755–782
St. Peter sandstone (106 feet penetrated; top 269 feet below sea level):	
"Sand"	782–888
Sandstone, white, fine, exceptional grains 1 mm. diameter, grains frosted, fairly well rounded, some secondary enlargements	782–850
Sandstone, white, finer than above, larger grains generally well rounded and frosted	850–888

Notes.—The following description of two samples of the cuttings is omitted from the above record as their labels are probably interchanged or otherwise misplaced.

Limestone, gray, in sand, rapid effervescence, some chips of brown, noninflammable shale	260–460
Shale, blue gray, in concreted mass, calcareous, some very feebly so	460–590

These samples, which contradict the log as to the place of the Kinderhook shale, contradict also the cuttings and logs of earlier wells at Keokuk.

The shales and sandstone at 150 feet are noted in the sections of the Y. M. C. A. and the Poultry Company's wells. In the above log the sandstone is called "gray lime;" as it occurs in chips and its arenaceous nature is not evident without test.

The "sand" of the driller's log from 590 to 755 feet is evidently the Galena-Platteville dolomite of the samples, a rock which, as is often noted, is apt to crush under the drill into sparkling crystalline dolomitic sand.

WELL OF THE KEOKUK PURE ICE CO.

This well, 701 feet in depth and 6 inches in diameter, was drilled in 1913 by T. J. Haggerty of Keokuk. The main supply was found at 680 feet. On completion the natural flow was 85 g.p.m. In 1914 the company, needing more water, put in a centrifugal pump with the pipe placed at about 40 feet and the supply was thus increased to 110 g.p.m. Two years later this amount became insufficient. The well was now cased for the first time, using 200 feet of 5 inch pipe, and an air lift was installed with the nozzle at 150 feet. The yield was now raised to 180 g.p.m. and later experiments with lowered nozzle and larger motor failed to increase it.

The natural flow gradually lessened until early in 1918 it probably was not more than 50 g.p.m. At this time two large wells (those of the J. C. Hubinger Bros. Co.) were put down one mile distant from the well and on ground 70 feet lower than the curb. In July it was found that, as an effect of interference, the static level had fallen to 6 feet below the curb and since that time it has fallen to 41 feet below that level. The delivery at present is 135

g.p.m., with the air lift nozzle at 150 feet. The temperature of the water is 62° F.

WELL NO. 1, J. C. HUBINGER BROS. CO.

In June, 1928, this well was completed by the S. B. Geiger Company of Chicago. The depth is 692 feet and the diameters are from 15½ to 10 inches. The main flow came from between 597 and 692 feet. On completion the flow was 890 g.p.m., but by December 1 of that year it had fallen to 705 g.p.m. The pressure or head was not taken. The temperature of the water is given as 64° F. The elevation of this well and that of well no. 2 are stated to be that of the Union station, or approximately 504 feet above sea level. There were placed 34 feet of 16 inch casing at the top of the well and 227 feet of 10 inch casing on the 459 foot level.

Driller's log

	Depth in Feet		Depth in Feet
Dirt and clay	0–33	Lime rock	564–597
Lime rock	33–243	Sand rock	597–650
Shale	243–564	Sand and lime	650–692

Record of strata

	Depth in Feet
Mississippian:	
Keokuk formation, Montrose cherts (top 471 feet above sea level)—	
Chert, white; limestone, light gray and whitish, rapid effervescence, only a little limestone at 100; Montrose cherts, 33-53 and	100
Burlington and Kinderhook limestones (121 feet thick; top 379 feet above sea level)—	
Limestone, white, soft, macrocrystalline	125
Limestone, light gray, crystalline-earthy	138
Shale, light blue-gray, in concreted masses with chips of gray and yellow-gray limestone	143
Sandstone, blue-gray, of microscopic grains of crystalline quartz, argillaceous, calcareous, in chips	148, 157
Shale, light blue-gray	165
Limestone, light gray, calcilutite, conchoidal fracture, somewhat siliceous, rapid effervescence as are all limestones above	172–175
Dolomite, brownish gray, fine-crystalline, some gray limestone	188
Limestone, light yellow-gray, fine-grained, rapid effervescence; some brown dolomite	200
Sandstone, blue-gray, argillaceous, calciferous, grains microscopic	232–237
Kinderhook shale (204 feet thick; top 258 feet above sea level)—	
Shale, blue-gray, siliceous, calcareous	246
Shale, blue	274
Shale, brown, some chips slightly inflammable	310
Shale, gray and light blue-gray	344, 350, 392, 400
Devonian (106 feet thick; top 54 feet above sea level):	
Limestone, light gray, some brown-gray, earthy, rapid effervescence	450
Limestone, gray and buff, hard, in coarse sand, rapid effervescence	502
Limestone, brown, mottled gray, in flaky chips, rapid effervescence	523

Limestone, light gray and yellow-gray, laminated, calcilutite, rapid effervescence	556
Ordovician:	
Unknown, no samples	556–580
Galena-Platteville (samples for 17 feet; top 76 feet below sea level)—	
Dolomite, light brownish, crystalline granular, in sparkling sand	580, 597

Notes.—No attempt is made to separate the Burlington from the Kinderhook limestones in the above section, although the dolomite and sandstone at 188 feet and below clearly belong to the latter both by place and by character. The Kinderhook shale has thinned both southward from Fort Madison, where it is 268 feet thick, and also eastward from Donnellson, where it is 325 feet thick. The Devonian limestones are characteristic and the calcilutite recurs which is found near the base at both Donnellson and Fort Madison. Nothing similar to the Niagaran dolomites occurs in this area. The Maquoketa shale also is wanting and it will be noted that at Donnellson it had thinned to five feet and was found but 18 feet thick at Fort Madison.

According to the samples of the Electro-Metals Company's well, the Galena dolomite extends to 269 feet below sea level, 81 feet below the footing of well no. 1 of the J. C. Hubinger Bros. Co. The log of this well thus makes the common mistake of confusing the sparkling dolomite sand of cuttings of the Galena with the quartz sand of the Saint Peter, where especially the former is water-bearing. The thickness of the Galena-Platteville is about the same as at Donnellson and about 50 feet thinner than at Burlington.

Although well no. 2 of this company is 45 feet deeper than well no. 1, reaching 233 feet below sea level, it still falls short of the horizon of the Saint Peter at 269 feet below sea level in the well of the Electro-Metals Co. The yield of well no. 2 also leads to the inference that the Saint Peter was not reached. Large as is the yield from the Galena it would appear that wells at Keokuk should be drilled to the base of the Saint Peter sandstone and that for certainty samples of the cuttings should be submitted to a competent geologist.

WELL NO. 2, J. C. HUBINGER BROS. CO.

On the 25th of July, 1928, S. B. Geiger completed a second deep well for the Hubinger Bros. Co. This is located 295 feet due

west of well no. 1 and is of the same diameters. The depth is 737 feet. The main flow came from 630 feet to the bottom. Although this well is deeper than well no. 1, the discharge was much less—339 g.p.m. which later (December 1) had fallen to 310 g.p.m. Thirty-four feet of 16 inch casing was placed on the 34 foot level and 227 feet of 10 inch casing on the 459 foot level.

Driller's log

	Depth in Feet		Depth in Feet
Dirt and clay	0–34	Lime rock	459–630
Lime rock	34–250	St. Peter's sand and rock	630–737
Shale	250–459		

Mineral analysis of the J. C. Hubinger Bros. deep wells

	Parts per million	Grains per gallon
Total solids	3860	225.0
Potassium	115	6.7
Sodium	813	47.4
Magnesium	82	4.8
Calcium	187	10.9
Ammonium	4.3	0.3
Bicarbonate	301	17.6
Sulphate	1490	86.9
Chloride	690	34.2
Hypothetical Combinations		
Potassium chloride	220	12.8
Sodium chloride	966	56.4
Sodium sulphate	1341	78.2
Magnesium sulphate	406	23.7
Calcium sulphate	364	21.2
Calcium carbonate	212	12.4
Silica	26	1.5
Alumina and ferric oxide	20	1.1
Hydrogen sulphide	1.4	

KNOXVILLE

WELL NO. 2 OF THE STATE HOSPITAL FOR INEBRIATES

Record of strata

	Depth in Feet
Pleistocene and Recent (25 feet thick):	
Clay, light buff, slightly calcareous	10
Des Moines:	
Shale, drab	25
Sandstone, gray, micaceous	33, 36
Limestone, gray, rapid effervescence in cold dilute HCl; powder of shale in cuttings	48
Shale, light blue-gray, fissile	60
Limestone, light gray, rapid effervescence, earthy, in large chips	70
Shale, dark gray	80

Limestone, as at 48 feet; powder of shale; pyrite	90
Limestone, white, rapid effervescence, in concreted fine sand and powder, highly arenaceous with small imperfectly rounded grains of quartz, which occasionally are seen imbedded	100
Sandstone, light gray, fine irregular grains	108
Shale, black, coaly	117
Shale, gray, hard	125
Shale, calcareous, cherty, pyritiferous, in powder and fine sand	130
Limestone, reddish, reaction rapid; chert; shale; all in coarse washed sand	142
Shale, dark and light gray, arenaceous, micaceous	150
Shale, dark gray; sandstone, light gray, of minute quartzose-angular grains, argillaceous, noncalcareous	159 and 161
Limestone, light gray, rapid reaction, with obscure minute structure as of foraminifers	170
Limestone, blackish, hard, argillaceous, response rapid, pyritiferous	175
Limestone, as at 170 feet	179
Shale, drab, fissile; 5 samples	190–225
Coal	225
Shale, light gray, highly siliceous	240
Limestone, gray, effervescence rapid, fossiliferous	250
Shale, blackish	260
Sandstone, gray, moderately fine, some secondary enlargements	270, 280
Sandstone, gray, coarser than above, soft, friable	290
Sandstone, light gray	300
Sandstone, light buff	310
Limestone, brown, mottled, earthy, rapid reaction	315
Sandstone, whitish, fine, grains imperfectly rounded, calcareous	320
Sandstone, rather fine	330
Limestone, blue-gray, rapid effervescence	340

LAKE MILLS, WINNEBAGO COUNTY

Lake Mills has two city wells, one 235 feet deep, 6 inches in diameter, with a pumping capacity of 80,000 g.p.d., the other 374 feet deep, 12 inches in diameter, with a pumping capacity of 250,000 g.p.d. The average town consumption is 40,000 g.p.d. and maximum 60,000 g.p.d. The record given below is of the deeper well.

Record of strata in the City well of Lake Mills

	Depth in Feet
Pleistocene and Recent (122 (?) feet thick; top 1266 feet above sea level):	
No samples	
Devonian and inferior Paleozoic terranes (penetrated 252 feet; top 1144 feet above sea level):	
Dolomite, bright buff in small chips and crystalline sand "rotten rock" of label	122, 134
Dolomite, gray, crystalline-granular, soft, in small chips; 4 samples	144–174
Dolomite, buff, fine-grained, large dark argillaceous residue	184–194
Limestone, drab, fine-grained, rapid effervescence in cold dilute HCl	204
Limestone, blue-gray, moderately rapid effervescence	214
Limestone, magnesian, blue-gray, reaction moderately slow, fine-grained	224
Limestone, grayish buff, fine-grained, some calcite, response moderately rapid. All the above from 184 feet have large argillaceous residue	234
Limestone, light blue and yellow-gray, fine-grained	244

Limestone, magnesian, or dolomite, gray and grayish buff, soft, fine-grained, earthy; 3 samples	254–274
Dolomite, gray, with chert at 284; 3 samples	284–304
Dolomite, light blue-gray, earthy, soft, fine and close-grained, large argillaceous and minutely quartzose residue	314
Limestone, light gray and white, soft, earthy, argillaceous with finely divided cryptocrystalline silica; rapid effervescence	324
Dolomite, gray-buff, fine crystalline-granular, much white chert, large drab argillaceous residue with finely divided white chert and minute grains of crystalline quartz	334
Dolomite, gray, fine crystalline-granular, soft, argillaceous	344
Dolomite, in fine buff crystalline sand	354, 364
Limestone, crystalline-earthy, disseminated calcite crystals, encrinital	374
"Shale and whitish clay, unable to get samples"	

Notes.—The shale reached at the bottom of the well, 892 feet above sea level, appears to correspond with the Maquoketa reached at Mason City at 824 feet above sea level. But with the gradient of the summit of the Saint Peter from Mason City to Blue Earth, Minnesota, the Maquoketa would be reached some 75 feet higher, provided that the Galena and Platteville maintained their thickness to the northwest from Mason City to Lake Mills. It is possible that the basal dolomites of the section belong to the Galena, which they much resemble lithologically and that the shale at 374 feet is the Glenwood.

*Mineral Content of City Well, Lake Mills**

	P.P.M.
Bicarbonate	456.
Chloride	2.
Sulfate	37.
Silica	43.8
$Fe_2O_3+Al_2O_3$	5.8
Calcium	99.7
Magnesium	34.5
Na + K as Na	23.6
Total solids	474.4

LAKE PARK, DICKINSON COUNTY

(Altitude 1469 feet)

WELL OF CHICAGO, ROCK ISLAND AND PACIFIC RAILWAY

The following account of this well is given by Meinzer in his report on the underground waters of Jackson county, Minnesota.[56] "At Lake Park, Iowa, * * * a well was drilled for the railway company to a depth of 804 feet. Stratified formations,

* Analysis by Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

56 Geology and Underground waters of Southern Minnesota, U. S. Geol. Survey Water Supply Paper 256, p. 213.

chiefly shale, sand, and sandstone, seem to make up about 550 feet of this depth. The upper portion is supposed to be Cretaceous in age, but the lower probably belongs to some Paleozoic formation. This well was tested with a large steam pump. The water is said to stand nearly 300 feet below the surface, or about 1200 feet above sea level. It is so hard that it is not used by the railway company."

LAMONI, DECATUR COUNTY

(Altitude 1123 feet)

The city well of Lamoni was drilled in 1927 by Thorpe Bros. Well Co. of Des Moines and is 2193 feet in depth. The diameters are from 16 to 6⅝ inches. The casing is as follows: 94 feet of 16 inch pipe from the surface; 552 feet of 12 inch pipe from the surface; 271 feet of 10 inch pipe from 510 feet to 781 feet; 500 feet of 8 inch pipe from 635 feet to 1135 feet; 561 feet of 6⅝ inch pipe from 1070 feet to 1631 feet.

The static level was found to be 340 feet below the surface of the ground, with a drawdown to 525 feet when pumped on test for 36 hours at the rate of 100 to 105 gallons per minute.

City well, Lamoni, Driller's log

	Depth in Feet		Depth in Feet
Clay and boulders	0–100	Fire clay	559–562
Sand	100–105	Black shale	562–590
Clay	105–150	Lime rock	590–600
Mixed shale	150–158	Soft light shale	600–611
Rock	158–160	Black shale	611–620
Rock, very hard	160–165	Light shale	620–642
Blue shale	165–169	Black shale	642–652
White shale	169–175	Gray shale	652–680
Lime rock	175–218	Gray sandy shale	680–770
Black shale	218–231	Sandstone, hard, cut very fine	770–780
Gray shale	231–237	Sand and lime, cut very fine	780–785
Lime rock	237–259	Sandstone, hard, cut very fine	785–839
Black shale	259–264	Hard black lime	839–842
Lime rock	264–291	Black shale	842–885
Black shale	291–302	Sandstone, hard and fine	885–955
Gray shale	302–322	Blue shale	955–1010
Lime rock	322–337	Black shale	1010–1015
Black shale	337–345	Gray sandy shale	1015–1070
Black shale streaked with rock	345–410	Lime rock	1070–1120
Black shale	410–430	Shale	1120–1180
Lime rock	430–442	Lime	1180–1185
Gray shale	442–464	Shale	1185–1195
Black shale	464–475	Light shale streaked with rock	1195–1223
Gray shale	475–543	Hard lime	1223–1363
Black shale	543–557	Light shale	1363–1367
Coal	557–559	Hard lime	1367–1481

Gray shale	1481–1523	Sand and lime, fine, hard, mostly sand	2020–2075
Lime rock	1523–1543	Lime rock	2075–2100
Hard lime	1543–1870	Sandstone, water-bearing	2100–2143
Lime streaked with shale	1870–1876	Flinty lime	2143–2193
Hard lime	1876–1920		
Lime rock	1920–2020		

Record of strata

	Depth in Feet
Sandstone, fine, highly irregular grains, rusted; pyrite	900
Sandstone, as above	940, 950
Shale, blackish	990
Sandstone, gray in mass, fine irregular grains, argillaceous, calcareous	1030
Limestone, white, earthy, in large flaky chips, rapid effervescence in cold dilute HCl; much quartz sand; some black shale	1070
Limestone, light gray, rusted, crystalline-earthy, rapid effervescence; chalcedonic silica in chips, sandstone in sand and calciferous chips	1090
Sandstone, in sand and chips, fine-grained, some cryptocrystalline silica	1110
Limestone, light gray, crystalline-earthy, rapid effervescence; shale, blue-gray	1120
Limestone, gray, very fine-grained, hard	1140
Limestone, yellow-gray, calcilutite; gray, softer and in some chips arenaceous and involving chips of chert; greenish shale	1150
Limestone, very light gray, soft, in thin flakes, rusted buff in mass	1170
Limestone, or dolomite, brown, hard, fine-crystalline, slow effervescence, in sand; limestone, gray, rapid effervescence	1190
Shale, light blue-gray, calciferous; 3 samples	1200–1220
Limestone, light gray, rapid effervescence, in sand; with light blue shale at 1240; 3 samples	1230–1250
Limestone, gray and yellow-gray, rapid effervescence; some light brown chert	1260
Limestone, gray and brown-gray, fossiliferous, rapid effervescence, in large chips	1270
Limestone, gray and drab, some mottled, rapid effervescence, in sand	1280
Limestone, gray, rapid effervescence, much brown and white chert, in sand	1290
Limestone, gray, light gray and whitish, rapid effervescence, in sand; chert, gray and white, and chalcedonic silica; 6 samples	1300–1350
Shale, light blue-gray, in friable masses, with minute quartz grains; some chalcedonic silica	1360
Limestone, light gray; milky white translucent silica	1370
Silica, chalcedonic, milky white, in small chips; whitish limestone, rapid effervescence; some shale; 5 samples	1380-1420
Limestone, gray and white, rapid effervescence; a little silica as above; considerable gray shale	1430
Chert, gray; shale, hard, blue-green, in flakes, calcareous; gray limestone; "caving some"	1440
Limestone, gray and yellow-gray, rapid effervescence; chert; pyrite; shale	1470, 1480
Shale, light blue-gray, plastic, calcareous, some brown-gray; 4 samples	1490–1520
Limestone, gray, light gray, and whitish, rapid effervescence, fossiliferous at 1570; with more or less gray and drab shale and a little brown inflammable shale, in chips and powder; 8 samples	1530–1600

Notes.—As many of the labels of the cuttings taken above the depth of 900 feet have become illegible, the geologic section of this depth is best made out from the driller's log. This portion of the

section clearly lies in the Pleistocene and the Pennsylvanian. The sandstone at the base of the Pennsylvanian may be compared with that found at the same horizon at Atlantic, Glenwood and Bedford. After passing this sandstone the well was tested —at 1080 feet—and was found to yield 55 g.p.m.

The cuttings below 1070 feet at least as far as 1523 feet, are typically Mississippian in the predominance of light gray and whitish limestone, nonmagnesian in its reaction to acid, milky white, more or less translucent cryptocrystalline silica, and considerable shale. The shale from 1481 to 1523 feet in the log (samples from 1490 to 1520 feet) is assigned to the Kinderhook. This gives a total thickness to the Mississippian of 453 feet, with its top at 53 feet above sea level and its base 400 feet below that datum. The map of the elevation of the top of the Mississippian published in our 1912 report gave this elevation at Lamoni at about 25 feet above sea level.

The limestone from 1523 to 1600 feet thus falls to the Devonian. Below this it is hardly safe without cuttings to assign the geological formations. Probably the water-bearing sandstone at 2100 feet is referable to the Silurian, corresponding to the Silurian water-bearing sandstone at Des Moines. At Des Moines the strata measure (Greenwood Park well) 947 feet from the base of the Coal Measures to the base of the Silurian. At Lamoni the distance from the base of the Coal Measures to the base of the water-bearing sandstone assigned to the Silurian measures somewhat more—1073 feet. It is hardly probable that this sandstone at 2100 feet (1077 feet below sea level) is the Saint Peter. In that case the Saint Peter would be actually higher at Lamoni than at either Des Moines (1114 feet below sea level) or Stuart (1176 feet below sea level), while the Saint Peter in the southwestern county of the state is shown by the deep boring at Nebraska City to reach at least 1853 feet below that level. The absence in the log of any shale referable to the Glenwood also makes against the placing of this sandstone with the Saint Peter.

LEON

(Altitude 1019 feet)

On May 23, 1923, Thorpe Bros. Well Co. finished a well for the town of Leon at the depth of 1103 feet. The well stood a

pumping test of 35 gallons per minute. The static head was 380 feet below curb, the pumping head 490 feet. The altitude of the well is about 1100 feet above sea. Casing was inserted as follows:

Length, feet	Diameter, inches	Depth, feet
333	16	0 to 333
149 8 in.	12	310 to 462–8 in.
148 2 in.	10	442–8 to 590–10
344 10 in.	8	565–2 to 910
127 5 in.	6	872–7 to 1000

Driller's Log of Well at Leon

	Thickness feet	Depth feet
Yellow clay	55	55
Blue clay and stone	80	135
Blue clay and boulders	5	140
Yellow clay	23	163
Blue clay	22	185
Sand	1	186
Blue clay	40	226
Gravel	14	240
Blue clay	47	287
Clay and gravel	6	293
Blue clay	40	333
Limestone	2	335
Coal	2	337
Soapstone	7	344
Bluestone	10	354
Blue soapstone	23	377
Coal	1	378
White soapstone	62	440
Limestone	4	444
Black slate	6	450
Hard soapstone	20	470
Black slate	1	471
Coal	4	475
Blue soapstone	33	508
White limestone	7	515
White soapstone	6	521
Hard white soapstone	44	565
Coal	4	569
Blue soapstone	56	625
Sandrock, some water	15	640
Lime	10	650
Sandrock, some water	20	670
Shale	95	765
Sandy shale	20	785
Sand rock	10	795
Shale	5	800
Lime	10	810
Sandrock	5	815
Lime	7	822
Sand	8	830
Shale	5	835
Sandrock	5	840

Shale	20	860
Sandrock	10	870
Lime	20	890
Shale	4	894
Sandrock, some water	6	900
Lime rock	10	910
Shale	84	994
Lime	26	1020
Shale	83	1103

DECATUR COUNTY FARM WELL

Messrs Thorpe Brothers of Des Moines have furnished the following log of a well which they drilled for the Decatur County Farm near Leon. This well was finished in December, 1924, and is cased with 10 inch pipe to 287 feet, thence with 8 inch pipe to 343 feet, 6 inch pipe to 636 feet and 282 feet of 4 inch pipe at the bottom. The static head of the well is 380 feet below curb and the pumping head is 440 feet below curb. The well yielded 30 gallons per minute under a forty-eight hour pumping test.

Driller's log of well

	THICKNESS FEET	DEPTH FEET
To solid formation	343	343
Lime	5	348
Shale	288	636
Sand rock	30	666
Shale	42	708
Sand rock	45	753
Shale	167	920
Lime	5	925
Shale	17	942

LYTTON, SAC COUNTY

(*Altitude 1225 feet*)

The well from which Lytton draws its public supply is 1150 feet deep and 8 inches in diameter at top. It was completed in 1920 by Thorpe Brothers of Des Moines. Water was found in sandstone at the bottom of the drill hole. The static level is "about 75 to 100 feet". The cost of the well and pumping machinery combined was $10,000.

Log of Well at Lytton, Sac County

	THICKNESS FEET	DEPTH FEET
Black dirt	10	10
Yellow clay	30	40
Sand	10	50

Blue clay	110	160
Shale	60	220
Lime rock	30	250
Shale	80	330
Lime rock	190	520
Shale	40	560
Lime	200	760
Shale	20	780
Lime	285	1065
Sand rock	75	1140
Lime	10	1150

100 feet of 10 inch standard pipe. 8 inch pipe extends down 160 feet to solid formation, 6 inch pipe 420 feet, 4 inch pipe to the bottom.

MANSON, POCAHONTAS COUNTY

(Altitude 1237 feet)

CITY WELL NO. 2, 1928

This well was completed May 1, 1928, by the Thorpe Brothers Well Co. of Des Moines. The depth is 1211 feet and the diameters are 16 to 10 inches. The static level is 90 feet from the top of the curb. The well tested to 300 g.p.m. with a draw down of 2 feet on a 24 hour run. On a half hour test the yield was 360 g.p.m. with a draw dawn of 5½ feet. Besides 59 feet of temporary pipe the following casing was placed:

400 feet of 16 inch pipe from surface
616 feet of 12 inch pipe from 350 feet to 966 feet
191 feet of 10 inch pipe from 904 feet to 1105 feet

The cost of the well was $20,000.

Record of strata, Manson City well, 1928

	Depth in Feet
Pleistocene and Recent (230 feet thick; top 1232 feet above sea level):	
Till, blue-gray, calcareous	35
Sand and gravel, up to 1 cm. diameter, pebbles of drift; lumps of gray-blue clayey till. In one lump out of 15 pebbles 6 were limestone, 7 dolomite, 1 crystalline rock, 1 black shale. In the coarse sand of this lump out of 24 grains 11 were limestone and dolomite, 1 shale, 8 quartz, 4 other minerals of crystalline rocks	90
Till, yellow, calcareous	174
Clay, yellow, finely arenaceous, calcareous, in hard lumps	200
Cretaceous (?), Pennsylvanian (?):	
Shale, gray, in hard concreted masses inclosing pebbles of light gray and yellowish limestone, gray and buff dolomite, red sandstone, yellow jasper, one of red quartzite	230
Shale, blue-gray, few pebbles	250
Shale, drab, in hard concreted masses, inclosing many pebbles. Out of 37, 21 were of limestone, 8 of dolomite, 3 red clay-ironstone, 2 white quartz, 1 arkose; limestone and dolomites were of various textures and colors	270
Shale, drab, in hard masses inclosing much coarse material, mostly varicolored limestones and dolomites; one pebble, 3½ cm. diameter,	

subangular smoothed, of light gray, fine calciferous sandstone; one decayed mass, 1 inch diameter, greenish gray, of crystalline rock with disintegrating particles of crystalline quartz and other minerals 280

Shale, drab, as above, nodule of drab feebly calcareous shale, large fragment of gray fine-grained crystalline limestone 290

Shale, drab, as above, included chips and pebbles mostly limestones and dolomites; some brick red finely arenaceous shale; some weathered feldspathic material. Of identified grains of included sand up to 3 mm. diameter 23 were limestone, 9 magnesian limestone, 13 silica or feldspar, 2 red shale, 1 red sandstone, 1 gray sandstone, 1 arkose 300

Shale, drab as above 310

Shale, drab, as above, included chips and pebbles examined were mostly limestone and dolomite, several of feldspar with or without associated ferromagnesian minerals 320

Shale, drab, as above 330

Limestone, light buff, soft, some crystalline, some earthy, rapid effervescence in cold dilute HCl 340

Shale, drab, in concreted masses, inclosed chips of shale, calcareous, with inclosed fragments of limestone, etc.; at 360 blackish, fine, hard, only microscopically arenaceous, pyritic; at 400 with fewer included pebbles: buff dolomite, drab limestone, red ochreous ironstone; arkose, red jasper; 13 samples 350–470

Shale, blackish, in concreted masses, inclosed chips of shale, noncalcareous 480

Shale, drab, in concreted masses. At 510 feet of 20 included fragments examined 6 were limestones, 2 dolomites, 2 calcite, 4 sandstone, 5 quartz of various colors, 1 feldspar-quartz aggregate. At 500 feet chips of shale noncalcareous; 5 samples 490–540

Sandstone, gray, coarse to fine, some pebbles up to 5 mm. diameter; grains subangular, mostly of clear quartz, some yellow, pink, and bright red; some white limestone; some feldspathic 550

Sandstone, as above; shale, chocolate brown and drab 560

Shale, drab and blackish 570

Sandstone, as at 550, concreted into friable masses with drab shale 580, 590

Shale and sandstone as above; coarse irregular grains, considerable arkose; fragment 2 cm. diameter of gray and red argillaceous arkosic sandstone, noncalcareous; pebble of gray siliceous rock of 15 mm. diameter with irregular pitted surfaces 600

Shale, ocher-red, concreted with much quartz sand; 4 samples 610–640

Sandstone, red, fine subangular grains, with much red shale 650

Shale, red, noncalcareous; 10 samples 660–750

Sandstone, fine to coarse, grains of clear quartz highly irregular, some yellow and pink; feldspathic material; chips of fine red argillaceous sandstone; all concreted in friable masses with red shale..... 760

Shale, blue-gray and red 770–780

Sandstone, fine to coarse, grains irregular; some yellow quartz; some of feldspathic rock; bluish sandstone very fine-grained; fine red sandstone; red and gray shale 790, 800

Shale, drab and red, plastic 810, 820

Sandstone, fine to coarse, grains irregular, some yellow and red quartz; a little feldspathic rock; in friable masses with red shale 830

Shale, red, some blue 840

Sandstone, irregular grains, fine to coarse, a little limestone and calcite; concreted in friable masses with gray shale 850

Shale, drab and blackish 860

Shale, blue-gray 870

Sandstone, coarse to fine, some grains rose-red and yellow, considerable feldspathic material, considerable limestone very light gray, of rapid effervescence, and yellow and blue-gray, of slow effervescence; fine red sandstone; chips of shale; fragment of "fine arkosic

sandstone with quartz, altered feldspar, ferromagnesian and altered ferromagnesian minerals; some of the latter staining the surrounding grains''* 880
Shale, drab, some red 890
Sandstone, blue-gray in mass, fine irregular grains of clear quartz, secondary enlargements; feldspathic material, limestones, whitish, light yellow and gray, some of rapid effervescence, some of slow; concreted with much drab shale 900, 910
Shale, reddish gray, in lumps 920, 930
Sandstone, coarse to fine, irregular grains, some pink quartz; ''fragments of light gray feldspar, arkosic sandstone, and fine iron-cemented sandstone'';* limestone whitish and drab; much drab and red shale in chips and lumps 940, 950
Shale, drab with reddish tinge concreting quartz sand as above, arkose and limestone 960
Shale, drab, plastic, arenaceous 970
Shale, drab, some red, concreting much arkose, a little gray limestone; fragment 1.5 cm. diameter composed of ''fragments of white feldspar, quartz, and some ferromagnesian mineral altered to iron oxide. There are veinlets of clear calcite through the mass and what appear to be joint surfaces covered with a light green mineral 0.1 to 0.3 mm. thick''* 980
Shale, drab, in small chips and lumps, with much arkose and grains of fine and coarse quartz sand as above 990
Sandstone, arkosic, grains of quartz up to 1.5 mm. diameter, ill-rounded, some secondary enlargements; much drab shale, some red shale, in chips 1000
Arkose, in mass gray, speckled whitish; much feldspathic material in whitish chips up to 7 mm. diameter, some speckled with blackish mineral; quartz grains fine to coarse, irregular, some pink and yellow 1010
Shale, drab, in hard lumps, concreting coarse material as above 1020
Arkose as at 1010; whitish feldspathic grains up to 5 mm. diameter 1030
Arkose, purplish red in mass, speckled white; chips of shale and fine red sandstone; quartz sand grains up to 5 mm. diameter 1040
Arkose, as above, fragment of rolled pebble of yellow silica 12 mm. in diameter; red shale; one ''arkosic fragment 5 mm. diameter seems to be a single fragment of a ferromagnesian granite with probably augite as the carrier of the iron. Spots of pyrite in the ferromagnesian mineral. Ochreous spots between quartz and feldspar on some surfaces''* 1050
Arkose, drab, speckled white in mass; constituents as above, whitish feldspathic material, quartz sand, drab shale; 5 samples 1060-1100
Sandstone, coarse, up to 6 mm. diameter; rusted, rolled pebbles of limestone; chips of sandstone, feldspathic material, micaceous material, shale 1110, 1120
Arkose, as at 1060 1130
Arkose, gray, fine to coarse, much white feldspathic material. At 1160 one fragment 10 mm. in diameter ''of gneissic rock which has layers of quartz and feldspar separated by irregular layers of what seems to be chlorite to give greenish color and gneissic structure'';* 3 samples 1140–1160
No sample 1190
Arkose, light reddish brown in mass, in chips and sand. Reddish sandstone of microscopic grains of clear quartz, highly argillaceous and ferruginous; ''arkosic sandstone and fragments composed of feldspar and ferromagnesian minerals; somewhat less than one-half of the samples in bulk;''* 3 samples 1200–1211

* Determination by Dr. Earl T. Apfel of Syracuse University.

Driller's log, Manson City well, 1928

	Depth in Feet
Soil, yellow clay and boulders	0–20
Blue clay and gravel	20–52
Coarse gravel	52–58
Blue clay	58–92
Sand	92–102
Blue clay	102–145
Sand	145–154
Yellow clay	154–175
Blue clay	175–340
Blue shale, streaked with rock	340–385
Light blue shale, with rock	385–525
Rock	525–528
Red shale	528–530
Blue shale and rock	530–545
Hard rock	545–560
Rock (some sand running in from behind the pipe)	560–608
Red shale	608–683
Rock	683–692
Red shale	692–708
Rock	708–711
Red shale	711–750
Shaly rock	750–765
Red shale	765–767
Light blue shale	767–825
Flinty sandstone	825–850
Lime rock and shale	850–863
Blue shale	863–875
Rock	875–890
Rock and shale	890–920
Red shale	920–946
Lime rock	946–960
Blue shale	960–981
Rock	981–986
Red shale	986–996
Flinty rock	996–1004
Lime and sand rock	1004–1105
Sandstone (lighter in color and finer at 1140, with some water)	1105–1160
Hard white sandstone	1160–1207
Red sandy shale	1207–1211

Notes.—The Manson city wells are unique not only in the quality of their water but also in their geologic section. This is clearly seen if the Manson section is compared with the strata pierced by other deep wells of the area. If the strata between here and Fort Dodge, 19 miles east of Manson, were continuous, unchanged and horizontal between the two points, the drill at Manson would have entered the Saint Louis limestone at about 900 feet above sea level, 332 feet below the surface, and would have stopped in limestones of the Galena-Platteville. From the top of the Mississippian to the bottom of the well, it would have been predominantly in limestone. Instead, the drill did not reach the Mississippian or other limestone formations and below the drift is almost wholly in shale, sandstone and arkose, some of the rock with the appearance of conglomerate.

If the strata rose from Fort Dodge westward to Manson the Mississippian limestones would be struck at a still higher level and the abnormality of the well section would be still greater. As to the actual lie of the strata in this area, it is known that the Paleozoic formations dip westward as far as Webster City, as measured by the contours of the Saint Peter sandstone. From Webster City to Fort Dodge the Saint Peter sandstone is about on the level. From Fort Dodge the Saint Peter rises from 406 feet below sea level westward to 27 feet above sea level at Hol-

stein, west-northwest to 323 feet above sea level at Cherokee, and west-southwest to 249 feet below sea level at Rockwell City. The elevation of the Saint Peter at Rockwell City seems to preclude any considerable downfold west of Fort Dodge in whose trough Manson might be located.

If we entertain the supposition that the Mississippian and other limestones have changed to shales and arkosic sandstones in the short distance west of Fort Dodge to Manson, we are met with the fact that they carry through still farther west to Cherokee and Holstein, as well as southwest to Rockwell City. Not only the surface exposures but also the deep wells of northern Iowa show that the Mississippian is there predominantly of limestone. If the rocks pierced by the drill at Manson belong in whole or part to the Mississippian they must have been deposited under abnormal conditions.

If the entire section at Manson below the drift be assigned to either the Pennsylvanian or the Cretaceous or both, it remains abnormal both in thickness and in facies. At Manson the combined thickness of the Pennsylvanian strata penetrated below the drift is 981 feet. At Fort Dodge (Beaver Products Co. well) the thickness of the Pennsylvanian is 70 feet, at Rockwell City 160 feet, at Somers at most 402 feet, at Gowrie 230 feet, at Holstein 170 feet, at Cherokee 495 feet, and at Herndon 100 feet.

The facies of the cuttings also is abnormal, especially in the appearance of conglomerate and in the large amount of arkosic material. In some aspects they are strikingly similar to those of the De Witt well below the Saint Peter sandstone, and to similar sections at Maquoketa and Preston, which the writer has interpreted as the fill of deep erosion channels cut in rocks of the Prairie du Chien during the interval preceding the deposit of the Saint Peter sandstone.

The exceptional character and thickness of the shales and arkose of the Manson well are explainable by a like hypothesis—the fill with continental deposits, and finally with marine sediments also, of a valley of erosion. The depth of the valley, 300 feet deeper than that of the Mississippi in northeastern Iowa, is notable. The arkosic material of the fill suggests that the

headwaters of the river worked in the igneous rocks of the states bordering Iowa on the north.

The deposits themselves, so far as the cuttings reveal them, do not appear to offer conclusive evidence as to their age, whether they were laid at the close of the long erosion interval preceding the deposit of the Pennsylvanian or of that preceding the Cretaceous. The fact that Manson is located less than 5 miles west of the provisional eastern border of the Cretaceous would preclude the expectation of finding there any great thickness of normal marine sedimentary deposits of Cretaceous age, but not the fill of a deep pre-Cretaceous valley.

The character of the water, so far as that goes, would seem to favor the reference of the deposits to the Pennsylvanian. The water is of extraordinary softness, standing in strong contrast to that of the deep wells of north-central and northwestern Iowa, and especially to the heavily mineralized well waters of the Cretaceous. The water of well no. 2 has not been analyzed, but no doubt it is the same chemically as that of well no. 1, 1250 feet deep, analyzed by Hendrixson.* Hendrixson comments as fol-

	P.P.M.
Silica (SiO_2)	10.0
Iron (Fe)	0.2
Aluminum (Al)	0.8
Calcium (Ca)	16.0
Magnesium (Mg)	8.0
Sodium (Na) and Potassium (K)	221.0
Bicarbonate radicle (HCO_3)	4.0
Carbonate radicle (CO_3)	38.0
Sulphate radicle (SO_4)	162.0
Chlorine (Cl)	206.0
Total solids	651.0

lows:* "The well at Manson is the only deep well in the state whose water was found to contain normal carbonates; the magnesium and calcium in it are very low, the solids being mostly alkaline chlorides and sulphates. It may be questioned whether its comparatively soft water and its alkalinity may not be due to contamination by surface water owing to faulty casing."

This tentative suggestion by Hendrixson of surface contamination was as good an explanation as could then be made with the

* Hendrixson, W. S., Iowa Geol. Survey, vol. XXI, p. 178.
* *Ibid.* p. 174-5.

data at hand. The log of the well, no. 1, was also found "exceedingly peculiar" by Norton.† In the absence of cuttings little attempt was made toward its interpretation. The reference of the basal sandstone of the well to the Saint Peter by the driller and by citizens was controverted. The suggestion was made that the so-called "sandstone" was the Galena dolomite, "not infrequently called sand rock because of the sparkling crystalline sand to which it is crushed by the drill." This also was perhaps as good a suggestion as could be made with the data then at hand. Fortunately the complete set of samples of the cuttings saved by the Thorpe Bros. Well Co. points the way toward a solution of the dual mystery. The "exceeding peculiarity of the log" of well no. 1 is now seen to be due to the exceeding peculiarity of the formations it pretty faithfully records. The abnormal quality of the water is not due to surface contamination but to the abnormal arkosic aquifer and the absence of limestone in beds of any considerable thickness. The character and thickness of the deposits and the quality of the water are entirely normal in the continental deposits of the fill of a deep erosion channel, although such channels and fills are exceptional in Iowa deep wells.

The log of well no. 1 records "sandstone" from 1050 to 1220 feet, and "red shale" from 1220 to 1250 feet, at which depth "granite-like rock" was struck. According to the log of well no. 2 the "red shale, sandy" is penetrated four feet, from 1207 to 1211 feet. Apparently then the reddish sandstone and arkose extends some twenty feet, more or less, below the footing of well no. 2. The "granite-like rock" at the base of well no. 1 may have been a boulderet in a coarser conglomerate. It will be remembered that even in the field, as at Colorado Springs, arkose may have a strong superficial resemblance to the granite which is its source. The large content of crystalline rock in the lower cuttings of the Manson well indeed gave rise to the question whether the drill was working in decayed gneiss or granite. The quartz sand and limestone pebbles of the cuttings answered this question in the negative. The softness of the deposit is shown by the fact that the drill penetrated from 1110 to 1180 feet in somewhat less than four days.

† Norton, W. H., Iowa Geol. Survey, vol. XXI, p. 1017.

From the cuttings it is difficult to draw the line between glacial tills and shales on which they rest, although the distinction is usually perfectly obvious. Assuming that the driller's logs use the term "blue clay" only of till, the logs of the wells give the Pleistocene thicknesses of 310 and 340 feet. But on account of the close resemblance of the cuttings of shale below 340 feet, at which depth a thin bed of limestone was struck, and the samples of "blue clay" above it, it seems somewhat more probable that both above and below 340 feet the drill was working in shale and that the lower limit of the drift is 230 feet. In ease of drilling there was little if any difference between "blue clay" and "shale", the drill making 30 or 40 feet a day in each.

As the description shows, the cuttings of the gray and drab shales both above and below 340 feet are by no means of the texture of the cuttings of shales of the Pennsylvanian in central Iowa, as in the Nevada well (p. 273). While the argillaceous material at Manson concretes into tough masses, it is less unctuous and incloses much coarse material in the lumps. At 290 feet a nodule of pure shale was brought up, but for the most part the rock, as in cuttings of the Maquoketa shale, has been thoroughly crushed by the drill and affords few if any chips of pure shale. The source of the coarse material in these shales is not determined. A good deal probably came from the sand beds (92-102 and 145-154 feet of the log). Only the upper bed is represented by a sample and in this the large proportion of limestone and dolomite pebbles is noteworthy, a proportion which carries through the coarse material in the cuttings from the shales. The variety in texture and color of the limestone fragments of the shales is to be considered, since it proves that these fragments were not broken by the drill from limestone beds in place. In weak shales the upper casings could hardly be so firmly bedded as to prevent the inwash from water-bearing glacial sands and gravels, and it will be noted that the log states that at 560-608 feet "some sand was running in from behind the pipe."

But it seems possible that these sand beds are not the only source. The large amount of sand and pebbles and fragments of various rocks and minerals, including much feldspar, in many of the cuttings and especially the presence of arkosic sandstone

in heavy beds at the base of the section point to the conclusion that some of the coarse material of the cuttings may be native to the strata in which the drill was working. It seems possible that the samples of shale mingled with more or less of sand and gravel and fragments of igneous rock come from lenses and layers of the coarser interbedded with the finer materials, the "shale with streaks of rock" of the log.

MARQUETTE (formerly North McGregor) CLAYTON COUNTY

(Altitude 628 feet)

The well of the Chicago, Milwaukee, St. Paul & Pacific Railroad, completed in 1917, is 450 feet deep and flows about 250 gallons per minute. A flow of 10 gallons per minute was had at 300 feet. At 420 feet the flow increased to about 200 gallons per minute, and reached its maximum at the bottom of the well. The diameters of the well are 20 inches to 90 feet, 14 inches to 125 feet, and 12 inches to the bottom. The curb is about 624 feet above sea level.

Record of Strata

	Depth in Feet
Alluvium and rock, cuttings in concreted masses, light drab, of grains of quartz sand rounded and frosted, in slightly calcareous argillaceous powder; some chert	0–60
Saint Lawrence formation, Trempealeau beds:	
Shale, light yellow-green and drab, noncalcareous, coarsely fissile, in chips, with some chert and quartz sand	60–70
Dolomite, gray, earthy, microquartzose, with white and pinkish chert; and sandstone, cuttings chiefly quartz sand in well rounded grains	70–75
Chert, varicolored, with crystalline buff dolomite, and light yellow sandstone of minute particles; 3 samples	75–87
Sandstone, light yellow-gray, calciferous, of microscopic angular particles; 2 samples	87–100
Saint Lawrence formation, Franconia beds (190 feet thick; top 524 feet above sea level):	
Shale, calcareous and quartzose, light blue, quartz in fine angular particles; 4 samples	100–140
Dolomite, light gray, cuttings in sand; 2 samples	140–160
Dolomite, blue-gray, sporadic grains of glauconite and quartz particles	160–175
Sandstone, green-gray, argillaceous, dolomitic, glauconitic, in friable masses and occasional chips, quartz grains minute and fine, ill-rounded, highly dolomitic at 200, highly glauconitic at 210 feet; 11 samples	175–285
Sandstone, fine, grains moderately well rounded, glauconitic	285–290
Dresbach sandstone (penetrated 160 feet; top 334 feet above sea level):	
Sandstone, white, clean, fine to coarse; 15 samples	290–450

Notes.—In the above section the first sample is somewhat ambiguous, and its exact position is unknown. The second sample, at 564 feet above sea level, clearly represents the Saint

Lawrence formation and probably is taken at or near its summit, as the top of the Jordan sandstone outcropping in the McGregor bluffs is but 115 feet higher, a measure somewhat less than the total thickness of the Jordan exposed in the bluffs at Lansing.

It is therefore probable that the first sixty feet of the section belongs largely or wholly to the Jordan sandstone, here more or less cut out by the filled channel of Mississippi river.

The City well no. 4 at McGregor furnished samples of alluvial sands at 35 and 50 feet, while at 60 feet a sandstone was struck, perhaps the Jordan, and the Trempealeau dolomite was encountered at 74 feet. The Dresbach was entered at about the same depth as at Marquette.

The section of the deep well at Prairie du Chien[57] corroborates and extends the well sections of the west side of Mississippi river. The Saint Lawrence was found there 115 feet thick, and at 365 feet above sea level the drill passed into the Dresbach sandstone, which is 118 feet thick. Since at Marquette the Dresbach had been penetrated to a depth of 160 feet, it is probable that there the base of the formation was nearly reached. At 247 feet above sea level, at Prairie du Chien (73 feet above the footing of the Marquette well), the shaly beds of the upper Eau Claire appeared and extended to 38 feet above sea level, while the clean sands of the lower Eau Claire reached at least to 272 feet below that datum, where 45 feet of red sandstone was struck. This latter may perhaps be the equivalent of the Red Clastic beds of Minnesota.

Record of Strata in Aherns Bros. Farm well near Prairie du Chien, Wisconsin (Se. ¼, Sw. ¼ Sec. 18, Tp. 7, R. 6 W.)

The following record is added in corroboration of the Iowa sections through the courtesy of Dr. F. T. Thwaites, of the Wisconsin Geological Survey. The elevations above sea level are added.

	Depth in Feet
Surface deposits (77 feet thick; top about 650 feet above sea level):	
Sand, no samples	0–77
Trempealeau (123 feet thick; top about 573 feet above sea level):	
Dolomite, with some sandstone, no samples (Lodi "Shale")	77–130
Sandstone, yellow, very fine, dolomitic, hard (Lodi)	130–135
Dolomite, gray, sandy (St. Lawrence)	135–195

57 Geol. of Wisconsin, vol. IV, p. 61: Iowa Geol. Survey, vol. XXI, p. 353.

No sample	195–200
Franconia (115 feet thick; top 450 feet above sea level):	
Sandstone, fine to exceedingly fine, green, calcareous, glauconitic (no sample from 225-235)	200–285
Sandstone, exceedingly fine, gray, calcareous	285–295
Sandstone, like above, harder, glauconitic (shale)	295–305
Sandstone, coarse, gray, calcareous, glauconitic	305–315
Dresbach (150 feet thick; top 335 feet above sea level):	
Sandstone, coarse, white to light gray	315–450
Sandstone, fine to medium, white	450–465
Eau Claire (penetrated 287 feet; top 185 feet above sea level):	
Sandstone, fine to medium, gray, dolomitic, hard	465–475
Sandstone, fine to very fine, gray, calcareous, glauconitic	475–515
Sandstone, fine, gray and pink, calcareous, hard	515–545
Sandstone, very fine, gray, very calcareous	545–555
Shale, gray, slightly calcareous	555–565
Sandstone, fine, pink, calcareous	565–570
Sandstone, medium, gray; shale, gray, hard	570–580
Sandstone, medium, light gray, slightly calcareous	580–710
Sandstone, coarse to fine, light gray, flow	710–720
Sandstone, fine, light gray	720–730
Sandstone, very coarse to fine, light gray, main flow	730–752

MASON CITY

(Altitude 1125 feet)

WELL NO. 3 OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

A well 1278 feet deep was completed for this company in 1913 by Jas. D. Shaw of Davenport. The diameters are 16 inches to 259 feet 6 inches, 12½ inches thence to 820 feet, and 10 inches to the bottom. Elevation of the curb is about 1125 feet.

The static level on completion and at present is 115 feet below the curb. With the pumping cylinder at 134 feet the capacity of the well is 266 gallons per minute. The casing is 41 feet of 16 inch pipe at the top, casing out the glacial drift deposits; 38 feet of 12 inch pipe from 221 feet 6 inches to 259 feet 6 inches; and 190 feet of 10 inch pipe from 629 feet 6 inches to 819 feet 6 inches, casing out the Saint Peter sandstone, the Glenwood shale and the basal portions of the Galena-Platteville.

Driller's log of well no. 3 of Chicago, Milwaukee & St. Paul Railway, 1913

	Depth in Feet
Clay	0–41
Limerock	41–689
Shale (Glenwood)	689–719
Saint Peter sandstone	719–779
Limestone (Prairie du Chien)	779–1149
Jordan sandstone	1149–1268
Sand and limestone mixed (Trempealeau)	1268–1278

Chemical analysis of water of well of Chicago, Milwaukee & St. Paul Railway, 1913

	Grains per U. S. gallon
Calcium carbonate	11.75
Magnesium carbonate	7.75
Calcium sulphate	2.61
Incrusting solids	22.11
Alkali sulphate	0.13
Alkali chloride	0.85
Non-incrusting solids	0.98
Total	23.09

WELL OF THE AMERICAN BEET SUGAR CORPORATION, MASON CITY

This well was drilled in 1924 by the McCarthy Well Company of St. Paul. The depth is 1347 feet, the diameters are 20 inches to 240 feet, 16 inches to 640 feet and 12 inches to the finish. The static level is 40 feet below the curb. The capacity of the well is about 650 gallons per minute with the cylinder set at 240 feet drawing through a pipe 20 feet in length. Eight hundred and fifteen feet of 12 inch casing are placed heading at 653 feet. The cost of the well was about $20,000.

Driller's log of well of American Beet Sugar Corporation

	Depth in Feet		Depth in Feet
Limerock	0–54	Hard rock (Prairie du Chien)	930–1145
Shale	54–68	Sandrock (Prairie du Chien)	1145–1195
Limerock	68–626	Shale (Prairie du Chien)	1195–1205
Shale	626–725	Sandrock (Jordan)	1205–1235
Hard rock	725–742	Hard rock (St. Lawrence)	1235–1275
Sandrock (Saint Peter)	742–930	Shale (St. Lawrence)	1275–1347

WELL NO. 2 OF J. E. DECKER AND SONS, MASON CITY

The first well drilled for this packing company was described in the author's report for 1912, and since that time has suffered no deterioration. A second well was drilled some years later with a depth of 1200 feet and diameters from 20 to 12 inches. The principal supply was found in the Jordan sandstone, in which the well foots. On completion water rose within 90 feet of the surface. The delivery on first tests was 450 gallons per minute, but on later installing larger pumps the delivery was increased to 650 gallons with the cylinder set at 140 feet. Continuous pumping produces a draw down of 20 feet.

MASON CITY WATERWORKS WELL NO. 8

This well, 1219 feet deep, was completed in 1912 by W. L. Thorne of Platteville, Wisconsin. The diameter is 16 inches to

200 feet, from 200 to 960 feet 13 inches, and 10 inches to the bottom.

The main supply was found in the Jordan sandstone, in which the well foots, and some water was obtained in the Saint Peter sandstone at 800 feet. On completion the static level was 82 feet below the curb. The present head is 123 feet below the surface, and with the air foot at 300 feet the well delivers about 1200 gallons per minute. The well was uncased except the first 20 feet, but later reports mention 200 feet of 14 inch casing at top, and 100 feet of 12 inch casing about 600 feet down, shutting out the shales above the Saint Peter. The cost of the well was $6295.

MASON CITY WATERWORKS WELL NO. 9

The ninth well drilled for Mason City was completed in 1913 by W. L. Thorne. The depth is 1200 feet. The diameters and casing are as follows:

24 inch diameter	0–55 feet.	20 inch casing with concrete fill
19 inch diameter	55–225 feet	
16 inch diameter	225–720 feet.	12 inch casing 540-720 feet
12 inch diameter	720–1200 feet	

During the drilling of the well water stood at the curb until the New Richmond sandstone was struck when it fell to 77 feet below the surface. The original draw down was about 7 feet and in 1919 it was reported as reaching to 140 feet, 56 feet lower. In 1919 the head was reported to be at 105 feet, and in 1925 it was stated to stand at 115 feet "with no appreciable drop after draw down".

The well delivers 1200 gallons per minute. The cost of this well was $10,000.

MASON CITY WATERWORKS WELLS NOS. 6 AND 7

These wells, whose original depths were 616 and 875 feet, were deepened about 1920 to 1218 and 1219 feet. Both wells reach the deeper water beds with eight inch holes. Under air the wells supply 700 and 800 gallons per minute.

WELL OF THE PEOPLE'S GAS AND ELECTRIC COMPANY, MASON CITY

This well, 1200 feet deep, was completed in 1915 by James Kutcher of Plymouth, Iowa. The diameters are 20 inches to 125

feet, 16 inches to 700 feet, 12 inches to 960 feet and 10⅝ inches to the bottom.

The main supply was found at 1182 feet (Jordan sandstone). The head is maintained up to the present at 50 feet below the curb. With the pumping cylinder at 125 feet the well delivers 800 gallons per minute with a draw down to 65 feet. Casing is set as follows: 20 inch to 100 feet; 12 inch from 625 to 700 feet; 10⅝ inch from 700 to 960 feet. The cost of the well was $15,000.

Driller's log of the well of the People's Gas and Electric Co.

	Depth in Feet
Limestone	0–636
Mixed limestone and shale	636–660
Shale (Glenwood)	660–682
Mixed limestone and shale (Glenwood)	682–688
Sandstone (St. Peter)	688–778
Limestone (Shakopee)	778–810
Sandstone (Shakopee)	810–816
Limestone (Shakopee)	816–917
Sandstone (New Richmond)	917–944
Limestone (Oneota)	944–1125
Sandstone (Jordan)	1125–1182
St. Lawrence formation	1182–1200

WELL NO. 1, OF NORTHWESTERN STATES PORTLAND CEMENT COMPANY

This well was commenced in 1923 and was completed July 6, 1924. It is 1281½ feet in depth and is 19 inches in diameter to 267 feet, 15 inches to 747 and 12 inches to the bottom. Casing with a length of 87.5 feet was inserted at the foot of the 15 inch section of the well to prevent caving of the shale at that depth. The well yields 1500 gallons per minute when pumped with air. The water has a temperature under these conditions of 56° F.

Following is the log of the well as furnished by Mr. W. J. Maytham, consulting engineer.

	Thickness Feet	Depth Feet
Limestone, high magnesian	680	0–680
Shale	85	680–765
Sandstone, St. Peter	65	765–830
Limestone, high magnesian, with streaks of shale	320	830–1150
Sandstone, Jordan	70	1150–1220
Sandstone, mixed with shale	25	1220–1245
Shale, penetrated	36½	1245–1281½

The following analyses also were furnished by Mr. Maytham for the company.

Devonian and Silurian limestone, between 0 and 680 feet

	0-400 ft. per cent	400-500 ft. per cent	500-600 ft. per cent	600-680 ft. per cent
Silica	14.80	16.48	4.28	6.12
Alumina and iron oxide	4.00	4.48	2.32	2.68
Lime (CaO)	27.14	32.92	40.92	48.12
Magnesia (MgO)	17.06	11.75	11.90	3.80
Loss	37.00	34.37	40.58	39.28

	Maquoketa shale, between 680 and 765 feet per cent	St. Peter sandstone, 765 to 830 feet per cent	Prairie du Chien beds, between 830 and 1150 feet per cent	Jordan sandstone, 1150 to 1220 feet per cent	St. Lawrence beds, 1245 to 1281½ feet per cent
Silica	48.00	96.56	32.30	97.52	21.26
Alumina and iron oxide	29.60	0.88	4.88	1.20	6.51 2.05
Lime	1.80	1.72	19.72	0.80	21.56
Magnesia	trace	trace	13.60	trace	14.47
Loss	10.54	0.40	29.50	0.48	32.62

WELL OF LEHIGH PORTLAD CEMENT CO., MASON CITY

Thorpe Brothers began this well November 14, 1923, and finished it February 13, 1924. It is 1260 feet deep and its diameters are 20 inches to 251 feet, 15 inches to 755½ feet, and 12 inches to bottom. It is cased with 20 inch pipe to 14 feet, 10 inches, and 12 inch pipe to 154 feet, 7 inches. The test produced 875 gallons per minute. The static head of water is 30 feet below curb.

Log of well for Lehigh Portland Cement Co. of Mason City

	THICKNESS FEET	DEPTH FEET
Soil and broken rock	10	10
White limestone	10	20
White limestone	10	30
Dolomite limestone	300	330
Argillaceous limestone	30	360
Dolomite limestone	70	430
Argillaceous limestone	20	450
Dolomite limestone	70	520
Magnesian limestone—light	30	550
Limestone—light	30	580
Limestone—gray	10	590
Limestone	30	620
Limestone—light gray	30	650
Blue shale, soft, some lime	20	670
Blue shale, soft	50	720
Blue shale and white sand	10	730
White sand with some blue shale	20	750
White and brown sands	10	760
White sand	30	790
White sand with some brown sand and gray shale	10	800

Dolomite limestone with some gray shale	10	810
Dolomite limestone	20	830
Dolomite limestone and some white sand	60	890
Limestone and white sand	20	910
Dolomite limestone, light color	10	920
Dolomite limestone, dark gray	10	930
White sand	10	940
Dolomite limestone, gray	20	960
Dolomite limestone, light gray	50	1010
Dolomite limestone, light	70	1080
Dolomite limestone, light with some sand	10	1090
Dolomite limestone, light gray	10	1100
Dolomite limestone, gray	10	1110
White sand, coarse	40	1150
White sand, coarse and fine	20	1170
Dolomite limestone, gray with some blue shale	10	1180
Dolomite limestone, gray	60	1240
Dark gray limestone	20	1260

MAYNARD, FAYETTE COUNTY

(Altitude 1099 feet)

The town of Maynard formerly drew its public supply from a well 702 feet deep. The diameter is reported at 10 inches and the yield at 32,000 g.p.d., while the town consumption amounted to but 8,000 g.p.d. at maximum. This well has now been abandoned, and a shallow well, dug to the depth of eight feet and thence drilled to a total depth of 70 feet, has been substituted. The water stands so that a suction pump with a pumping capacity of 60,000 g.p.d. can be used.

MONONA, CLAYTON COUNTY

(Altitude 1216 feet)

WELL OF INTERSTATE POWER COMPANY

This well was drilled in 1922 by the F. M. Gray, Jr., Company. The depth is 814 feet and the diameters are from 12 to 8 inches.

*Record of Strata**

	Depth in Feet
Drift, no samples	0–46
Galena (269 feet thick):	
Dolomite, buff and blue	46–95
Dolomite, mottled gray and blue	95–105
Dolomite, gray	105–190
Dolomite, gray; chert, white	190–240
Dolomite, gray	240–255
Dolomite, gray and blue; chert, white	255–275
Dolomite, gray	275–285
Dolomite, coarse-grained, mottled gray and blue	285–295
Dolomite, gray; chert, white	295–315

* By F. T. Thwaites, geologist, Madison, Wisconsin.

Decorah (50 feet thick):	
Limestone, blue	315–335
Limestone, mottled blue and gray	335–355
Shale, blue, very calcareous	355–365
Platteville and Glenwood (40 feet thick):	
Limestone, light bluish gray	365–385
Dolomite, gray	385–395
Dolomite, gray; floating sand grains; shale greenish blue	395–405
Saint Peter (55 feet thick):	
Sandstone, medium to fine, coarser below	405–455
Sandstone, fine to coarse, gray, calcareous; shale, green	455–460
Shakopee (85 feet thick):	
Dolomite, light gray	460–545
New Richmond (6 feet thick):	
Sandstone, medium, light gray	545–551
Oneota (194 feet thick):	
Dolomite, gray, slightly sandy	551–565
Dolomite, gray	565–595
Dolomite, bluish and yellowish gray, creviced	595–600
Dolomite, gray	600–620
Dolomite, gray; chert, white	620–650
Dolomite, light gray	650–670
Dolomite, light gray; chert, white	670–680
Dolomite, light gray	680–725
Sandstone, fine, hard, calcareous, light gray	725–740
Dolomite, sandy, gray, specks of green shale	740–745
Madison (20 feet thick):	
Sandstone, coarse to fine, gray, calcareous; shale, green	745–765
Jordan (40 feet thick):	
Sandstone, fine to medium, white, calcareous	765–805
Saint Lawrence (penetrated 9 feet):	
Sandstone, exceedingly fine, light gray, very calcareous	805–814

MORNING SUN, LOUISA COUNTY

(Altitude 741 feet, C., R. I. & P. Ry.)

In 1928 a well 1205 feet deep was drilled at Morning Sun for city supply. No information is obtainable from the town officials, and possibly nothing is known locally as to this important property. The drillers, the McCarthy Well Company of Saint Paul and Minneapolis, have kindly supplied the data given below.

The diameters are from 10 to 8 inches. The static level is about 122 feet from the surface of the ground. At the test of the well 130 gallons per minute were pumped for 10 hours, with a drop pipe of 195 feet, without drawing air. The chief supply comes from the Saint Peter sandstone, which was encountered at 1141 feet.

Driller's log

	Thickness in feet
Pleistocene and Recent (64 feet thick; top 745 feet above sea level):	
"Black dirt"	0–4
"Yellow clay"	4–64
Kinderhook, upper beds (101 feet thick; top 681 feet above sea level):	
"Limerock and shale"	64–99

"Sandrock"	99–102
"Limerock"	102–165
Kinderhook shale (283 feet thick; top 580 feet above sea level):	
"Shale, cavy"	165–448
Devonian, Silurian and Maquoketa (340 feet thick; top 297 feet above sea level):	
"Rock"	448–458
"Rock and shale, cavy"	458–788
Galena and Platteville (304 feet thick; top 33 feet below sea level):	
"Rock"	788–1048
"Sandrock"	1048–1051
"Shale"	1051–1054
"Rock"	1054–1092
Glenwood formation (49 feet thick; top 347 feet below sea level):	
"Sandrock (St. Peter)"	1092–1117
"Shale"	1117–1141
Saint Peter sandstone (36 feet thick; top 396 feet below sea level):	
"Sandrock (St. Peter)"	1141–1177
Prairie du Chien, Shakopee (penetrated 28 feet; top 432 feet below sea level):	
"Limerock"	1177–1190
"Shale"	1190–1205

Notes.—Although Morning Sun is well within the boundary of the outcrops of the Osage group of the Mississippian, it seems probable that at the depth of the bed rock only the limestones, shales and sandstones of the upper beds of the underlying Kinderhook would be encountered. The heavy Kinderhook shale is well delimited, but the Maquoketa shale is vaguely indicated as a part, whose thickness is unstated, of the 330 feet described as "Rock and Shale, cavy" extending from 458 to 728 feet.

The sandstone assigned to the Saint Peter is overlain as usual by a shale, the Glenwood. In its outcrops in northeastern Iowa and in many deep well sections of the state the Glenwood beds include sandy layers resembling in color and shape of grain the underlying Saint Peter sandstone. Here the sandstone of the Glenwood is exceptionally thick.

*Mineral Content of City Well, Morning Sun**

	P.P.M.
Bicarbonate	370.9
Chloride	24.
Sulphate	77.9
Silica	6.0
$Fe_2O_3+Al_2O_3$	9.6
Calcium	63.7
Magnesium	23.7
Na + K as Na	61.4
Total solids	451.6

* Analysis by Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

MOUNT PLEASANT

(Altitude 725 feet)

WELL OF THE MOUNT PLEASANT ELECTRIC LIGHT AND WATERWORKS

A well was drilled for this company in 1915 by J. D. Shaw of Davenport. The depth is 1820 feet, the diameters from 12 to 8 inches. The main water bed is the Jordan sandstone at 1715 feet. Water was also found at 198, 1103, 1340, 1560, and 1668 feet.

The static level is 74 feet below the surface, or 659 feet above sea level, with a draw down of 25 feet under pumping. The varying static levels as the drilling was in progress are shown in the following table:

Depth in feet	Static Level in feet	Depth in feet	Static Level in feet
590	100	1293	122
770	105	1592	110
930	110	1690	100
1081	110	1738	98
1125	110	1779	80
1280	96	1820	87
			After casing 74

Thus the Cambrian waters are under higher head than are the Ordovician waters, while their normal static level may be lowered by leakages through uncased higher pervious beds.

This well is cased with wrought iron drive pipe as follows: 12 inch from curb 68 feet to first limestone; 10 inch from curb to 500 feet; 8 inch 67 feet long joined above with lead packer and below with reducing nipple to 1113 feet of 6 inch, packed at bottom with wall packer. The cost of the well was $10,000.

Chemical analysis of water by Dearborn Chemical Co., Chicago

	Grains per gallon
Silica	.595
Oxides of iron and aluminum	.153
Calcium carbonate	5.480
Calcium sulphate	13.880
Magnesium carbonate	8.600
Sodium and potassium sulphates	32.299
Sodium and potassium chlorides	8.500
Loss	.339
Total	69.846
Total incrusting solids	28.708
Total nonincrusting solids	41.138

Record of strata, well of Mount Pleasant Electric Light and Waterworks

	Depth in Feet
Pleistocene and Recent (68 feet thick; top 719 feet above sea level):	
No samples	0–68
Mississippian, undifferentiated (166 feet thick; top 651 feet above sea level);	
Limestone, blue-gray, argillaceous, soft, earthy, effervescence rather slow in cold dilute HCl; some buff limestone	68–80
Limestone, light gray, soft, crystalline-earthy, in flaky chips; some drab shale	80–130
Chert, white; some white limestone	165
Limestone, blue-gray, effervescence rapid; chert, blue	198
Limestone, white, crystalline-granular, rapid reaction	210
Limestone, yellow-gray and drab, response rapid; 2 samples	220, 231
Kinderhook (Devonian shale at base?) (368 feet thick; top 485 feet above sea level):	
Shale, blue, hard, calcareous, siliceous (microscopic angular grains), in chips	234
Shale, blue, in concreted masses	241
Sandstone, buff, calciferous, microscopic angular grains	260
Shale, blue, plastic; some white chert at 286	286, 317
Shale, drab, plastic	329
Shale, blue, plastic	351
Shale, blue, some brown	370
Shale, blue, plastic	387
Shale, brown, inflammable	398
Shale, blue, drab at 484; 8 samples	424–561
Devonian (138 feet thick, top 117 feet above sea level):	
Limestone, light yellow and gray, rapid effervescence, in sand	602, 622, 660
Shale, yellowish, calcareous, in concreted mass	689
Shale, whitish, calcareous, in concreted mass	729
Silurian (68 feet thick, top 21 feet below sea level):	
Limestone, light brown, response rapid; some gypsum	740
Limestone, gray, response rather slow; gypsum in white grains	770
Limestone, yellow-gray, response slow; gypsum in white chips and concreted masses; drab shale	790
Shale, gray, calcareous, in concreted masses; much gypsum	803
Maquoketa (37 feet thick; top 89 feet below sea level):	
Shale, blue, plastic	808
Dolomite, buff, in chips; shale; fine quartz sand in well-rounded grains	830
Galena, Platteville, Glenwood (305 feet thick; top 126 feet below sea level):	
Dolomite, buff and gray, below 882 feet in sand and powder, cherty at 965 and 983; 11 samples	845–1032
Shale, brown, highly inflammable; some dolomite and limestone	1061
Dolomite, light buff and gray, in sand and powder	1081
Dolomite, buff, in sand; some brown shale from above	1099
Dolomite, light yellow-gray, in chips; a fragment of brown crystalline quartz	1103
Sandstone, white, fine, grains rounded and frosted; some dolomite, yellow-gray, in chips	1112–1122
Shale, blue green, hard, noncalcareous	1131
Saint Peter sandstone (38 feet thick; top 431 feet below sea level):	
Sandstone, white, Saint Peter facies; larger grains up to 1.2 mm.	1150
Sandstone, white	1165
Prairie du Chien (527 feet thick; top 469 feet below sea level):	
Dolomite, light gray in chips; cuttings chiefly quartz sand	1188
Dolomite, buff and gray	1210, 1230
Dolomite, gray; some quartz sand	1246–1253
Dolomite as above	1280–1293
Dolomite, gray; a little quartz sand; 3 samples	1300–1328
Dolomite, yellow-gray, chert at 1340; 4 samples	1340–1382

Dolomite, gray; much chert	1425
Dolomite, gray; some quartz sand	1439
Dolomite, gray, cherty, much fine quartz sand	1458
Dolomite, gray, much fine quartz sand, but no imbedded grains	1475
Dolomite, gray, highly arenaceous, grains fine, rounded, secondary enlargements	1495
Dolomite, light buff, cherty	1500, 1505
Dolomite, whitish, some chert	1524
Dolomite, gray	1542
Dolomite, gray; some chert	1567
Chert, in large chips	1592
Dolomite, gray; much chert	1622
Dolomite, light gray, a little chert	1642
Dolomite, blue-gray, crystalline, pure except for slight residue of microscopic siliceous particles	1664
Chert, white and yellow-gray; some gray dolomite	1666–1668
Dolomite, gray and buff, rusted; some chert	1670
Dolomite, light gray, arenaceous, in sand	1690
Dolomite, gray and light brown; some chert	1703, 1706
Jordan sandstone (100 feet thick; top 996 feet below sea level):	
Sandstone, light cream colored in mass, fine, grains rounded, some dolomitic cement, some chert matrix	1715–1719
Sandstone, whitish, dolomitic cement, fine	1738
Sandstone, gray, some stained brown, fine-grained, secondary enlargements, dolomitic cement, in chips; 2 samples	1741, 1758
Dolomite, yellow-gray, arenaceous, in chips showing imbedded grains; 2 samples	1762, 1770
Sandstone, whitish, fine, in sand and powder, grains rounded, largest reaching 0.7 mm. diameter, dolomitic cement	1804
Sandstone, whitish, dolomitic, secondary enlargements, in chips	1796
Saint Lawrence, Trempealeau dolomite (top 1096 feet below sea level):	
Dolomite, gray and yellow-gray, in fine chips	1815

Notes.—The beds superjacent to the Maquoketa carry much gypsum, as in other deep well sections at Mount Pleasant, and are therefore assigned to the Silurian (Salina group). The dolomites of the Niagaran outcrops are not in evidence.

The Maquoketa shales, while clearly defined, have thinned much from their normal thickness in east-central Iowa. If any sandstone is connected with the formation, as appears to be the case at New London, it escaped notice and record while the well was being drilled, although some quartz sand grains appear in a sample at its base (830 feet). The Galena-Platteville is wholly dolomitic.

The relations of the Saint Peter sandstone and the Glenwood shale are peculiarly intimate, and it is to be remembered that in its outcrops the latter formation is sometimes sandy. According to a drawing of the well supplied by the Company, a sandstone extends from 1103 to 1115 feet, and is underlain by a shale 18 feet thick referable to the Glenwood. Below this lies the

Saint Peter sandstone, or the main body of the Saint Peter sandstone, 40 feet thick. The sample cuttings described above confirm this record as to the sequence of the strata, although differing somewhat from it as to dimensions.

The strata of the Prairie du Chien are typical both in their complete dolomitization and in the presence of chert and quartz sand at various levels. The New Richmond sandstone is not in evidence. Water was found at two horizons.

The main aquifer is stated to be the Jordan sandstones. This formation, while 100 feet thick, is by no means a clean pervious sandstone throughout, but has, on the whole, a large dolomitic content.

WELL OF MOUNT PLEASANT STATE HOSPITAL FOR THE INSANE, 1915

A well 1945 feet in depth was put down for this institution in 1915 by J. D. Shaw, of Davenport. The diameters are from 8 to 6 inches. The main supply was found at 1900 feet, and no records are extant of other water beds. The static level was 52 feet from the surface on completion of the well, with a pumping capacity of 80 g.p.m. The static level now stands at 110 feet, with a draw down to 150 feet. Under compressed air, the jet placed at 340 feet, the well delivers 200 g.p.m.

NAHANT, SCOTT COUNTY

(Altitude 563 feet)

WELL OF THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD AT THE NAHANT SHOPS NEAR DAVENPORT

This well, drilled by C. W. Varner, of Dubuque, is 1030 feet deep and was completed in 1928. The diameters are 20 inches for 115 feet in which are placed 30 feet of 20 inch casing and 115 feet of 15 inch casing; 15 inches to 306 feet, lined with 306 feet of 12 inch casing; 12 inches to 600 feet and 10 inches to the bottom, both uncased.

Static water stands at ground level, with a draw down to 70 feet when pumped at 225 g.p.m.

Driller's Log

	Depth in feet	Elevation above sea level, feet
Sand and gravel	0–18	563
Boulders and blue shale	18–26	
Shale and limestone	26–115	
Limestone	115–165	
Shale and limestone	165–300	
Limestone	300–420	
Shale (Maquoketa)	420–560	143
Limestone (Galena-Platteville)	560–905	3
Shale (Glenwood)	905–920	342
Sandstone (Saint Peter)	920–1030	357

*Chemical analysis**

	Grains per Gallon
Oxides	0.47
Calcium carbonate	7.50
Calcium sulphate	2.89
Magnesium carbonate	6.05
Alkali sulphate	14.95
Alkali chloride	30.20
Total	62.06

This analysis was received too late for consideration under the subject of the saltness of the wells of the Davenport field. The content of sodium chloride (alkaline chloride), 30.20 grains per gallon, is but little in excess of that of similar wells analyzed before 1900, such as the Witt's Bottling Works well, sodium chloride content 26.17 g.p.g. and the Crystal Ice and Cold Storage Company well, sodium chloride content 26.26 g.p.g.[57a] It can hardly be said, therefore, that the Nahant well offers proof of any considerable recent rise of the deep saline waters underlying this area.

NEVADA

In 1916 a city well was completed by the J. P. Miller Artesian Well Company of Chicago. The depth reached was 2792 feet. The diameters of the well are from 16 to 6 inches. The well is cased to 1780 feet.

The principal supply is said to have been struck at 2792 feet, while other water beds were found from 1800 feet downward.

The static level is 163 feet below the surface of the ground, while under continuous pumping at capacity of 180 gallons per minute there is a draw down to 212 feet below the curb.

* By Chemist of Chicago, Milwaukee, St. Paul and Pacific R. R. Co., January, 1929.

57a Norton, W. H.; Artesian Wells of Iowa: Iowa Geol. Survey, vol. VI, pp. 274-275.

*Mineral Content of City Well of 1916, Nevada**

	P.P.M.
Bicarbonate	317.2
Chloride	35.
Sulphate	417.2
Silica	7.2
$Fe_2O_3+Al_2O_3$	7.6
Calcium	114.7
Magnesium	48.8
Na + K as Na	108.9
Total solids	898.0

*Record of strata, Nevada city well, 1916**

	Depth in Feet
"Glacial drift" (60 feet thick; top 1005 feet above sea level)	0–60
"Coal Measures" (198 feet thick; top 945 feet above sea level)	60–258
Mississippian (332 feet thick; top 747 feet above sea level):	
"Limestone"	258–260
"Brown sandy shale"	260–277
"Limestone, white; 3 samples"	277–310
Shale, drab, calcareous; limestone, buff and gray, considerable quartz sand in irregular grains, and chalcedonic silica	305–310
Shale, lighter drab, calcareous	310–320
Limestone, gray-buff, fine-grained, earthy, rather slow effervescence in cold dilute HCl	320
"Shale, gray, calcareous"	330
"Shale, as above, with the addition of some light blue shale"	340
Shale, drab; limestone, gray-buff; white chert; flakes of chalcedonic silica	350
Limestone, gray, soft, fine crystalline-granular and earthy, rather rapid effervescence; vein quartz and crystals	350–360
Limestone, brown, reaction rather rapid, a little white chert, and chalcedonic silica intercrystallized with calcite	370
Limestone, light gray, soft, earthy, rather slow effervescence	390
Chert, light blue-gray and drab, large flakes; gray limestone in smaller chips; chalcedonic silica; quartz crystals; 4 samples	400–430
Chert, as above; buff limestone, minutely arenaceous	440
Limestone, yellow and buff, reaction rapid, crystalline and some oölitic; 4 samples	450–480
Limestone, dark drab, and gray-buff, rapid effervescence	490
Limestone, dark gray-buff, and light yellow-gray, in flakes, reaction rapid	500, 520
Limestone, gray-buff; rather slow effervescence; a little white chert	530
Limestone, gray-buff, rather slow effervescence	540
Limestone, brown, fine-grained, reaction rapid; blue chert	550
Limestone, brown, reaction rather slow; blue chert	560
Limestone, dark brownish gray and buff, reaction rather slow; white chert	570, 580
Shale, blue-gray, reddish brown, purple, calcareous	590
Shale, green and blue-gray, calcareous; 4 samples	600–630
"Limestone, gray, contains rounded quartz grains"	640
"Shale, light blue, noncalcareous"	650, 660
Devonian and Silurian (680 feet thick; top 335 feet above sea level):	
Limestone, light gray, calcilutite, in flaky chips	670

* Analysis by Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

* Apparently no samples of cuttings were saved below 1917 feet. The set examined by the writer is somewhat incomplete, and it is therefore supplemented by determinations made in the geological laboratory of the State College of Agriculture and Mechanic Arts when the well was drilled, and by the driller's log.

Limestone, blue and light yellow-gray and whitish, fine-grained, compact, reaction rapid, some blue shale at 680, fossiliferous at 780; 6 samples 680–730
Limestone, brown, fine crystalline-granular, and light yellow-gray 740
"Limestone, white and brown, pyritiferous" 740–780
Shale, blue, plastic, calcareous 780
Shale, gray, with some impure gray and buff limestone of rather slow effervescence 790
Shale, blue, as at 780 800
Limestone, blue-gray, reaction rapid, limestone, buff, rather slow effervescence 810
Dolomite, brown, crystalline 820
Limestone, whitish and light gray, rapid reaction; 3 samples 830–850
Limestone, brown, reaction rather slow; limestone, gray, rapid reaction; in sand 860
Limestone, light blue-gray, calcilutite, rapid effervescence 870, 880
Shale, light blue-gray, highly calcareous 890
Limestone, gray-buff, crystalline-granular, reaction rapid, some rather slow 900, 910
"Limestone, dolomitic, brownish white" 920, 930
Dolomite, gray-buff, very fine crystalline-granular; 4 samples 940–970
Dolomite, light yellow-gray and buff, crystalline-granular; some limestone, reaction rapid; 3 samples 980–1000
"Dolomite, brown; contains some light blue noncalcareous shale" 1010
Dolomite, brown and buff, crystalline-granular; 4 samples 1020–1050
Gypsum, white, in hard concreted masses, with some dolomite; 3 samples; at 1080 rusted and pyritiferous 1060–1080
Dolomite, buff; limestone, buff; a little gypsum 1090
Dolomite, buff-gray, fine-grained, compact, a little gypsum at 1120; 3 samples 1100–1120
"Limestone, white, argillaceous" 1130
Limestone, light buff-gray, calcilutite, rapid effervescence 1140, 1150
Limestone, brown and light gray, rather slow effervescence 1160, 1170
Shale, light blue-gray, calcareous 1180
Dolomite, buff, argillaceous; 3 samples 1190–1210
Dolomite, buff and gray; shale, drab, fissile 1220
Limestone, buff, reaction rather slow; much blue-gray and white chert 1230
Chert, blue-gray and white, some translucent, limestone, light gray, reaction rather slow; 3 samples 1240, 1260
"Dolomite, white, highly siliceous, very hard to dissolve in HCl; 6 samples" 1270–1320
Dolomite, whitish; some white chert 1320
"Dolomite, brownish white" 1330
Dolomite, light yellow-gray; a little chert 1340

Maquoketa shale (50 feet thick; top 345 feet below sea level):

Shale, blue, calcareous, in moulded masses, including some chips of white chert 1350
Shale, blue, calcareous; some purplish drab, fissile, somewhat calcareous 1360
Shale, drab and purplish drab 1370
Shale, light blue-green, calcareous 1380, 1390

Galena to Platteville inclusive (480 feet thick; top 395 feet below sea level):

Dolomite, brown, cherty 1400, 1410
Dolomite, gray, cherty, in fine crystalline meal 1420
Dolomite, gray, much chert of the same color in chips of same size 1430
"Dolomite, brownish white" 1440–1490
Dolomite, gray, much chert of same color 1500
"Dolomite, white" 1510–1530
Dolomite, yellow-gray, in fine crystalline sand 1540
"Dolomite, white" 1550–1570
Dolomite, yellow-gray, in fine crystalline sand, cherty at 1600 and 1620; 3 samples 1580–1620
Limestone, whitish, argillaceous, in friable masses; rather slow reaction 1630

Dolomite, light buff, in crystalline sand	1650
"Limestone, brownish white"	1660–1720
Dolomite, light buff-gray	1720
"Limestone, brownish white; 2 samples"	1720–1830
"Limestone, brown"	1830
"Dolomite, white, contains particles of blue noncalcareous shale (Glenwood shale)"	1840–1860
"Limestone, white"	1870
Saint Peter sandstone (47 feet thick; top 875 feet below sea level):	
"Sandstone, white, water-worn; and blue shale"; 2 samples	1880–1917

Driller's Log

	Depth in Feet		Depth in Feet
Soil and yellow clay	0–30	Lime	775–780
Gravel and boulders	30–33	Shale	780–810
Sand and yellow clay	33–60	Lime	810–811
Black and gray shale	60–75	Shale	811–820
Red marl	75–93	Lime, very good	820–1140
Brown shale	93–100	Very dark brown hard lime	1140–1260
Dark brown shale	100–150	Quartz lime (1260)	1260–1325
Black shale	150–200	Brown lime	1325–1345
Gray slate	200–202	Green shale	1345–1406-5
Black shale	202–248	Brown hard limestone	1406-5–1513
Gray soft slate	248–258	White hard lime	1513–1690
Lime	258–260	Brown yellow lime	1690–1800
Brown sandy shale	260–277	Had 2 feet soft drilling after 1800 and green shale	1800–1840
Got solid lime at	277	Hole caves badly	1844
Gray and brown lime	277–305	Hard lime	1844–1870
Brown shale	305–310	Lime	1870–1884
Gray shale	310–320	Sand, hard	1884–1917
Shale	320–345	Lime	1917–2080
Lime	345–355	Sand	2080–2090
Shale	355–365	Lime	2090–2120
Broken lime	365–430	Sand and sandy lime	2120–2198
Brown lime	430–470	White sand	2198–2235
Gray and blue lime	470–570	Lime	2235–2407
Red and brown shale, looks like iron bog	570–580	Sand	2407–2432
Shale, blue, looks whitish when drilled up	580–667	Sandy lime	2432–2650
Lime	667–668	Shale, marl and lime, streaked; water stands at 145 feet from the surface	2650–2720
Shale	668–672	Green sand and lime	2720–2750
White lime	672–760	Lime and sand rock	2750–2792
Shale	760–775		

CITY WELL OF 1928

This well, drilled by Thorpe Bros. Well Co. of Des Moines, is 2791 feet deep with diameters from 16 to 6 inches. The main supply was found from 2723 to 2791 feet, in or just below the Franconia beds of the Saint Lawrence formation. Other water beds reported are: 1890 to 1925 feet (Saint Peter sandstone), 2190 to 2215 feet (New Richmond sandstone), and 2240 to 2250 feet (Oneota dolomite). Tests, however, of these beds "did not show much water". The final tests showed a pumping capacity

of 250 g.p.m. The static level is 165 feet below the surface or within 2 feet of that of the well of 1916. The static level as the well was drilled is stated to have been about the same as at the completion. The draw down is to 241 feet below the surface of the ground. The temperature of the water is 67°. Its effect on boilers is bad. The cost of the well was $29,000.

The casing of the well is as follows: 303 feet of 16 inch, 533 feet of 12 inch, 622 feet of 10 inch, 519 feet of 8 inch, and 885 feet of 6 inch.

*Mineral Analysis of Nevada well of 1928**

CONSTITUENT	PARTS PER MILLION	GRAINS PER U. S. GALLON
Sodium and potassium	103.2	5.99
Calcium	139.5	8.10
Magnesium	59.97	3.50
Iron and alumina	4.34	0.25
Sulphate	554.3	32.2
Nitrate	none	none
Chloride	30.0	1.74
Bicarbonate	327.0	18.98
Normal carbonate or hydroxide	none	none
Silica	22.2	1.29
Total mineral residue	1217.	70.5
Fixed mineral residue	1011.	58.6
Organic and volatile residue	206.	11.9
Total hardness (soap method)	380.	22.1

An analysis made in August, 1928, by the International Filter Co. of Chicago gives the following hypothetical combinations:

	PARTS PER MILLION		PARTS PER MILLION
Calcium carbonate	273.	Suspended matter	20.
Calcium sulphate	88.	Sodium sulphate	482.
Magnesium sulphate	195.	Sodium chloride	63.
Iron oxide (unfiltered sample)	4.3	Free carbon dioxide	6.0
Silica	13.		

Record of strata, Nevada Well, 1928

	DEPTH IN FEET
Pleistocene and Recent (68 feet thick; top 1005 feet above sea level):	
Till, brown-buff, sandy, calcareous, in lumps	10
Till, buff, calcareous	20
Till, or clay, light drab, feebly calcareous; some coarse sand; in moulded masses	30
Till, bright yellow, sandy, calcareous	35, 40
Till, yellow, pebbly, calcareous	57
Sand and gravel, pebbles up to 2½ cm.	65
Till, greenish drab, calcareous, sandy	68

*By M. K. Tenny, Des Moines, August, 1928.

Pennsylvanian (203 feet thick; top 937 feet above sea level):	
Shale, red, yellow and whitish, unctuous, noncalcareous	77
Shale, pink, some blue	88
Shale, drab and black	95
Shale, blackish, some pebbles from the drift; coal	105
Shale, light blue-gray, very finely arenaceous	115
Shale, pink and gray; 3 samples	127–150
Shale, black	162
Shale, gray	170
Shale, dark drab	185
Shale, gray and blackish	205
Shale, drab	220
Shale, black	230, 240
Shale, very light gray, finely arenaceous	258
Shale, drab; sandstone, gray, calcareous, fine irregular grains	262
Shale, gray and blackish	268
Mississippian (390 feet thick; top 725 feet above sea level):	
Limestone, yellow-gray, fine-grained, rather rapid effervescence in cold dilute HCl; in large chips concreted in shale	280
Limestone, drab in mass, yellow-gray, crystalline-earthy, rapid and moderately rapid effervescence, slightly arenaceous with fine irregular grains of clear quartz	300, 310
Shale, light gray	320
Shale, drab, and limestone	350
Chert and chalcedonic silica in chips; some quartz sand; a little buff and drab limestone; concreted with gray shale	360
Shale, drab, a little white chert; drab argillaceous limestone	370
Shale, gray; milky quartz; gray soft limestone of rapid effervescence; colorless quartz	380
Limestone, light gray and drab, rather slow effervescence; milky quartz; shale, gray, in hard concreting masses	390
Limestone, gray; some milky quartz	390–400
Chert, light blue-gray and white in large chips; milky quartz; some gray limestone of rather slow effervescence	410–430
Limestone, buff, rapid effervescence; some white chert; chip of aggregate of calcite, pyrite, chalcedony and clear quartz	440
Limestone, yellow and buff, rapid effervescence, crystalline-granular, in sand	450–470
Limestone, light brown and gray, some mottled, rapid effervescence; in large flakes	480, 490
Limestone, gray, yellow-gray and brown, rapid effervescence	500-520
Limestone, drab, fine crystalline, moderately rapid effervescence; in large flakes	530
Limestone, brown, moderately slow to rapid effervescence; much blue-gray, gray and white chert; 4 samples	540–570
Kinderhook shale:	
Shale, brown, some light blue, arenaceous	580
Shale, greenish and light blue-gray, calcareous	600, 610
Limestone, gray, cherty, pyritic, slow effervescence	630
Shale, light blue-gray, calcareous; 3 samples	640–660
Devonian (330 feet thick; top 335 feet above sea level):	
Limestone, gray, fine-grained, earthy, rather rapid effervescence; in large flakes	670
Limestone, light yellow-gray and gray, calcilutite and fine-grained, rapid effervescence; 5 samples	680–720
Limestone, very light gray, fossiliferous, soft, earthy-fine-crystalline; gray limestone harder, compact, of very fine grain; all of rapid effervescence	740, 750
Limestone, as above, in sand; much blue-gray calcareous shale in chips and a little dark gray argillaceous and microscopically quartzose limestone	760
Limestone, drab, fine-crystalline, rather slow effervescence; some shale	770

Shale, blue-gray; limestone of same color, crystalline-granular, rather rapid effervescence 780
Shale, light blue, calcareous; in hard moulded masses 800, 810
Limestone, whitish and light gray, rapid effervescence, earthy; 4 samples 830–860
Limestone, or dolomite, dark gray, slow effervescence, fine-crystalline..... 870
No samples 880, 890
Limestone, light gray, rapid effervescence 900
Dolomite, buff and gray, crystalline-granular 910–920
Dolomite, buff and yellow-gray; some drab limestone 930
Dolomite, buff, hard, crystalline-granular 940
Limestone, magnesian, or dolomite, gray-buff, rather slow effervescence, fine-grained 950, 960
Limestone, buff, gray-buff and brown, some macrocrystalline, rather slow effervescence, with calcite 970, 980
Limestone, light yellow-gray, some rapid, some slow effervescence; in sand 990
Limestone, gray and light yellow-gray, rather rapid effervescence 1000

Silurian (340 feet thick; top 5 feet above sea level):

Dolomite, brown, some gray, a little gypsum in small white chips 1010
Dolomite, buff, brown and gray, a little gray shale 1020
Dolomite as above, a little gypsum in white chips 1030
Dolomite, brown and buff, fine crystalline-granular; flakes of yellow-gray limestone 1040
Dolomite, gray; drab laminated shale, considerable gypsum in chips..... 1050
Gypsum, in large gray chips; hard greenish drab shale, laminated, non-calcareous in large chips; brown dolomite in sand 1060
Dolomite, gray, fine-grained, rather slow effervescence, a little gypsum 1070
Gypsum, gray, in hard concreted mass with some dolomite 1080
Dolomite, buff and gray, fine-grained, much gypsum in chips and concreted masses 1090, 1100
Dolomite, gray and buff, hard; an occasional flake of dolomite with selenite 1110, 1120
Dolomite, buff; some white argillaceous masses with a little chert..... 1130
Limestone, light buff-gray, rapid effervescence; some buff dolomite; considerable light blue shale 1140
Dolomite, buff-gray; some limestone 1150
Dolomite, brown, rather slow effervescence, cherty at 1160; 3 samples..1160–1180
Dolomite, buff and yellow-gray, argillaceous; 3 samples 1190–1210
Chert, white, blue and yellowish, some translucent, but polarizing as flint; some gray limestone or dolomite of rather slow effervescence; 10 samples 1220–1310
Dolomite, light yellow-gray, a little white chert 1320
Dolomite, blue-gray 1330

Ordovician:

Maquoketa shale (80 feet thick; top 335 feet feet below sea level)—
Shale, light blue-gray and red, calcareous, in concreted masses 1340
Shale, blue and greenish gray, drab at 1390, with chips of chert probably from above; 6 samples 1350–1400
Galena-Platteville (440 feet thick; top 415 feet below sea level)—
Dolomite, buff and brown in mass, in fine crystalline sand, cherty, much gray and buff chert at 1460; 5 samples 1420–1480
Shale, drab; much dolomite in fine crystalline sand 1490
Dolomite, drab, highly argillaceous, in chips; much drab flint and shale 1500
Dolomite, buff-gray, in crystalline sand and chips, argillaceous; much flint of same color, and some milky quartz 1510
Dolomite, drab in mass, argillaceous; much flint of same color 1520
Shale, drab; considerable light gray limestone of rapid effervescence and white chert 1530
Dolomite, gray, yellow-gray and buff, in crystalline sand; 11 samples 1540–1640

Limestone, buff-gray and light gray, rapid effervescence; some dolomite; cinders; 3 samples 1650–1670
Limestone, gray, fine-crystalline, soft, in large chips 1680, 1690
Dolomite, gray and light brown, in sand, cherty except at 1700; 4 samples 1700–1730
Limestone, gray and yellow-gray in mass, rapid effervescence, some large thin flakes; some dolomite and chert 1740, 1750
Limestone, light gray, whitish, gray and buff, earthy, rapid effervescence; fossiliferous and with a little shale at 1830; 8 samples 1760–1830
Limestone, gray in mass, some brown inflammable shale in large flakes 1840
Limestone, gray, fossiliferous 1845
No samples 1845–1860

Glenwood shale (20 feet thick)—
Shale, dark green, in small flakes; much limestone, light gray, soft, earthy; pyrite 1860
Shale, as above, feebly calcareous, in large flakes; limestone as above 1860–1870
Shale and limestone as above 1870–1878
Shale, dark slaty green, hard, in parts with conchoidal fracture, noncalcareous 1878–1880

Saint Peter sandstone (40 feet thick; top 875 feet below sea level)—
Sandstone, gray in mass, grains medium, well rounded, frosted, of clear colorless quartz; much green shale in large flakes 1880–1890
Sandstone as above, grains up to .7 mm. in diameter; much shale in small flakes 1890–1895
Sandstone, white, as above; considerable shale; sandstone finer at 1913; 4 samples 1895–1920

Prairie du Chien—
Shakopee dolomite (190 feet thick; top 915 feet below sea level)—
No samples 1920–1950
Dolomite, brown; much white chert; a little quartz sand 1950
Dolomite, gray, some quartz sand 1960, 1970
Dolomite, buff, white siliceous oölite in fine spherical grains 1980
Chert, white; dolomite, brown-gray 1990
Dolomite, light buff and light gray; cherty at 2000 and 2020; a little quartz sand; 4 samples 2000–2030
Dolomite, buff and gray; considerable quartz sand; imbedded grains in dolomite chips; secondary enlargements; some chert and pyrite; 6 samples 2040–2090
Dolomite, brown-gray, highly arenaceous; imbedded grains; an occasional quartz crystal 2100
Dolomite, light buff, oölitic; highly arenaceous 2110

New Richmond beds (100 feet thick; top 1105 feet below sea level)—
Sandstone, white, grains well rounded, frosted, secondary enlargements, grains up to 1 mm. in diameter; some buff dolomite 2120–2130
Dolomite, yellow-gray; a large chip pyritic and with sandstone laminae 2140
Dolomite, yellow-gray; some quartz sand 2150
Dolomite, gray, arenaceous with imbedded grains; sandstone fine, in chips and sand, secondary enlargements 2160
Dolomite, very light gray; sandstone with dolomitic cement and secondary enlargements 2170
Sandstone, white, rusted yellow, fine, larger grains well rounded, frosted; secondary enlargements; a little dolomite 2180, 2190
Sandstone, white, larger grains 1.2 mm. in diameter, well rounded, frosted; some chips of fine sandstone with dolomitic cement 2200, 2210

Oneota dolomite (160 feet thick; top 1205 feet below sea level)—
Dolomite, gray and buff, vesicular and macrocrystalline at 2240, embedded grains of quartz sand at 2250; cherty at 2300; more or less quartz sand in all samples; 15 samples 2220–2370
No samples 2380, 2390

Cambrian:
Jordan sandstone (30 feet thick; top 1385 feet below sea level)—
Sandstone, light yellow-gray in mass, fine, well rounded grains; some dolomite in chips showing imbedded grains 2400, 2410
Sandstone, yellow, clean, larger grains 1 mm. diameter 2420
Saint Lawrence—
Trempealeau dolomite (200 feet thick; top 1415 feet below sea level)—
Dolomite, gray, a little quartz sand 2430
Dolomite, light yellow-gray, in finest crystalline sand or in chips; 3 samples 2440–2460
Sandstone, blue-gray in mass, grains minute or microscopic, pyritic, dolomitic; in chips and powder slightly concreted 2470
Dolomite, blue-gray, minutely arenaceous, pyritiferous; argillaceous at 2510; 4 samples 2480–2510
Dolomite, gray, brown and buff; 3 samples 2520–2540
Dolomite, gray, minutely arenaceous, pyritic, in chips and concreting powder 2550
Dolomite, dark gray, in chips 2560
Dolomite, gray, pyritic and minutely arenaceous at 2580; 6 samples 2570–2620
Franconia beds (165 feet penetrated, top 1615 feet below sea level)—
Shale, light gray, in friable moulded masses; dolomite, glauconitic, minutely arenaceous 2630
Shale, drab, unctuous, in hard concreted masses inclosing small chips of highly quartzose dolomite 2640
Sandstone, gray, grains minute, highly glauconitic, dolomitic 2650
Sandstone, gray, grains minute, some fine and rounded, pyritic, glauconitic, dolomitic; splintery flakes of dark drab laminated shale slightly dolomitic; 3 samples 2660–2680
Shale, dark drab, finely laminated; a little limestone, very light gray, mottled dark gray and buff, rapid effervescence, soft, earthy, in thin flakes, minutely quartzose, glauconitic; some sandstone at 2710, grains minute, calcareous, rapid effervescence, glauconitic; 3 samples 2690–2710
Sandstone, fine and of microscopic grains, glauconitic, dolomitic; shale, dark drab, in large flakes 2720
Shale, strong green, highly glauconitic and arenaceous; or sandstone, argillaceous; in concreted friable masses; shale, dark drab, fissile, in flakes 2730
Sandstone, gray in mass, in detached grains, highly diverse in size from minute quartzose particles to fine, some grains well rounded, a few secondary enlargements of clear colorless quartz, highly glauconitic; 3 samples 2735–2745
Sandstone, green and gray, grains as above, highly glauconitic; argillaceous, powder; much drab shale in thin flakes 2750, 2760
Sandstone, gray, grains as above, glauconitic; splinters of drab shale 2765, 2770
Sandstone, clean except for a little drab shale, very fine, not well rounded except some of larger grains, an occasional grain of feldspar and ferromagnesian mineral 2775, 2780
Sandstone, buff, coarser, a few grains reaching 1 mm. diameter; much green shale in friable masses, highly arenaceous and glauconitic; much drab shale 2785
Sandstone, buff, gray and green, in small chips, hard, minute, some grains fine and rounded, highly glauconitic, non-dolomitic; much drab shale in large thin flakes, cuttings mostly shale 2790

Notes.—In the Nevada section no attempt has been made to discriminate the different formations of the Mississippian above the Kinderhook shale. To this formation is assigned the shale from 570 to 680 feet (driller's log of well of 1916), which clearly is the same as the shale in the Marshalltown well at corresponding depth.

No definite line can be drawn between the Devonian and Silurian, since the lower beds of the Devonian are, in places, as at Cedar Rapids, dolomitized. At Ames Beyer assigned to the Devonian a thickness of 310 feet. A like thickness at Nevada will carry the Devonian near to the gypsum-bearing beds at 1010 feet (well of 1928), which credibly may be taken as Silurian of the Salina group. The heavy chert bed near the base is worthy of note, since chert characterizes the basal beds of the Niagaran.

The shale from 1340 to 1420 may be assigned to the Maquoketa with confidence, and perhaps the shales and argillaceous dolomite from 1490 to 1540, together with the 70 feet of overlying cherty dolomite, should go to the same formation. Gray cherts are characteristic of this horizon.

In the cuttings of the well of 1916 a sample labelled 1620-1650 is of sandstone of St. Peter facies, with shale of Glenwood facies and some dolomite. This was omitted from the record of strata as evidently an error in labelling. The samples of the well of 1928 show no sandstone of the kind above the Saint Peter at 1880 feet.

The persistent brown inflammable shale at 1840 feet signalizes the near approach of the Glenwood shale and the Saint Peter sandstone.

The Glenwood shale is not well made out in the cuttings of 1916, but is clearly shown in those of the well of 1928. Here it is 20 feet thick, and unless the limestone in the upper cuttings is foreign, includes considerable limestone, showing a gradation into the overlying Platteville.

The Saint Peter sandstone occurs considerably below the depth at which it might be expected with a fairly uniform descent from the east and some share in the Ames Anticline of Beyer. The gradient from Cedar Rapids, where the Saint Peter is abnormally thin, to Belle Plaine is five feet to the mile. From Belle Plaine to Nevada the gradient is somewhat steeper, 6.5 feet to the mile.

But in the eight miles from Nevada west to Ames the Saint Peter rises 455 feet in the Ames anticline and but 30 feet of this can be laid to the greater thickness of the formation at Ames. This pronounced upfold is thus narrower on the eastern limb than might have been expected and the position of the Saint Peter is correspondingly deeper at Nevada. A rather narrow downfold at Nevada may accompany the Ames upfold. Thus the writer's forecast of the normal depth to the Saint Peter at Nevada, as about 1600 feet, based on a uniform dip from the east, was about 280 feet astray.[58] The three members of the Prairie du Chien are well demarked—the Shakopee dolomite, oölitic at two levels, the sandstone and sandy dolomites of the New Richmond, and the Oneota dolomite.

The Jordan is but 30 feet thick and in part carries a dolomitic matrix which seriously interferes with its capacity as an aquifer.

The Trempealeau dolomites of the Saint Lawrence include characteristic sandy layers of minute angular grains of clear quartz, and at 2630 feet pass into the Franconia beds, characterized by shales, minutely arenaceous dolomites, and sandstones of microscopic grain, all of which may be glauconitic. In certain beds the glauconite is so abundant as to constitute a veritable "greensand".

No coarse, clean sandstone of Dresbach facies was encountered. Apparently at the bottom of the well the drill was still in the Franconia. It is possible, however, that the sandstone at 2765 feet is the westward extension of the Dresbach and that the footing of the well is in the Eau Claire beds.

The following table shows the comparative thickness in feet of the formations below the Saint Peter in the deep wells of this area.

	Nevada	Grinnell	Ames	Boone	Des Moines
Prairie du Chien	450	449	610	-----	393
Jordan	30	60	105	-----	147
Trempealeau	200	110	10+	-----	-----
Total of above	680	619	725+	525	540
Franconia	165+	140+		421?	435?
Dresbach				54?	
Eau Claire				14+?	

[58] Underground Waters of Iowa, Iowa Geol. Survey, vol. XXI, p. 912.

Driller's log of Nevada Well, 1928

	Depth in Feet
Soil	0–5
Yellow clay and sand	5–23
Blue clay	23–35
Yellow clay, sandy	35–186
Dark yellow clay	186–195
Sand and gravel	195–203
Light blue shale	203–213
Red shale	213–223
Shale mixed	223–251
Red shale	251–264
Light shale	264–274
Dark colored shale	274–288
Slate colored shale	288–331
Dark colored shale	331–375
Lime rock broken with streaks of shale	375–448
Solid white lime	448–485
Broken lime and shale	485–701
Shale, blue	701–744
Lime rock	744–766
Shale	766–781
Lime rock	781–864
Shale	864–866
Lime, white	866–911
Shale, light	911–933
Lime rock, white	933–1132
Brown lime	1132–1205
Lime, brown, hard	1205–1254
Lime, white	1254–1268
Brown lime	1268–1315
Gray lime	1315–1350
Lime broken with shale, sandy	1350–1420
White lime	1420–1500
Brown lime	1500–1550
Hard white lime	1550–1620
Brown lime	1620–1630
Hard brown lime	1630–1715
White lime	1715–1765
Brown lime	1765–1827
Shale, blue	1827–1828
Brown lime	1828–1845
Green shale	1845–1849
Brown lime	1849–1878
Green shale	1878–1890
St. Peter sand	1890–1925
Gray lime	1925–1932
Case with 8 in. casing 532-4	1932–2451
Gray lime	1932–1940
Gray lime, hard	1940–1980
White lime	1980–1992
White lime, hard	1992–2030
Brown lime	2030–2103
White sandy lime, dolomitic	2103–2190
New Richmond sand	2190–2215
Lime, dark, hard	2215–2240
Lime, some water, no cuttings	2240–2250
Brown lime, hard	2250–2280
White lime	2280–2340
Brown lime	2340–2404
Sand	2404–2425
Brown lime	2425–2580
Gray lime	2580–2654
Green shale	2654–2660
Lime, broken, streaks of shale	2660–2723
Sand, green color	2723–2785
Lime	2785–2791

NEW ALBIN, ALLAMAKEE COUNTY

(*Altitude 651 feet*)

Eight artesian wells in the village of New Albin are listed in the Report on the Underground Water Resources of Iowa, 1912, and since that time several others have been drilled. As for the most part no pains have been taken to prevent waste, the supply is now overdrawn and the static level has sunk from 682 feet to 659 feet above sea level.

In 1925 a deep well was completed for public supply by the Howard R. Green Company of Cedar Rapids, with J. W. Welsh of La Crescent, Minnesota, as driller. The depth is 585 feet, the diameters are 10 and 8 inches. During the drilling water stood between 25 and 30 feet below the surface until at a depth of 365 feet, in the sandstones of the Mount Simon formation, it overflowed. The head is four feet above the surface and the pump-

ing capacity is more than 150 gallons per minute. In a 30 hours pumping test with this discharge the water level in the casing was lowered one foot. Wrought iron 10 inch casing is inserted to the depth of 148 feet. The cost of the well was $924. The discharge is kept under strict control without surface waste.

Record of strata in New Albin City well no. 1

	Depth in Feet
Pleistocene and Recent:	
Cambrian:	
Eau Claire—	
Sandstone, light green-gray, argillaceous, calcareous, grains mostly microscopic, with some coarser rounded grains	165
Sandstone, buff, very fine, grains imperfectly rounded	185
Sandstone, green-gray, glauconitic, argillaceous, grains minute, noncalcareous	220
Shale, red, highly arenaceous, quartz grains coarse and fine, in tough concreted masses	270
Shale, gray, calcareous, highly arenaceous, grains coarse and fine; in friable concreted masses	302
Sandstone, light green-gray, coarse and fine, larger grains rounded, argillaceous	325
Mount Simon:	
Sandstone, white, clean, rounded grains up to 1 mm. and 1.5 mm. diameter; 2 samples	365, 463
Sandstone, light yellow-gray, grains rounded, coarse and fine, at 515 feet many about 2 mm. diameter and some more than 3 mm.; 3 samples, 467½, 515 and	530
Sandstone, red, coarse and fine grains of clear quartz with much red argillaceous material, noncalcareous	575
Sandstone, light pink in mass, mixture of grains of clear quartz and minute chips of red sandstone	585

Notes.—At New Albin the summit of the Jordan sandstone has been placed by Calvin [59] at 966 feet above sea level. The 476 feet which intervene between this datum and the first argillaceous sandstone in the above section seems a fairly ample measure to include the Jordan, the Saint Lawrence and the Dresbach, whose combined thickness at Lansing, McGregor and Dubuque is about 500 feet. It is therefore assumed that the Dresbach sandstone has been cut out by the ancient channel of the Mississippi, and that the first clayey sandstone struck belongs to the Eau Claire.

From New Albin to McGregor the summit of the Jordan outcrops falls 292 feet, and the summit of the Eau Claire in deep well sections falls at least 288 feet from New Albin to Prairie du Chien. Thus with some thickening of the Eau Claire beds, it is easily possible that the red argillaceous sandstone struck at 575

59 Calvin, Iowa Geol. Survey, vol. IV, p. 55.

feet at New Albin (80 feet above sea level) may be the same as a red sandstone 45 feet thick which was struck at 272 feet below sea level at Prairie du Chien.[60]

Both the character of the material and the probable nearness of the Algonkian or Archean floor—crystalline rock was struck at 108 feet below sea level at Lansing—suggest that the red sandstone at the bottom of the New Albin well may also be the equivalent of the Red Clastic beds of Minnesota. The Mount Simon, however, also includes in Wisconsin pink and reddish beds.

NEW LONDON, HENRY COUNTY

(Altitude 765 feet)

In 1916 a deep well was completed for the town of New London by William Jennings of Burlington. The depth is 1485 feet and the diameters are from six to four inches. The principal supply was found at 1450 feet in the Prairie du Chien dolomites. No other water beds are reported. The static level is 140 feet below the surface. With the pumping cylinder at 250 feet the pumping capacity is now 40 g.p.m., a decrease of but 10 g.p.m. since the well was completed. The water is reported too hard for boiler use. Maximum consumption is stated to be 60,000 gallons per day.

Record of strata of well of town of New London, 1916

	Depth in Feet
No samples, or record	0–273
Mississippian:	
Limestone, buff and light yellow, rapid effervescence in cold dilute HCl, in fine sand; quartz sand in ill-rounded grains; white chalcedonic silica	273–286
Sandstone, light blue-gray, calciferous, argillaceous, grains microscopic, angular; in rusted chips	285–295
Limestone, brown and dark gray, rather slow effervescence; some whitish, soft, rapid; white chert and chalcedonic silica	294–302
Sandstone, as at 285; some chert and chalcedonic silica; 2 samples	302–320
Kinderhook (and Devonian shale at base ?) (287 feet thick; top 448 feet above sea level):	
Shale, blue, calcareous	320–460
Shale, brown, inflammable	460–470
Shale, blue, calcareous	470–607
Devonian (153 feet thick; top 161 feet above sea level):	
Limestone, light blue-gray, highly argillaceous, rapid effervescence; some shale, chert and pyrite; 2 samples	607–632
Limestone, yellow-gray and buff, effervescence rapid; shale and white chert	632–646
Limestone, blue-gray, earthy, fossiliferous, soft, some large chips	646–651
Limestone, yellow-gray, effervescence rapid, in fine chips	651–663

[60] Geol. of Wisconsin, vol. IV, p. 61.

Limestone, brown, effervescence rapid, earthy, in chips 663–667
Limestone, blue-gray, effervescence rapid; pyrite and a little chert 667–670
Limestone, blue-gray, argillaceous, fossiliferous 670–673
Limestone, dark gray, earthy, in large flakes, rapid effervescence 673–685
Limestone, blue-gray, rapid effervescence; in fine chips 685–695
Limestone, yellow-gray, earthy, rapid effervescence, fossiliferous, in flaky chips; 4 samples 695–720
Limestone, yellow-gray, compact, effervescence rapid, fossiliferous, in fine chips 720–730
Limestone, whitish, rapid effervescence, in flaky chips 732–740
Limestone, blue-gray and yellow, compact, effervescence rather slow; chocolate brown limestone, effervescence rapid, inflammable; whitish limestone, rapid effervescence 740–744
Limestone, yellow-gray, effervescence rapid, in sand; 2 samples 744–760

Silurian (58 feet thick; top 8 feet above sea level):
Limestone, brown and buff, effervescence rapid, in sand; gypsum in white soft masses and chips; 3 samples 760–796
Limestone, brown, effervescence rapid, some slow; white chips of crystalline quartz, nongranular, a few cleavages noted (altered from anhydrite?) 796–806
Limestone, blue-gray, effervescence rapid; some quartz; shale in powder 806–818

Ordovician:
Maquoketa shale (42 feet thick; top 50 feet below sea level)—
Shale, blue, plastic, calcareous 818–830
Shale, blue; limestone, blue, argillaceous; limestone, light gray 830–837
Sandstone, light gray, fine ill-rounded grains, in flaky chips 837–843
Limestone, blue-gray, highly arenaceous, or sandstone, calciferous, grains as above 843–850
Sandstone, gray, calciferous, larger grains well rounded, up to 0.6 mm. diameter, in chips and sand 850–852
Galena, Platteville, Glenwood (282 feet thick; top 84 feet below sea level)—
No sample 852–860
Dolomite, blue-gray and light buff, cryptocrystalline, in sand 860–870
Dolomite, buff and light yellow-gray, in fine crystalline sand and flour; some powder of limestone with rather rapid effervescence from 1065 to 1082; 24 samples 870–1100
Dolomite, brown and buff, in fine chips 1100–1105
Dolomite, buff, in fine sand; shale brown, inflammable; brown and gray chert 1105–1113
Limestone, light buff, in fine sand, effervescence rather rapid; 2 samples 1113–1134
Saint Peter sandstone ? (top 366 feet below sea level)—
Sandstone, white, grains well rounded, some secondary enlargements, larger grains 0.5 mm. in diameter 1134–1170
Shale, green, unctuous, noncalcareous, pyritiferous 1170–1180
No samples 1180–1340
Prairie du Chien:
Dolomite, gray, in sand; much quartz sand in sample and a little chert 1340–1345
Chert, white; dolomite, light yellow-gray 1345–1360
Dolomite, gray, in sand; much fine quartz sand 1360–1385
Dolomite, light yellow-gray; chert 1385
Dolomite, light buff, oölitic; quartz sand 1390
Dolomite, light yellow-gray; chert 1400
Dolomite, light buff 1418
Dolomite, gray, with minute cavities as from removal of oölitic grains; chert, oölitic 1440
Dolomite, gray, cherty at 1460 and 1482; 4 samples 1450–1482
Sandstone, clean, white, grains well rounded and frosted, many larger grains of 1 mm. diameter, some secondary enlargements 1485

Notes.—The thin bed of sandstone or calciferous limestone at the base of the Maquoketa may be compared with the layer of sandstone in the well of the Electric Company, Mount Pleasant (page 265) at about the same horizon, and represented only by well rounded sand grains in a single sample. Sand grains are also found in one of the samples representing the Maquoketa from Hospital well no. 3 at Mount Pleasant.

It is quite possible that the sandstone at 1134 feet and the shale at 1170 feet may be the Glenwood, and that the Saint Peter lies within the reach unrepresented by samples from 1180 to 1340. The sandstone encountered at the base of the well, 1485 feet, might easily be referred to the Jordan, but this would assign a considerable less thickness to the Prairie du Chien than it carries at Mount Pleasant, where it reaches 527 feet.

*Mineral Content of City Well, New London**

	P.P.M.
Bicarbonate	261.1
Chloride	149.
Sulphate	491.8
Silica	6.6
$Fe_2O_3+Al_2O_3$	17.0
Calcium	86.5
Magnesium	35.4
Na + K as Na	272.2
Total solids	1189.0

NORTH ENGLISH, IOWA COUNTY

(Altitude 784 feet)

A deep well was completed in 1921 for this city by Thorpe Brothers' Well Company of Des Moines. The depth is 1678 feet and the diameters are from 13 to 6 inches. The chief supply was found at 1678 feet, and another water bed at 1300 feet. The water rises within 70 feet of the surface. With the pumping cylinder at 220 feet the capacity of the well is 100 gallons per minute and continuous pumping has no effect on the height of the water.

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

*Chemical Analysis of Water**

	Parts per million
Silica, SiO_2	3.00
Iron, Fe	2.38
Aluminum, Al	2.12
Calcium, Ca	269.20
Magnesium, Mg	107.80
Sodium, Na	33.90
Potassium, K	28.00
CO_3 radicle	102.70
SO_4 radicle	1462.60
NO_3 radicle	.035
Chlorine, Cl	63.90
Barium, Ba	3.44
Total solids	2079.075

Before the well was drilled this office was consulted by the city officials and the advice was given to exhaust the possibilities of the drift and country rock above the Kinderhook shale before going deeper. It was stated that the Maquoketa shale would probably be found to lie from 800 to perhaps 950 feet from the surface and the Saint Peter at about 1300 feet, while lower water beds to 1900 or 1950 feet would give a larger supply. But as no log can be obtained of the well it is impossible to say how accurate these forecasts were. The water bed at 1300 feet may be the Saint Peter, which was predicted at this depth.

OAKDALE, JOHNSON COUNTY

(Altitude 805 feet)

The well drilled for the State Sanatorium at Oakdale in 1919 by the Thorpe Bros. Well Company of Des Moines has a depth of 1137 feet and diameters from 12 to 6 inches. The principal supply was struck at 1097 feet at the bottom of the Saint Peter sandstone. A small vein was found at 750 feet at the summit of the Galena dolomite. The static level is 127 feet below the curb and is lowered "greatly" by continued pumping. An air compressor is used. At the test it lifted 50 gallons per minute at the start and after five hours 40 gallons to the end of 24 hours. The temperature is reported as about 67° Fahr. The water is hard and needs softening for boilers. The well is cased with 12 inch casing to 154 feet and with 6 inch casing from the top to 785 feet.

* By Dr. Nicholas Knight, Chemical laboratory of Cornell College.

Record of strata, State Sanatorium well, 1919

	Depth in Feet
Pleistocene and Recent (165 feet thick; top 805 feet above sea level):	
Till, yellow, predominantly clayey, sandy, calcareous, some pebbles	85, 95
Till, drab	105, 125
Clay, yellow-drab, fine-grained, plastic, calcareous, practically free from grit; 3 samples	135–155
Sand, grains varicolored, coarse and fine, irregular; some limestone, light gray, rapid effervescence in cold dilute HCl, in sand	165
Devonian:	
Limestone, blue-gray, soft, earthy, rapid effervescence, encrinital, fragments of shells of ribbed brachiopods, in flaky chips	175
Limestone, blue-gray, response rapid, earthy, of almost lithographic fineness, conchoidal fracture, fossiliferous	185
Limestone, whitish gray, argillaceous, in meal and powder, rapid response, some residue of fine quartz sand and cryptocrystalline silica; 3 samples	195–215
Limestone, in fine sand and powder, light yellow-gray, some mottled blue, response rapid, pyritiferous, a little quartz sand in drillings	225
Limestone, light yellow-gray, fragments of fine ribbed brachiopods, earthy, rapid response	235
Limestone, light brown, calcilutite, conchoidal fracture, some gray flint; some minutely fragmental limestone with small mass of whitish crystalline quartz; fossil of young *Atrypa* in gray limestone, and some blue-gray soft earthy limestone (from above ?)	245
Limestone, yellow-gray, fine-grained, rapid response	255
Limestone, light yellow-gray, argillaceous, in powder and sand, at first rapid response, then slow; some blue-gray, some buff, moderately slow response	265
Limestone, blue-gray, and buff, argillaceous, moderately slow response; light yellow, rapid response	275
Limestone as above, some chips of limestone with thin laminæ of dark brown shale, resembling certain layers of the Otis limestone at the Cedar Rapids quarries	285, 295
Dolomite, or magnesian limestone, light yellow-gray, finely crystalline, in sand and flour, response slow; 3 samples	305–325
Shale, blue, calcareous, in concreted masses and powder	335
Dolomite, light yellow-gray, some blue-gray; in sand with much blue argillaceous powder	345
Dolomite, or magnesian limestone, gray, moderately slow response, with blue argillaceous powder	355
No samples	355–650
Devonian and Niagaran (see record of well no. 2):	
"Shale, green"	355–395
Niagaran:	
"Lime"	395–570
Ordovician:	
Maquoketa (145 feet thick; top 235 feet above sea level)—	
"Shale, light blue"	570–600
Dolomite, or magnesian limestone, dark blue-gray, crystalline-granular, soft, labelled "washed from blue shale"	650
Galena-Platteville—	
Dolomite, buff, in fine sparkling sand; no quartz, "About 10 feet of sand at 750 feet, water raised to 180 feet of top"	750
Dolomite, brown, in sand and chips, rather slow, some cryptocrystalline silica, and a very little quartz sand	760
Dolomite, gray, soft, earthy, argillaceous, fine crystalline-granular, in chips, sample washed	780
Limestone, light yellow-gray, rapid effervescence; with some darker, rather slow	820
Limestone, gray, soft, earthy, effervescence rapid; limestone, light	

brown, response rather slow; some chips show both colors, effervescing rapidly on one side and rather slowly on the other 834, 842, 850
Dolomite, or magnesian limestone, light brown, compact, crystalline, response rather slow; limestone, light gray, response rapid, in larger chips; 4 samples 858–886
Magnesian limestone, response moderately rapid, light brown, with considerable chert; limestone, whitish, rapid response 896
Limestone, light gray to buff, earthy, response rapid, cherty at 925, 910, 954, 947, 989; large flakes of drab shale at 944 and 964; 7 samples 910–989
Shale, brown, inflammable; limestone, gray, rapid response 994
Limestone, gray, response rapid, in flakes; flakes of green shale.... 1010, 1020
Limestone, blue-gray, soft, earthy, fossiliferous 1030
Glenwood—
Shale, drab, inflammable; some light gray limestone 1040
Shale, green, plastic, calcareous 1048
Limestone, blue-gray, rapid response, some flakes of shale 1050
Saint Peter (51 feet thick; top 254 feet below sea level)—
Sandstone, gray in mass, of clean quartz grains rounded and frosted, up to 1 mm. diameter; some shale 1059
Sandstone, white, fine; 4 samples 1070–1100
Prairie du Chien—
Shakopee (penetrated 27 feet; top 305 feet below sea level)—
Dolomite, gray; quartz sand; 3 samples, bottom of well 1137.... 1110–1130

Driller's Log

	Depth in Feet		Depth in Feet
Glacial drift	0–118	Shale, light blue	570–600
Sandstone	118–132	Limestone	600–695
Broken shale and lime	132–152	Shale	695–715
Shale and limestone	152–162	Lime	715–1047
Limestone	162–348	St. Peter sandstone	1047–1097
Green shale	348–395	Lime to bottom	1097–1137
Lime	395–570		

WELL OF THE STATE SANATORIUM, OAKDALE, 1928

This well was drilled 16 feet from the well of 1919 and the curbs are at practically the same elevation, 805 feet above sea level. The depth is 1754 feet and 10 inches. The diameters are from 15 to 10 inches. The main supply was found in and below the Jordan sandstone (driller's log). No report of water from higher horizons has been made. Under a sixty hour test the well maintained a discharge of 370 g.p.m. The static level is 117 feet (688 feet above sea level), with a draw down to 126 feet. The well is cased with 164 feet of 20 inch pipe to 164 feet, 350 feet of 16 inch pipe from the surface into the Niagaran limestone, 223 feet of 12 inch pipe from 325 feet to 548 feet and 591 feet of 10 inch pipe from 548 feet to 1140 feet, footing in the Shakopee; thus cutting out all water above that formation.

The static level, 688 feet, of Jordan water may be compared

with that of the Saint Peter water in 1919 in the well of Oakdale sunk that year, which then stood at 678 feet. It may also be compared with the original head of the lower water beds at Cedar Rapids, which in 1888 stood at 761 feet above sea level, and with static level of the West Liberty wells, which in 1888 was 705 feet above sea level, from the Jordan water beds, and the head three years later of the well at Wilton, 684 feet, from the Saint Peter.

The Oakdale well was drilled by Thorpe Bros. Well Co. of Des Moines.

*Chemical analysis of water of Oakdale Sanatorium well, 1928**

	Parts per million	Grains per gallon
Sodium	155.4	
Magnesium	49.0	
Calcium	113.8	
Iron	0.1	
Ammonia	0.2	
Carbonate (CO_3)	0.0	
Bicarbonate (HCO_3)	266.0	
Sulphate (SO_4)	498.0	
Chlorine (Cl)	42.0	
Nitrate (NO_3)	0.1	
Silica (SiO_2)	14.9	
Hypothetical Combinations		
Sodium nitrate	0.138	0.008
Sodium chloride	69.287	4.05
Sodium sulphate	395.523	23.13
Ammonium sulphate	0.732	0.04
Magnesium sulphate	242.591	14.18
Calcium sulphate	51.667	3.02
Calcium bicarbonate	246.195	14.39
Ferrous bicarbonate	0.031	0.002
Silica	14.9	.87
Total	1021.164	59.69

Record of strata, State Sanatorium well, 1928

	Depth in Feet
Pleistocene and Recent (164 feet thick; top 805 feet above sea level):	
Sample no. 1 yellow till	
Sample no. 2 blue till	
Sample no. 3 sand, fine, dark gray, mostly of clear quartz, but many of dark minerals, a few greenish and pink, and of limestone, grains irregular	
Sample no. 4 sand, coarse, and gravel up to 1 cm. diameter, blackish diorite, etc., common.	
Devonian, Cedar Valley (84 feet thick; top 641 feet above sea level):	
Limestone, yellow-gray, fossiliferous, encrinital, earthy, rapid effervescence in cold dilute hydrochoric acid, in large flaky chips, same as sample no. 5	164–175

* Done under supervision of Prof. Jack J. Hinman, Laboratories of State Board of Health, Iowa City.

Limestone, blue-gray, speckled dark, fossiliferous, encrinital, effervescence rapid; nodule of blue chert with white rim, large chips.... 181
Limestone, gray and brown, in small chips, limestone gray with dark crusts, fossiliferous, encrinital, rapid reaction in large chips 181–190
Shale, blue-gray, calcareous, response rapid, laminated, pyritic, in large flakes 190–200
No sample, "light blue shale" of log 200–210
Limestone, light gray, some speckled, fossiliferous, crushes to powder similar to cuttings at 215 feet in well of '19 210–220
Limestone, buff-gray, crystalline-earthy, rapid reaction, speckled in sand, some chips fossiliferous 220–230
Limestone, gray, earthy, rapid effervescence, soft, sample taken at 240 feet 230–240
Limestone, buff-gray, earthy, argillaceous, effervescence rapid, speckled, highly fossiliferous 242–244

Devonian, Wapsipinicon (100 feet thick; top 557 feet above sea level):
Limestone, dark gray, crystalline-earthy, texture of Upper Davenport beds, rapid response, fossiliferous, some chips a fine coquina 248–260
Limestone, light yellow-gray, calcilutite, conchoidal fracture, rapid reaction; some dark gray, macrocrystalline-earthy, and fine crystalline mottled, pyritic; 2 samples 260–275
Limestone, magnesian, or dolomite, dark gray, fine crystalline, in clean small chips; limestone, fine crystalline-earthy, light gray, rather rapid effervescence 275–285
Limestone, magnesian, or dolomite, light cream yellow, fine crystalline-granular, in minute chips with highly argillaceous powder of same, effervescence at first rapid, then slow. "White mud" of log 285–290
Limestone, light cream-yellow, very fine grain, disintegrating under weak acid under rather slow effervescence into large whitish argillaceous residue; some of same color, rapid reaction 290–298
Shale, light blue-gray, plastic, in concreted masses, with a little argillaceous limestone; gray limestone rapid in reaction 300–305
Limestone, light gray, moderately slow, response markedly less slow than LeClaire, in small chips; limestone, light yellow-gray of rapid response; limestone, larger chips, blue-gray, mottled, crystalline, rapid reaction 305–308
Limestone, magnesian, or dolomite, dark gray, reaction less slow than LeClaire, fine crystalline, some saccharoidal, moderately large argillaceous residue slightly quartzose 308–315
Limestone, magnesian, or dolomite, blue-gray, moderately slow effervescence, some rapid; some yellowish flint 315–325
Dolomite, gray, cryptocrystalline, nonargillaceous, effervescence slow as LeClaire, very slight quartzose residue 325–328
Shale, light greenish gray, in friable masses, calcareous, somewhat arenaceous with fine grains of clear quartz, many of which are well rounded; (cuttings from below show a light green-gray unctuous noncalcareous shale, arenaceous, apparently caved from this horizon); white chert pyritic; much gray dolomite 330–348

Silurian:
Niagaran (162 feet thick; top 457 feet above sea level)—
Dolomite, light gray, and blue-gray; 4 samples 348–380
Dolomite, drab, highly argillaceous 380–390
Dolomite, light yellow-gray 385–398
Shale, whitish, calcareous, microscopically quartzose 398–404
Dolomite, light yellow-gray 404–415
Dolomite, whitish, much powder 415–425
Dolomite, light blue-gray in mass; 7 samples 425–500
No cuttings 500–510

Ordovician:
Maquoketa (190 feet thick; top 295 feet above sea level)—
Shale, light blue-gray, plastic; 2 samples 510–545

Dolomite, crystalline, dark blue-gray; 2 samples 546–570
Shale, light blue-gray 570–575
Dolomite, drab 575–585
Dolomite, blue-gray, earthy, cherty, argillaceous; 3 samples 585–615
Dolomite, buff-gray, earthy, in flaky chips 615–620
No sample, "sandy gray shale" of log 620–628
Shale, light blue-gray, not arenaceous, but microscopic grains of cryptocrystalline quartz in residue 628–638
Dolomite, gray, earthy 638–645
No sample, "dark shale" of log 645–652
Shale, light blue-gray; 2 samples 652–668
Shale, drab 680–700

Galena-Platteville (350 feet thick; top 105 feet above sea level)—
Dolomite, buff, hard, crystalline; 2 samples 700–725
Dolomite, as above, with rare flakes, slightly inflammable 725–730
No samples, "hard lime" of log 730–740
Shale, light blue-gray, calcareous, plastic 740–755
Dolomite, light buff, rough, vesicular, in rather large chips, clean; 3 samples 755–775
Limestone, light yellow-gray and buff, crystalline-earthy, in flakes and powder, rapid effervescence; 5 samples 775–835
Dolomite, gray-buff, crystalline, in small chips 835–870
Limestone, light yellow-gray, reaction moderately rapid; very light gray, rapid; a little buff dolomite 870–890
Limestone, light yellow-gray, rapid effervescence 890–902
Limestone, light buff-gray, rapid response 902–908
No samples, as below, according to log 908–918
Limestone, buff-gray, response moderately rapid and rapid, no quartz sand 918–930
Limestone, magnesian, or dolomite, with nonmagnesian limestones, in sand, cherty at 940–950; 4 samples 930–970
Limestone, whitish, soft, rapid effervescence 970–980
Limestone, light yellow gray, rapid response, in sand and powder; 4 samples 980–1020
Limestone, brownish, reaction rapid, inflammable, some chips highly inflammable 1020–1038
Shale, green-gray, calcareous 1038–1040
Limestone, very light yellow-gray, much powder 1040–1050

Glenwood (20 feet thick; top 245 feet below sea level)—
Shale, green, calcareous, pyritic 1050–1058
Limestone, light gray and mottled darker, rapid effervescence 1058–1060
Shale, green, plastic; some chocolate brown, inflammable 1060–1070

Saint Peter (32 feet thick; top 265 feet below sea level)—
Sandstone, rusted buff, Saint Peter facies, larger grains about 1 mm. diameter; some flakes of hard green noncalcareous shale (from above?) no flint or chert 1070–1080
Sandstone, light yellow in mass, finer than above, individual grains mostly clear uncolored quartz 1080–1100
Sandstone, white, medium to fine 1100–1102

Prairie du Chien (428 feet thick; top 297 feet below sea level)—
Shakopee dolomite (168 feet thick)—
Dolomite, gray, yellow-gray and whitish, cherty 1140-1180, and at 1260; 19 samples 1102–1270
New Richmond sandstone(20 feet thick)—
Sandstone, light gray, fine to medium, larger well rounded, secondary enlargements common, highly dolomitic, in chips and detached grains 1270–1280
Sandstone, well rounded grains of clear quartz; dolomite, light yellow-gray, in chips, no imbedded grains noted 1280–1290
Oneota dolomite (240 feet thick)—
Dolomite, light yellow-gray, some quartz sand in cuttings; 2 samples 1290–1310

Dolomite, whitish, a little quartz sand in detached grains; 2 samples 1310–1330
Dolomite, very light gray; 2 samples 1330–1350
Dolomite, light gray and yellow-gray, cherty at 1350, 1380, 1410, 1430-1450, highly cherty at 1390, 1450-1470; 15 samples 1350–1510
Dolomite, purplish, large chips show cavities lined with pearl spar and pyrite, vesicular; imbedded chert 1510–1520
Dolomite, light buff; white chert, some with imbedded grains of quartz sand, some highly pyritic; fine to medium, well rounded grains of quartz sand 1520–1530

Cambrian:
Jordan (30 feet thick; top 715 feet below sea level)—
Sandstone, yellow-gray in mass, fine, many secondary enlargements, dolomitic cement and dolomite with imbedded grains; some white chert 1530–1540
Sandstone, white, grains up to 0.7 mm. diameter, larger grains well rounded; secondary enlargements 1540–1550
Sandstone, white, well rounded, frosted grains up to 1 mm.; some fine pink sandstone with dolomitic matrix in chips 1550–1560
Saint Lawrence—
Trempealeau dolomite of the Saint Lawrence (187 feet thick; top 755 feet below sea level)—
Dolomite, light yellowish and light gray, highly arenaceous with fine fairly well rounded grains of quartz sand, in chips showing imbedded grains closely spaced; some pyritic; 13 samples 1560–1690
Dolomite, gray, slight microscopic residue quartzose and argillaceous; 4 samples 1690–1730
Dolomite, very light gray, residue argillaceous and of minute grains of clear quartz 1730–1747
Franconia beds of the Saint Lawrence (penetrated 8 feet; top 942 feet below sea level)—
Dolomite, pink; large argillaceous residue, with minute quartz grains 1747–1752
"Shale, red" 1752–1755

Notes.—The logs of the two Sanatorium deep wells are not in agreement as to the depth to rock. In that of the well of 1919, 14 feet of "sandstone" rests on "broken shale and lime" at 132 feet. In that of the well of 1928 42 feet of "quicksand" rests on "lime" at 164 feet. Such rapid changes in level in the preglacial rock surface are not unknown in this area, but in this case the log of well 1919 seems to be in error, as it is not supported by the cuttings, which from 135 to 155 feet are of yellowish sedimentary clay, entirely free of limestone and palpable grit. The log also gives "sandstone" from 118 to 132 feet, while cuttings from 125 feet are glacial till.

The log of well 1928 agrees here with the cuttings of well 1919, if we interpret the "blue mud" from 60 to 122 feet as blue till. The cuttings of the last well show a succession downward of yellow till, blue till, and sand, fine and coarse, but the depth of

these cuttings is not given. The first recorded depth is that of limestone at 164 feet and with this the log specifically agrees, and this is therefore taken as the thickness of the Pleistocene at Oakdale.

The clay of the cuttings of the well of 1919 from 135 to 155 feet is not represented in the well of 1928 in either cuttings or log.

In interpreting the Devonian portion of this geological section, it will be remembered that in outcrops in Johnson and neighboring counties to the north and east the Cedar Valley limestones rest on an assemblage of beds, the Wapsipinicon, which where fully developed consists of the following members:[61]

5 Upper Davenport limestone
4 Lower Davenport limestone
3 Kenwood, or Independence, shales
2 Otis limestone
1 Bertram beds

Number 1, found only in eastern Linn county, and the lower part of no. 2 are dolomitized. Number 2 and no. 4 are lithologically characterized by beds of calcilutite of lithographic fineness, while no. 2 embraces also a wide variety of other types of limestone. Number 2 is in places fossiliferous and no. 5 is universally highly fossiliferous. No fossils are to be expected in nos. 1 and 4. Number 3 is unfossiliferous, except in two or three outcrops of uncertain stratigraphic relations.

As the Wapsipinicon, we may assume, was laid on a subsiding erosion surface, we may expect to find the full succession of its beds only on the lower levels of that surface. The dolomitization of the strata also may be variable in vertical extent. In the cuttings of deep wells a difficulty is encountered in distinguishing the dolomitized beds of the Wapsipinicon from the Silurian dolomites which they overlie.

Interpreting the cuttings of the two Sanatorium wells at Oakdale and that of the University well at Iowa City in accordance with the sequence of Devonian strata in the nearby outcrops, we assign to the Cedar Valley limestone the beds above 235 feet in the Oakdale well of 1919, above 248 feet in the Oakdale well of 1928 and above 65 feet in the University well.

At this point a thin bed of highly fossiliferous limestone, with

61 Norton, Wapsipinicon Breccias of Iowa: Iowa Geol. Survey, vol. XXVII, pp. 370-433.

the facies of the Upper Davenport limestone in the Oakdale well of 1928, overlies in all three wells a bed of yellowish calcilutite of conchoidal fracture. The fossiliferous bed can not be lower than the Upper Davenport, while the calcilutite can not be higher than the Lower Davenport, and to these formations they are referred with some confidence. The underlying Kenwood is represented pretty clearly by first a light yellowish argillaceous limestone or calcareous shale, powdered by the drill, at 265 feet in the Oakdale well of 1919, at 285 feet in the Oakdale well of 1928, and at 110 feet in the well of the University. In one respect these cuttings differ from the typical Kenwood shale; they are dolomitized, as shown by a slow effervescence in cold dilute HCl, after a first rapid effervescence due to intermingling with the cuttings of powdered limestone from above. In their magnesian content these light yellowish argillaceous beds are like the lower dolomitized beds of the Otis.

In each of the three wells these argillaceous beds, crushing to powder under the drill, are underlain by beds represented by chip cuttings of argillaceous limestones, mostly magnesian or dolomitic. Some of these are peculiar in texture and as at 285 and 295 feet in Oakdale well of 1919, can be exactly matched at outcrops of the Otis, as at Cedar Rapids. In the University well, also, chips from 120 to 130 feet might have been taken from outcrops of the Otis in Cedar county.

These limestones rest in all the three well sections on green shale (Oakdale 1919, at 335 feet; Oakdale 1928, at 330 feet; University, at 201 feet).

The concreted masses of the shale are calcareous, but bits of green shale found in cuttings a few feet below apparently caved from this bed, are unctuous and noncalcareous. The shale also is sparingly arenaceous with fine rounded grains of clear quartz. It rests on the Niagaran dolomite.

Several placings of this shale are possible. With the shales above it and included argillaceous limestones it may be referred to the chief shale horizon of the Wapsipinicon, the Kenwood. Moreover, in places the Kenwood is finely arenaceous, like this shale, and with rounded grains.

Again, recalling the fact that the Otis develops in some of its

outcrops shaly partings, it is possible that here it has developed a bed of shale of considerable thickness. And since the stratigraphic place of the fossiliferous Independence shale is uncertain, its outcrops without discernible floor or cover in the midst of deformed Devonian strata permitting the theory of upthrust from below, or that of valley fill, the shale in question may be regarded as a possible Independence shale from below the horizon of the Otis. However, no basal shales occur where the Wapsipinicon is most fully developed, and the Siluro-Devonian contacts in Iowa show Otis limestones or dolomites in contact with the Niagaran.

It may also be suggested that the shale in question is a cavern fill in the Niagaran, such as are found at a number of points over the outcrop both of the Hopkinton and Gower limestones of that terrane. In favor of this reference is the three foot layer of dolomite, indistinguishable from the LeClaire phase of the Gower, which overlies the shale in the Oakdale well of 1928. The clays of cavern fills in the Niagaran are commonly whitish, and while quartzose, the quartz, at least in clay pockets at Mount Vernon and at Clinton, is in highly irregular particles and in a deposit near Miles according to Galpin,[62] in quartz fragments and crystals. Moreover, the occurrence of the shale both at Iowa City and at Oakdale makes in favor of a somewhat widespread deposit and against a local cavern fill. The heavy cover of Devonian limestones does not favor a Niagaran pocket fill in post-Devonian time, but does not preclude a fill before or at the beginning here of Devonian sedimentation.

On the whole, the writer is rather inclined to draw the Kenwood, or Independence, shale to include all the shales with the interbedded limestones, from 285 feet in the last Oakdale well down to the Niagaran limestone at 348 feet, and to assume that here the Otis limestones were not laid.

In the section at the Oakdale well of 1928 the thickness assigned to the Niagaran, 162 feet, shows a notable thinning to the south from Cedar Rapids, where it is about twice as thick. The Niagaran continues to thin farther southward, as at Washington it measures but 29 feet.

62 Galpin, S. L., Refractory Shales of Iowa: Iowa Geol. Survey, vol. XXXI, pp. 59-61.

The Maquoketa continues here in full force from its outcrops and well sections to the north and east. It includes considerable impure drab and blue-gray earthy dolomite, chiefly in a median body about 50 feet thick. It is probable that these washed samples of dolomitic chips represent considerable interbedded shale.

The light blue plastic shale at 740 feet has quite the facies of the Maquoketa. It is included here with the Galena, since the 35 feet of dolomite which overlies it is typically Galena, and at Iowa City the shale at this level has thinned to but 5 feet according to the driller's log.

The Galena-Platteville ranges as usual from a rough vesicular dolomite to light gray earthy limestones. Near the base occurs a bed of brownish inflammable *limestone,* taking the place of the brown bituminous shale characteristic of this horizon. In the cuttings of the Glenwood green shale are also found flakes of brown inflammable shale which may come from the upper horizon, although not found in the bailing taken to represent it.

The Saint Peter presents no abnormal lithologic feature. Rather strangely the elevation of the top differs by about 20 feet in the two Oakdale wells. If the shale of the University well struck at 156 feet below sea level is the Glenwood, the Saint Peter probably lies about 100 feet higher at Iowa City than at Oakdale, and we have another illustration of the wide margin of error to be reckoned with in forecasting for any locality the depth to this rather irregular formation.* Yet the tops of the formations above the Glenwood shale are about on the level at the two stations, as might be expected from their strike. The top of the Saint Peter is abnormally high compared with Cedar Rapids and West Liberty.

	Oakdale 1928 well	Iowa City	Cedar Rapids Y.M.C.A.
	Elevation in feet above sea level		
Top of Niagaran	457	467	638
Top of Maquoketa	295	312	289
Top of Galena-Platteville	105	119	13
Top of Glenwood	-245	-156(?)	.....
Top of St. Peter	-265		-292

In the Prairie du Chien the New Richmond horizon is well

* A note from the drillers stating that the drill "started to penetrate sandstone at 840 feet" confirms the inference as to the Glenwood shale.

marked. The Jordan sandstone is perhaps more closely defined by the log than by the sample cuttings.

The Trempealeau dolomite is in great force and may be compared with the sub-Jordan dolomites 230 feet thick in the Grinnell section, 110 feet of which is assigned to the Trempealeau, while the remainder is placed with the Franconia because of the presence of glauconite.

Driller's log, State Sanatorium, Oakdale, 1928

	Depth in Feet
Surface soil and clay	0–60
Mud, blue	60–122
Quicksand	122–136
Quicksand	136–164
Lime	164–178
Blue shale	178–181
Lime, white	181–190
Broken lime	190–197
Light blue shale, caves	197–200
Light lime	200–219
Shale	219–222
Broken lime	222–242
Shale, caves	242–248
Gray lime	248–285
White mud	285–290
Broken lime	290–298
Light shale	298–305
Limerock	305–308
Flinty sandstone	308–330
Green mud	330–348
Sandy lime	348–358
Limerock	358–360
Broken lime	360–375
Sandy lime	375–385
White mud	385–389
Hard lime	389–398
White slate	398–404
Lime	404–415
Hard lime	416–425
White muddy shale	425–430
Lime	430–475
Hard lime	475–485
Lime	485–500
Hard lime	500–510
Shale	510–545
Lime	545–550
Sandy shale	550–570
Blue mud	570–575
Lime	575–585
White shale	585–600
Sandy shale	600–608
Lime	608–615
Shaly lime	615–620
Sandy gray shale	620–638
Lime	638–645
Dark shale	645–670
Hard lime	670–675
Dark shale	675–705
Hard lime	705–740
Dark shale	740–755
Gray lime	755–815
White lime	815–820
Flinty lime	820–835
Hard brown lime	835–870
Gray lime	870–890
Hard gray lime	890–902
Hard brown lime	902–908
Very hard gray sandy lime	908–930
Lime rock	930–950
Lime rock, very hard	950–970
Lime rock	970–980
Lime rock, hard	980–1000
Shale and rock	1000–1010
Shale	1010–1020
Lime rock	1020–1030
Shale and rock	1030–1040
Lime rock	1040–1050
Shale	1050–1058
Lime rock	1058–1060
Brown shale	1060–1070
Saint Peter sandstone	1070–1102
Blue lime	1102–1112
Blue lime, very hard	1113–1117
Gray lime, very hard	1117–1128
Gray lime, not so hard	1128–1140
Gray lime, hard	1140–1150
Hard sandy lime	1150–1180
Gray lime	1180–1200
Gray lime, very hard	1200–1250
Gray sandy lime	1250–1275
Gray lime	1275–1300
Gray sandy lime	1300–1340
Gray lime, not so hard	1340–1360
Sandy lime	1360–1375
Hard gray lime	1375–1400
Hard brown lime	1400–1430
Gray lime, very hard	1430–1460
Gray sandy lime, hard	1460–1475
Gray sandy lime, very hard	1475–1512
Broken lime	1512–1534
Sandstone (some water), Jordan	1534–1550

Limestone	1550–1555	Lime and sandrock, very hard	1680–1700
Broken limestone, cavy (some water)	1555–1565	Lime, with crevices, very hard (some water)	1700–1747
Sandy limestone	1565–1580	Pink limestone	1747–1752
Sandy limestone, very hard	1580–1670	Red shale	1752–1754 10 in.
Sandstone (some water)	1670–1680		

Mineral Content of Sanatorium well, Oakdale, 1928*

	P.P.M.
Bicarbonate	312.3
Chloride	26.
Sulphate	258.8
Silica	15.8
$Fe_2O_3+Al_2O_3$	6.8
Calcium	97.5
Magnesium	39.1
Na + K as Na	72.8
Total solids	672.9

OAKLAND, POTTAWATTAMIE COUNTY

(Altitude 1102 feet)

The city well, drilled by the Thorpe Brothers Well Company of Des Moines, is 1936 feet in depth and its diameters are from 16 to 7 inches. The well is cased with 16 inch pipe to 65 feet, 12 inch to 460 feet, 10 inch to 960 feet, 8 inch to 1090 feet, 7 inch to 1608, and 5 inch to the bottom.

No water except seep was found until the depth of 1840 feet was reached where for 30 feet cuttings were washed away. Water was found in this bed of creviced dolomite from 1840 to 1925 feet. The static level is 92 feet from the surface and at the final test pumping at the rate of 150 gallons per minute produced a draw down of 66 feet with the cylinder at 230 feet. The cost of the well was $16,875.

Driller's log and Record of strata

	Depth in Feet
Pleistocene and Recent (62 feet thick; top 1102 feet above sea level):	
"Sandy clay"	0–10
"Sand"	10–35
"Sandy clay"	35–62
Pennsylvanian:	
Missouri series (393 feet thick)—	
"Lime rock and shale"	62–455
Des Moines series (635 feet thick)—	
"Shale with streaks of sandstone"	445–1090
Mississippian and other formations (top 12 feet above sea level):	

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

"Limestone" 1090–1486
Limestone, light yellow-gray and light blue-gray, rapid effervescence in cold dilute HCl; flakes and poorly rounded grains of limpid quartz; whitish cryptocrystalline silica; cuttings in sand and powder 1130
Limestone, gray, rapid effervescence 1140
Limestone, gray, fine grained, rapid effervescence, buff, moderately rapid; a little blue shale in minute chips, siliceous with irregular grains and minute particles of clear quartz and cryptocrystalline silica 1150
Limestone, blue-gray, effervescence moderately rapid; white, crystalline, rapid reaction, fine-grained; a little shale 1160
Shale, greenish, calcareous; limestone, effervescence rapid, blue-gray; chalcedony and clear quartz; a little brown shale 1170
Limestone as above; silica as above; a little shale 1180
Limestone, blue and brownish gray, effervescence moderately rapid, argillaceous; dark flint, chalcedony; 3 samples 1190–1210
Limestone, light brown, hard, siliceous, response slow; some rapid; silica as above 1220
Limestone, as above; some green shale; pyrite 1230
Shale, greenish, calcareous, in chips 1240
Limestone, light gray, response rapid; shale in minute chips; whitish silica; pyrite 1250
Limestone, gray, rapid reaction; white silica; black fissile shale at 1260 and 1280; 3 samples 1260–1280
Shale, drab; white chalcedonic silica; limestone, gray 1290
Shale, dark drab, fissile 1300
Shale, as above; limestone 1310
Limestone, response rapid; chert; chalcedonic silica; shale; pyrite 1320
Shale, blue 1330
Limestone, buff, in sand; chips of shale 1340
Shale and limestone, light buff, in fine sand; limpid quartz and cryptocrystalline silica 1350, 1360
Shale, blue, in powder; some limestone and cryptocrystalline silica; 3 samples 1370–1400
Limestone, buff, moderately rapid reaction; much cryptocrystalline silica in minute flakes and crystalline quartz in microscopic particles 1410
Sandstone, fine, grains imperfectly rounded 1420
Shale, blue, in chips 1430
Limestone, effervescence rapid, buff; cryptocrystalline silica and quartz 1440–1450
Limestone, light yellow-gray, rapid response; a little silica as above 1460
Shale, blue, in fine sand 1463–1467
Limestone, light buff, effervescence rapid; sandstone; some shale 1470
Limestone, light buff, slow effervescence 1480
Driller's log; "shale (Kinderhook?)" 1486–1583
Limestone, light buff, some slow, some rapid reaction; chalcedony and quartz sand; shale in powder and chips 1500
Shale, light blue, calcareous; 2d sample at 1500
Shale, blue, calcareous; 4 samples 1510–1540
Limestone, light yellow-gray, effervescence rapid; some chips of shale 1550
Limestone, as above; shale, blue, some bright green 1560
Limestone, as above, in flaky chips, earthy 1570
Limestone, as above, in small chips 1580
Limestone, gray, some whitish, rapid effervescence 1590, 1600
Dolomite, light blue-gray, crystalline 1610
Limestone, light buff and whitish, effervescence rapid, called "hard" by driller 1620
Limestone, buff, in fine sand, some rapid effervescence, some darker and rather slow, considerable residue of quartzose microscopic particles and some grains of limpid quartz; blue shale, pyrite 1630
Limestone, gray, reaction moderately rapid, "hard" 1640
Limestone, blue-gray, moderately slow reaction, argillaceous 1650

Limestone and shale, limestone brown, moderately slow reaction	1660
Shale and limestone, blue-gray, reaction slow; at 1680 also white and gray cryptocrystalline silica and microscopic quartz particles	1670, 1680
Dolomite, light blue and gray, cuttings in fine sand and flour, much chalcedonic silica and some fine quartz sand; 3 samples	1690–1710
Shale, blue-gray, with dolomite and silica as above	1720
Silica, white, chalcedonic; whitish limestone of rapid effervescence; fine quartz sand; all in powder and sand	1730
Shale, light blue-gray, siliceous as above, calcareous	1740
Dolomite, in powder and fine meal; shale, light blue-gray, in powder, quartzose	1750
Dolomite, gray, in fine crystalline sand; cuttings blue-gray in mass from argillaceous powder	1760
Dolomite, buff and gray, in fine crystalline sand; 6 samples	1770–1820
Dolomite, light yellow-gray; some flakes of blackish fossiliferous shale, inflammable, similar in appearance to that at 1280	1830, 1840
No samples, "drillings washed away"	1840–1870
Dolomite, subcrystalline, light yellowish and light brownish gray, in chips; some shale as above	1870
Dolomite, and some magnesian limestone of rather slow effervescence; light yellow-gray; considerable calcite	1927
Dolomite, light buff, in clean fine meal	1932

Notes.—The floor of the Coal Measures, placed by the above interpretation of the driller's log at 12 feet above sea level, is in accord with the elevation of this floor at points north, east and south where it has been reached. About 25 miles to the west in the Council Bluffs-Omaha area the altitude at the floor as defined by the summit of heavy limestones referred to the Mississippian stands 550 feet above sea level, indicating a rather sharp upwarp toward the west, if not faulting.

The Oakland well reaches a depth of 730 feet below sea level. No evidence of the Saint Peter sandstone or of its superincumbent shales is found in the cuttings and the sandstone probably lies 200 or 300 feet below the bottom of the well. The dolomites in which the well foots may be referred to the Galena with some probability.

OELWEIN

(Altitude 1042 feet)

WELL OF CHICAGO GREAT WESTERN RAILWAY COMPANY

This well, completed in July, 1919, was drilled by F. M. Gray, Jr., of Milwaukee. The depth is 1382 feet; the diameters are 12 inches to 397 feet, 9 inches to 950 feet, and 7 inches to bottom.

Water was found in the Saint Peter sandstone to the amount of 40 gallons per minute. The final tests, however, showed a capacity of at least 250 gallons per minute.

During the drilling of the well the static level remained stationary at about 18 feet below the surface, a fact which led to the opinion that little water had been found. A month afterwards the water had sunk to about 100 feet from the surface and when after various delays the pumping test was made in October the head was found at 200 feet below the surface.

Record of strata of well of Chicago Great Western Railroad Company

	Depth in Feet
Pleistocene and Recent (57 feet thick; top 1036 feet above sea level):	
Sand and gravel, yellow	0–57
Silurian:	
Niagaran limestone (108 feet thick, top 979 feet above sea level)—	
Dolomite, light buff, in fine sand and chips; 12 samples	57–130
Limestone, magnesian, or dolomite, light gray, crystalline, moderately slow effervescence in cold dilute HCl	130–145
Dolomite, buff and gray, cherty	145–165
Ordovician:	
Maquoketa shale (215 feet thick; top 871 feet above sea level)—	
Shale, blue, plastic, sample taken at 290	165–325
Limestone, gray, moderately rapid effervescence, fine-grained	325–365
Shale, blue-gray, in concreted masses	365–380
Galena and Platteville limestones (405 feet thick; top 656 feet above sea level)—	
Limestone, buff and light gray, fine-grained, moderate effervescence; and gray, rapid effervescence, in chips an dsand	380–510
Shale, light brownish gray, in concreted masses	437–439
Limestone, light gray, in powder, argillaceous, rapid effervescence	510–720
Shale, green, hard, fissile	702–703
Limestone, light gray, rapid effervescence	720–785
Saint Peter sandstone (75 feet thick; top 251 feet above sea level)—	
Sandstone, white, rounded grains; 2 samples	785–860
Prairie du Chien (380 feet thick, top 176 feet above sea level)—	
Dolomite, gray, cherty	860–881
Shale, green-gray	881–887
Dolomite, in fine crystalline sand, much quartz sand in cuttings and some shale	887–950
Dolomite, white and gray, sparse imbedded grains of quartz, some plastic blue shale	955
Dolomite, light buff	980
Shale, blue-gray, iu concreted masses with some quartzose marl	995–1002
Shale, blue-gray, in concreted masses	1002–1025
Sandstone, fine, rounded grains of clear quartz, dolomite and shale in cuttings (New Richmond ?)	1025–1037
Dolomite, gray, cherty	1037–1105
Dolomite, with much shale	1105–1145
Dolomite, gray, cherty	1145–1195
Dolomite, gray and white; 2 samples	1195–1240
Cambrian:	
Jordan sandstone (77 feet thick; top 204 feet below sea level)—	
Sandstone, fine-grained, with considerable dolomite in cuttings	1240–1265
Sandstone, in fine rounded grains	1265–1295
Sandstone, as above, with calcareo-argillaceous powder	1295–1317
Saint Lawrence (Trempealeau dolomite) (top 281 feet below sea level)—	
Dolomite, in fine crystalline sand with some argillaceous residue	1317

CITY WELL, OELWEIN

This well was drilled by the Bert Sharff Drilling Co. of Oelwein in 1924. The depth is 1316 feet and the diameters are from 12 to 8 inches. The only water found, so far as reported, was at 140 feet in the Niagaran limestone. Both the Saint Peter and the Jordan sandstones are stated to be hard and dry. The static level stands at 30 feet. Tests showed a capacity of only 90 gallons per minute and the well was never put into operation. Twelve inch casing was inserted to a depth of 37 feet and 248 feet of 8⅝ inch pipe were inserted from 152 to 400 feet to case out the Maquoketa shale. The cost of the well is stated to have been $10,000.

Since this well hole is entirely useless in its present condition it would seem quite worth while to experiment with a charge or charges of dynamite to see if deep lying water channels can not be opened up. In the well of the Chicago Great Western Railroad just described the deeper waters at first failed to find access to the tube and the water held the static level of the Drift and Niagaran waters. At last the deeper channels opened up without artificial aid and the static level fell accordingly, but in the severer case of the city well an operation is indicated.

Driller's log of City well, Oelwein (from blue print)

	Depth in Feet
Clay	0–38
Lime (Niagaran)	38–165
Shale (Maquoketa)	165–352
Limestone (Maquoketa)	352–373
Shale, blue (Maquoketa)	373–390
Limestone (Galena-Platteville)	390–435
Shale, brown (Galena-Platteville)	435–443
Limestone (Galena-Platteville)	443–739
Shale (Glenwood)	739–745
Sandstone (Saint Peter) hard and dry	745–795
Limestone (Shakopee)	795–864
Sandstone (New Richmond)	864–875
Limestone, very hard (Oneota)	875–1179
Shale, green	1179–1185
Sandstone, hard and dry (Jordan)	1185–1290
Limestone (Trempealeau)	1290–1316

OGDEN, BOONE COUNTY

(Altitude 1097 feet)

CITY WELL NO. 2

In 1929 a second well, 2852 feet deep, was completed for the city of Ogden by the Thorpe Brothers Well Company of Des Moines. The principal supply was found near the bottom, in the

Dresbach sandstone. Only small amounts were found above this stratum and these were cased out. The pumping capacity on completion was tested to 150 g.p.m., with a draw down from the static level of 163 feet below the surface to 297 feet. The well is cased with 16 inch casing to 403 feet, 12 inch to 670 feet, 10 inch to 1313 feet, 8 inch to 1851 feet, 6 inch to 2680 feet and 4½ inch to the bottom.

Record of strata

	Depth in Feet
Pleistocene and Recent (140 feet thick; top 1094 feet above sea level):	
Till, yellow, calcareous, clayey, in hard masses inclosing sand and pebbles of drift	10, 20
Till, gray, as above; 3 samples	30–50
Gravel, with some clay	50–60
Till, yellow, calcareous, with pebbles and sand; 2 samples	60–80
Till, gray, many pebbles	80–90
Till, yellow and orange, highly sandy and pebbly, feebly calcarous; 2 samples	90–110
Till, yellow, highly sandy and pebbly	110–120
Till yellow, clayey, calcareous	120–130
Till, drab, clayey, calcareous	130–140
Pennsylvanian:	
Des Moines (230 feet thick; top 954 feet above sea level)—	
Shale, drab, noncalcareous; 2 samples	140–160
No samples	160–180
Shale, gray and drab, blackish at 200, 220, 240, 250 and 270 feet; 17 samples	180–350
Conglomerate, largest pebbles 15 to 20 mm. diameter, a few rolled pebbles of yellow-gray and red granites and feldspathic rocks, greenstones, quartz, chert or chalcedonic silica, blue-white, with irregular surfaces, some limestones; with sand and powder of shale; 2 samples	350–370
Mississippian (260 feet thick; top 724 feet above sea level):	
Chert, blue-gray and white; some coarse sand	370–380
Chert as above; with much drab shale	380–390
Limestone, gray, rapid effervescence in cold dilute HCl, some soft, macrocrystalline, fossiliferous; some chert, some arkosic grains from above	390–400
Limestone, gray and drab, rapid effervescence, fine crystalline-granular; 10 samples	400–500
Limestone, brownish, tinge of drab, fine crystalline-granular, moderately rapid effervescence; 2 samples	500–520
Limestone, gray, oölitic, moderately rapid effervescence; 3 samples	520–550
Shale (Kinderhook), light blue-gray, calcareous; 6 samples	550–610
Limestone, drab and gray, rapid effervescence	610–620
Shale, light blue-gray, some large chips show lamination	620–630
Devonian (350 feet thick; top 464 feet above sea level):	
Limestone, cream-colored, laminated, in flaky chips, earthy, rapid effervescence	630–640
Limestone, cream and yellow-gray, rapid effervescence, fine-grained; 3 samples	640–670
Limestone, light gray, calcilutite, conchoidal fracture, rapid effervescence, laminated at 700; 4 samples	670–710
Limestone, light yellow gray, fine crystalline-granular, laminated, rapid effervescence; 2 samples	710–730
Limestone, light yellow-gray calcilutite, and blue-gray, crystalline-earthy, rapid effervescence, with powder of drab shale	730–740

Limestone, light yellow-gray, fine crystalline-granular, laminated, rapid effervescence 740–750
Shale, gray with greenish tinge, in tough concreted masses with chips of drab, fine-grained, hard limestone 750–760
Limestone, drab, fine crystalline-granular, hard, slow effervescence, residue highly argillaceous, quartzose with microscopic grains, sparsely arenaceous with minute ill rounded grains of clear quartz; 3 samples 760–790
Dolomite, gray, macrocrystalline and crystalline-granular, rough surfaced chips; 5 samples 790–840
Dolomite, brown-gray, fine-grained, compact; 5 samples 840–890
Dolomite, light buff, disintegrating under acid into fine crystalline sand 890–900
Limestone, light yellow-gray and buff, laminated, rapid effervescence (some slow); 4 samples 900–950
Limestone, buff and light gray mottled brown, rapid effervescence 950–960
Limestone, buff and light gray, slow and rapid effervescence 970–980

Silurian (280 feet thick; top 114 feet above sea level):
Dolomite, buff and brown, fine crystalline-granular 980–990
Dolomite as above; white grains of gypsum 990–1000
Dolomite as at 980, some limestone of rapid effervescence; 4 samples 1000–1040
Dolomite, blue-gray, some chips of gypseous dolomite, gypsum in white masses; 2 samples 1040–1060
Dolomite, gray, buff and brownish; chips of gypsum, anhydrite and gypseous dolomite; 7 samples 1060-1130
Clay, white, in powder and soft grains; dolomite, light gray and buff, in sand; gypsum considerable at 1130, in small amount at 1150; 3 samples 1130–1160
Dolomite, gray and buff, at 1190 light yellow-gray, soft and earthy; 10 samples 1160–1260

Ordovician:
Maquoketa (40 feet thick; top 166 feet below sea level)—
Shale, light greenish gray, some reddish brown, calcareous, unctuous, in hard lumps 1260–1270
Shale, ocher-yellow, calcareous 1270–1280
Shale, as at 1260 1280–1290
Shale, ocher-yellow and terra cotta red, calcareous 1290–1300
Galena-Platteville (484 feet thick; top 206 feet below sea level)—
Chert, light gray and whitish, a very little dolomite and fine quartz sand in ill rounded grains; 7 samples 1300–1370
Dolomite, gray and buff, cherty; 2 samples 1370–1390
Dolomite, gray 1390–1400
Chert and gray dolomite; 2 samples 1400–1420
Shale, gray, in hard masses, calcareous, not quartzose 1420–1430
Dolomite, light gray and light yellow-gray; gray shale at 1430; 4 samples 1430–1470
Dolomite, light gray; gray chert; 9 samples 1470–1560
Dolomite, light gray and buff, brown-gray at 1660; 14 samples 1560–1690
Dolomite, light yellow-gray, with much gray and blue-gray shale, slightly arenaceous, grains fine and rounded; 4 samples 1690–1730
Limestone, earthy, light yellow-gray, rapid effervescence; 2 samples 1730–1750
Shale, medium dark green, in hard masses concreting chips of limestone as above 1750-1760
Limestone, light yellow-gray and buff, in flaky chips, rapid effervescence; shale from above in dark green noncalcareous splintery flakes; 2 samples 1760–1784
Glenwood shale (6 feet thick; top 690 feet below sea level)—
Shale, dark green, hard, in noncalcareous chips and concreted masses 1784–1790
Saint Peter sandstone (38 feet thick; top 696 feet below sea level)—
Sandstone, white, grains rounded and frosted; 4 samples 1790–1828

Prairie du Chien (352 feet thick; top 738 feet below sea level)—
Dolomite, light gray, crystalline; much hard green shale from above in large flakes; quartz sand 1828–1840
Sandstone, fine; some dolomite 1840–1850
Dolomite, white, highly arenaceous, imbedded grains; 2 samples 1850–1870
Dolomite, light yellow-gray and gray, arenaceous, imbedded grains; 5 samples 1870–1920
Dolomite, very light gray; shale in concreting powder; quartz sand with secondary enlargements; splintery shale 1920–1930
Sandstone, white, larger grains about 0.8 mm. in diameter, secondary enlargements; some dolomite; 4 samples 1930–1970
Dolomite, light buff and gray, cherty at 2010, 2030, arenaceous in places, as 2070, 2080, 2150; much hard shale at 2120; 21 samples 1970–2180

Cambrian:
Jordan sandstone (30 feet thick; top 1086 feet below sea level)—
Sandstone, white, grains well rounded and frosted, larger grains a little over 0.8 mm. diameter; 2 samples 2180–2200
Sandstone, as above, finer 2200–2210
Saint Lawrence, Trempealeau beds (100 feet thick; top 1116 feet below sea level)—
Dolomite, gray, arenaceous at 2240 and 2300, argillaceous at 2260 and 2280; 10 samples 2210–2310
Saint Lawrence, Franconia beds (410 feet thick; top 1216 feet below sea level)—
Sandstone, light greenish gray in mass, glauconitic, dolomitic, argillaceous, grains minute, some medium, coarser at 2340, with chips of dolomite at 2350; 10 samples 2310–2410
Sandstone, green-gray, glauconitic, argillaceous, dolomitic, grains minute 2410–2420
Shale, blue-gray, in concreted masses, glauconitic, dolomitic, minutely arenaceous; flakes of hard drab shale; 2 samples 2430–2450
Shale, dark olive-green and drab, in flakes 2450–2460
Sandstone, gray in mass, in detached grains, some 1 mm. in diameter, well rounded, mostly in fine and minute grains, dolomite in chips, blue-gray, glauconitic, highly arenaceous in minute grains 2460–2470
Dolomite, buff-gray in mass, minutely and finely arenaceous; much quartz sand in detached grains 2470–2480
Dolomite, gray in mass, in fine sand with much quartz sand in grains from minute to medium 2490–2500
Shale, blue-green, hard, finely laminated, "paper shale" 2500–2510
Shale, blue-green, in moulded masses inclosing chips of same 2510–2520
Shale, reddish and blue-gray, finely laminated, noninflammable; 2 samples 2520–2540
Shale, red and green 2540–2550
Shale, blue-gray and olive-green, in thin splintery flakes; some sandstone, dolomitic and glauconitic of minute grains; 5 samples 2550–2600

(This record is completed in the appendix.)

Notes.—The gray, drab and blackish shales underlying the drift are typical of the Des Moines, but the conglomerate or gravel which underlies them is exceptional. It may be compared with the Pennsylvanian sandstone and conglomerate found in troughs eroded in the Mississippian and earlier formations of eastern Iowa, and with the much thicker arkosic sandstones and

conglomerate in which the drill stopped at Manson 1200 feet below the surface. The lack of rounding of the pebbles is not inconsistent with the theory of their origin as a land deposit. The presence of some of the pebbles is probably to be accounted for by cave. But it is highly improbable that all or even a large part are due to an extensive downfall from the gravels of the drift, the only other possible source, so accurately timed as to occur at the precise time when the drill had just passed through the shales of the Des Moines. The cherts with irregular surfaces are clearly Mississippian and probably are residual material. Those of the lower of the two samples, however, may belong to rock in place which the drill was entering.

The Mississippian may consist wholly of the Kinderhook limestones and shales, although the upper cherts suggest the Montrose beds. Cherty beds, however, occur in the Kinderhook of this area. The oölitic limestone at 520 feet is characteristic. The shale 80 feet thick at 550 feet is assigned to the Kinderhook shale. At Boone this shale extended from 590 to 630 feet.

The limestones placed with the Devonian permit only the most general reference at best and the lower limit is uncertain.

The gypseous dolomites pretty clearly belong to the Salina group of the Silurian, while the shale beneath them is readily assigned to the Maquoketa, although the ocher-yellow and terra cotta red of the basal layers are quite exceptional. But 25 feet of buff shale is reported by Beyer at this horizon in the deep wells at Boone.

The Galena-Platteville is present in great force, and is dolomitic throughout, except for 50 feet of limestone of "Trenton" facies and shale at base. The heavy beds of chert at top are worthy of note and perhaps should go to the Maquoketa.

The Glenwood shale is given a thickness of but six feet. An entirely similar shale in a thin bed along with limestone occurs about 30 feet higher up and in these transitional strata might possibly be placed with the shale beneath.

Both the Saint Peter and the Jordan sandstones are thin. The Prairie du Chien is divided, as is common, by the sandy beds of the New Richmond, 1930 to 1970 feet.

The Trempealeau and the Franconia beds of the Saint Law-

rence are sharply delimited, the latter showing its usual glauconitic, dolomitic and argillaceous sandstones of minute grains and its hard splintery shales.

ORANGE CITY

(Altitude 1471 feet)

CITY DEEP WELL NO. 2

Previous to 1921 the public supply of Orange City had been drawn from a drilled well 215 feet deep, two shallow wells, and a deep well sunk in 1911 to a depth of 562 feet. As these sources became inadequate and unsatisfactory a well 825 feet deep was drilled in 1921 by the Thorpe Brothers Well Company of Des Moines to tap the deeper water beds of the area. On completion the pumping capacity was found to be 110 gallons per minute with the cylinder set 280 feet below the surface. The static level, 200 feet below the curb, is not drawn down by continuous pumping.

The sandstone in which the well ends was considered water bearing as the cuttings were largely washed away. The work was stopped here because of extensive caving of the overlying shales. The diameter had already been reduced to 5 inches and to go on would require pulling 80 feet of casing and reaming. The water is very hard and unsatisfactory for boilers.

Record of strata

	Depth in Feet
Pleistocene and Recent (160 feet thick; top 1412 feet above sea level):	
Till, yellow, clayey, with pebbles	10, 20
Clay, dark buff, plastic, gritty	30
Gravel, with some clay	40
Till, bright yellow, with pebbles	50
Till, darker yellow, with pebbles	60
Sand, yellow, coarse	80, 90
Clay, blackish, fine-grained, in hard concreted masses, gritty with coarse sand consisting largely of chert and limestone	100
Till, brown, pebbly	110
Sand, yellow, rather fine	120
Till, dark buff, clayey, with pebbles	130
Clay, buff, sandy	140
Sand and fine gravel	150
Cretaceous:	
Colorado (330 feet thick; top 1252 feet above sea level)—	
Sandstone, gray, grains ranging widely in size, poorly rounded, mostly of quartz	160
Shale, brownish gray, calcareous, fine-grained, polishing under the finger nail, with sand and pebbles, chiefly of limestone, some of diorite	170
Shale, blue-gray, fine-grained, plastic, calcareous, somewhat gritty with fine sand mostly of quartz	180

Sandstone, as at 160 feet, but coarser, some grains of limestone, some of ferro-magnesian minerals, mostly of clear quartz; some pink and yellow 190, 200
Marl, light yellow-gray, rapid effervescence in cold dilute HCl, in powder concreted to friable masses, clayey, minutely arenaceous 210
Sandstone, very fine, of minute particles of quartz, mostly clear, some red and pink, some ferro-magnesian minerals, calcareous, argillaceous 220
Shale, gray, unctuous, calcareous, somewhat gritty, in hard concreted masses 230
Sandstone, as at 220 but more argillaceous 240
Shale, as at 170 250
Shale, yellow-gray, gritty, somewhat calcareous 260
Shale, as at 170; 3 samples 270–290
Shale, blue-gray, unctuous; 5 samples 300–340
Sandstone, gray, fine, grains imperfectly rounded; 3 samples 350–370
Limestone, rapid effervescence, in chips; shale, hard, calcareous, siliceous 380
Shale, highly pyritiferous and siliceous, in blue-gray powder and small chips 390
Shale, blackish and dark gray, unctuous; 5 samples 400–440
Shale, light gray, soft; dark gray, hard; in small chips, calcareous, siliceous; quartz sand 450
Shale, dark gray, highly siliceous with particles of impure cryptocrystalline silica and some grains of clear quartz 460
Shale, gray, hard, slightly calcareous, siliceous as above 470
Shale, blue-gray, pyritiferous, siliceous as above 480

Dakota (top 920 feet above sea level)—
Sandstone, gray and yellow-gray, fine and coarser, of clean quartz, grains imperfectly rounded, many larger grains angular and subangular; some coaly shale in cuttings at 570; 20 samples 490–685
(Fragments brought up from 635 to 637 are (1) of limestone, gray-buff, earthy, argillaceous, with black specks, highly siliceous with minute particles of crystalline quartz, and (2) of shale, hard, dark buff, calcareous, with much crystalline quartz in minute imbedded particles, and (3) of sandstone, gray, calcareous, moderately fine, grains imperfectly rounded, mostly of uncolored quartz, some pinkish.
Fragments from 670 to 672 are (1) a rounded concretionary mass of pyrite; (2) shale, blackish, coaly, burns white, but noninflammable; (3) shale, whitish, consisting largely of particles of cryptocrystalline silica, laminated, speckled with microscopic black grains)
Shale, greenish yellow, unctuous, noncalcareous 685, 696
(Of the fragment from 692-696 one-half is of whitish limestone of rapid effervescence, crystalline, vesicular, with greenish clay in vesicles, residue argillaceous and with small grains of crystalline quartz)
Sandstone, gray in mass, and light buff. of grains of clear quartz, widely differing in size, imperfectly rounded; at 750 some grains with bright red and orange stain as if from imbedment in red clay; 7 samples 696–750

Glenwood shale (?) (55 feet thick)—
Shale, dark red, plastic, in hard concreted mass, highly calcareous, residue of fine quartz sand with rounded grains 745-753
Shale. gray, fine-grained, calcareous, minutely arenaceous, samples in thin mud; 6 samples 753–790

Saint Peter (?) (penetrated 23 feet; top 610 feet above sea level)—
Sandstone, color in mass gray, moderately fine, but some irregular grains up to 2 mm. in diameter; grains of clear uncolored quartz excepting a few surficially stained pink or yellow.

Many grains well rounded and frosted, but not so uniformly as the grains of the Saint Peter of eastern sections; some chips of hard dark shale. Sandstone soft, 20 feet drilled in ten hours 802–825

CITY WELL NO. 1

The facts as to this well seem important enough to place on record although it is not now in use. It was completed in 1911 by G. J. Savidge of Sioux City. The depth is 652 feet; diameters are from 8 to 6 inches. Water was found from 410 to 564 feet and also at 300 feet. The capacity of the well was 20 gallons per minute, with the cylinder set at 320 feet. The static level was 225 feet below the surface of the ground.

The following log is made out from a diagram of the well:

Driller's Log

	Depth in Feet		Depth in Feet
No record	0–300	Sandstone, not much water	412–442
Rock	300–331	Clay	442–512
Blue clay		Sandstone, white, soft, water	512–562

*Mineral Content of City Well No. 2, Orange City**

	P.P.M.
Bicarbonate	351.4
Chloride	29.
Sulphate	829.0
Silica	10.2
$Fe_2O_3+Al_2O_3$	39.8
Calcium	276.5
Magnesium	97.8
Na + K as Na	153.0
Total solids	1610.0

OTTUMWA

(*Altitude 645 feet*)

WELL NO. 5, JOHN MORRELL AND COMPANY

In 1928 the fifth deep well of this packing company was completed by S. B. Geiger and Co. of Chicago. The depth is 2002 feet and the diameters are from 20 to 10 inches. The principal supply was found at 1803 feet, the horizon of the Jordan sandstone. Water was found also at 150 feet in brown sand of the Mississippian, at 1115 feet in "sand" supposed to be the Galena dolomite, and at 1680 feet in creviced dolomite of the Oneota.

After the drill reached 150 feet the static head never fell below the surface of the ground and on completion it stood at 28 feet above the surface, giving a natural discharge of 1,850 g.p.m. With a surface pump the capacity is 3,000 g.p.m.

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

From the top to 218 feet is set an 18 inch pipe and a 12 inch pipe extends from 266 to 706 feet, casing out the Kinderhook shale and some of the overlying strata.

Mineral analysis

Constituent	Grains per U. S. gallon	Constituent	Grains per U. S. gallon
Silica	0.28	Soluble incrusting solids	6.53
Iron and alumina oxides	0.04	Insoluble incrusting solids	15.02
Calcium carbonate	13.10		
Magnesium carbonate	1.60	Total incrusting solids	21.55
Magnesium sulphate	6.53	Hardness	20.50
Sodium sulphate	34.40	Alkalinity	15.00
Sodium chloride	12.10		
Organic and volatile matter	1.27		
Total solids	69.32		

Driller's log of Well no. 5, John Morrell Co., Ottumwa, with assignment to formations

	Depth in Feet
Pleistocene and Recent (20 feet thick, top 643 feet above sea level):	
Clay and quicksand	0–20
Mississippian, undifferentiated (535 feet thick; top 623 feet above sea level):	
Lime shell	20–25
Shale and lime shells	25–90
Sandy shale	90–105
Shale	105–142
Brown sand, water flow	142–150
Lime	150–165
Shale	165–213
Lime	213–280
Shale, cavy about 300 feet	280–315
Lime	315–320
Lime and shale	320–335
Lime	335–555
Kinderhook shale (140 feet thick; top 88 feet above sea level)—	
Shale	555–622
Broken lime	622–667
Shale	667–695
Devonian, and Silurian (?) (75 feet thick; top 52 feet below sea level):	
Lime	695–720
Lime and shale	720–725
Lime	725–770
Ordovician:	
Maquoketa shale (55 feet thick; top 127 feet below sea level)—	
Shale	770–825
Galena-Platteville (417 feet thick; top 182 feet below sea level)—	
Lime	825–835
Shale	835–845
Sandy lime	845–855
Shale	855–870
Lime	870–875
Shale	875–900
Lime	900–955
Sand	955–970
Hard lime	970–993
Blue shale	993–997
Hard creviced lime	997–1010

Lime	1010–1090
Sandy lime	1090–1115
Sand	1115–1120
Sandy lime	1120–1180
Sand	1180–1200
Blue shale	1200–1205
Soft sand	1205–1242
Glenwood shale (10 feet thick; top 599 feet below sea level)—	
Shale	1242–1252
Saint Peter sandstone (43 feet thick; top 609 feet below sea level)—	
White sand	1252–1295
Prairie du Chien—	
Shakopee (185 feet thick; top 652 feet below sea level)—	
Lime	1295–1325
Sandy lime	1325–1480
New Richmond (55 feet thick; top 837 feet below sea level)—	
Sand	1480–1535
Oneota (247 feet thick; top 892 feet below sea level)—	
Sandy lime	1535–1635
Lime	1635–1645
Sandy lime	1645–1655
Sand	1655–1665
Lime	1665–1680
Creviced lime	1680–1730
Sand	1730–1740
Lime	1740–1782
Cambrian:	
Jordan (100 feet thick; top 1139 feet below sea level)—	
Sandy lime	1782–1795
Sandy lime	1795–1803
Big flow	1803–1805
Lime	1805–1845
Sandy lime	1845–1872
Soft sand	1872–1882
Saint Lawrence—	
Trempealeau dolomite of the Saint Lawrence (penetrated 177 feet; top 1239 feet below sea level)—	
Lime	1882–1930
Lime	1930–1982
Sandy	1982–1992
Lime	1992–2002

Notes.—The geologic section at Ottumwa is based on five well logs, none of which is confirmed by any cuttings. There is much diversity among these logs, especially above the horizon of the Saint Peter, so that any interpretation is both difficult and uncertain. The first heavy shale, assigned to the Kinderhook, is reported in the Morrell well no. 5 at 88 feet above sea level and 140 feet thick; in well no. 1, at 123 feet above sea level and 185 feet thick; in well no. 2 at 37 feet above sea level and 102 feet thick. In the well of the Artesian Well Co. the first heavy shale is said to have been found at 219 feet above sea level and to be 160 feet thick.*

* Norton, W. H., Iowa Geol. Survey, vol. XXI, pp. 735-738.

The Maquoketa shale is not represented in the logs of the Artesian Well Co. and of Morrell well no. 1. In the log of the Morrell well no. 4 it appears as heavy shale extending from 137 to 307 feet below sea level, thus including strata assigned to the Galena in the log of well no. 5. The interpretation of well no. 5 is conservative as to the lower limits of the Maquoketa, which perhaps in fact includes some of the upper shaly beds placed with the Galena.

The same conservatism in interpretation limits the Saint Peter to the "white sand" at 609 feet below sea level which is overlain with a shale taken to be the Glenwood. In this and other logs we may discriminate between "white sand" and "sand", "sand rock", "sandy lime", or "limestone mixed with sand". As the latter terms are applied in the Ottumwa logs to beds high up in the Galena as well as to beds near its base they probably are used to designate the crystalline sand to which the Galena dolomite often crushes. This use by drillers is well known, as in the log of the well of the Electro-Metals Co. of Keokuk. On the other hand, if the term "sand" in the above log is consistently interpreted as sandstone, the Glenwood formation becomes of interesting and extraordinary complexity, with a thickness of 397 feet.

The Prairie du Chien is normal, but the horizon of the Jordan sandstone does not show any clear sandstone of considerable thickness, and the assignment is here quite uncertain. The heavy "lime" beginning at 1882 feet is probably the top of the Trempealeau. Well no. 4 of the Morrell Co. extends 203 feet below the footing of well no. 5, but it can not be told from the log whether or not the Eau Claire was reached. At these levels sandstones of microscopic grain cutting into chips are apt to be termed "lime".

OXFORD, JOHNSON COUNTY

(Altitude 736 feet)

In July, 1925, a well 586 feet deep was completed for the town of Oxford (Johnson county) by Chas. D. Nolan of Cedar Rapids. Ten inch casing extends to 156 feet and 8 inch casing "for 145 feet", the remainder of the well being uncased. A flow testing 3 gallons per minute was found at 305 feet in "sand rock". The main flow comes from 450 to 586 feet, probably in Niagaran limestone. The head is 62 feet below the curb and with the cylinder

at 125 feet the pumping capacity is 75 gallons per minute. The cost of the well was $3300.

Driller's Log

	Depth in Feet		Depth in Feet
Blue clay and sand	0–156	Rock	290–586
Lime, soapstone and shale	156–290	Shale	586

The driller reports also a second city well drilled at the same time as well no. 1 and 12 feet distant, apparently of the same dimensions, but not so strong a flow.

PLEASANTVILLE, MARION COUNTY

(Altitude 926 feet)

A well 1826 feet in depth was drilled in 1920 for the town of Pleasantville by the Thorpe Brothers Well Company of Des Moines.

The well is cased with 10 inch pipe to 135 feet. Eight inch casing reaches from the top to 348 feet, 6 inch casing from 340 to 1460 feet and 4 inch from 1400 feet to the bottom. The casing was perforated from the bottom up for 120 feet, and above the perforations were set two disc and two compression packers, sealing all lines completely from the surface to 1706 feet, and permitting only the water below the latter depth to enter the well.

Water was encountered at 328 feet at the top of the Mississippian with a flow of about 23 gallons per minute and of poor quality. Another water bed was found at the base of the Silurian from 1100 to 1190 feet. The chief water beds, apparently in the Saint Peter, the upper 40 feet of the Shakopee, and the lower 54 feet of the Galena-Platteville, on final test supplied 70 gallons per minute. The static level of this water is 180 feet below the curb.

Driller's log of Pleasantville City well

	Thickness in Feet	Depth in Feet	Elevation of top above sea level in Feet*
Glacial deposits	135	0–135	926
Pennsylvanian shales	190	135–325	791
Mississippian lime	351	325–676	601
Kinderhook shale	127	676–803	250
Devonian and Silurian	387	803–1190	123
Maquoketa shale	231	1190–1421	–264
Galena and Platteville	339	1421–1760	–495
Saint Peter sandstone	26	1760–1786	–834
Sandy lime (Shakopee)	40	1786–1826	–860

* Added by W. H. Norton.

Notes.—The above log with the assignment to formations as given by experienced drillers is so reasonable that it is accepted although unconfirmed by samples of cuttings and even though it involves the assumption of either an unexpected upfold or the practical absence of dip from at least as far east as Pella. In thickness and elevation of the different formations, the Pleasantville section nearly duplicates that at Pella, and the summit of the Saint Peter is but 17 feet lower at the former than at the latter point. Normally in this distance the difference might easily amount to 150 or 200 feet. Thus the broad spacing of the contours (see map, Plate I) showing the elevation of the summit of the Saint Peter, long known to exist in southeast Iowa, is now carried considerably farther to the west. If an upfold exists in this area it probably is a continuation to the south-southeast of the Ames anticline. And if the elevation of the Saint Peter at Pleasantville is but 834 feet below sea level, there must be an unusually steep descent to the bottom of the Des Moines syncline, since at Des Moines the Saint Peter lies some 300 feet lower.

*Mineral Content of City Well, Pleasantville**

	P.P.M.
Bicarbonate	300.1
Chloride	132.
Sulfate	579.8
Silica	12.4
$Fe_2O_3+Al_2O_3$	7.4
Calcium	105.5
Magnesium	39.5
Na + K as Na	231.7
Total solids	1258.3

PRESTON, JACKSON COUNTY

(*Altitude 659 feet*)

The deep well of the Preston Water Company was drilled in 1922 by Thomas James of Shullsberg, Wisconsin. The depth is 989 feet and the diameters are from 10 to 5 inches. The principal supply was found from 900 to 989 feet in the Jordan sandstone. Water rises within 19 feet of the surface and the pumping capacity of the well is 75 gallons per minute with the pumping cylinder set 145 feet below the curb.

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

A full set of cuttings from the well were saved, but unfortunately were soon destroyed. A blue print, however, which had been made by J. G. Thorne of Clinton, Engineer in charge, had a better fate and from it the following log is taken, with the elevations relative to sea level added:

Driller's Log

	Depth in feet	Elevation of top
Maquoketa shale	0–120	660
Galena to Platteville, inclusive	120–470	540
Blue shale (Glenwood)	470–490	190
Saint Peter sandstone	490–530	170
Red sandstone	530–743	130
Red sandstone	743–760	
Red shale	760–763	
Red sandstone	763–803	
Clay and sand	803–813	
Red sandstone	813–887	
Clay and sand	887–895	
Hard blue clay	895–897	
White sand	897–903	–237
Jordan sandstone	903–989	–243

*Mineral Content of City Well, Preston**

	P.P.M.
Bicarbonate	370.9
Chloride	15.
Sulfate	51.6
Silica	7.6
$Fe_2O_3+Al_2O_3$	19.0
Calcium	58.9
Magnesium	17.8
Na + K as Na	20.3
Total solids	375.6

RHODES, MARSHALL COUNTY

(*Altitude 1011 feet*)

A well for the public supply of this town was drilled in 1914 by E. A. Ford of Marshalltown. The depth is 300 feet, the diameter is 8 inches. The well ends in sand 95 feet thick after passing through 205 feet of clay. It has been sufficient for the consumption of the town, which averages 5000 gallons per day.

RIPPEY, GREENE COUNTY

(*Altitude 1068 feet*)

The well of the Rippey waterworks, completed early in 1922 by Thorpe Bros. of Des Moines, is 1770 feet deep. The pumping capacity is rated at 60,000 g.p.d., five times as much as the con-

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

sumption of the village. The diameters are 12 inches to 161 feet, 10 inches to 230 feet, 8 inches to 713 feet and 6 inches to the bottom. The total amount of casing is 1058 feet, placed as follows: 10 inch from top to 161 feet, 8 inches from 150 to 250 feet, 6 inch from 200 to 712 feet, and liners from 645 to 741 feet, from 1150 to 1237 feet, from 1337 to 1491 feet, and from 1640 to 1728 feet.

Record of strata

	Depth in Feet
No record	0–152
Pennsylvanian (minimum thickness, 98 feet; top (?) 912 feet above sea level):	
"Limestone"	152–153
"Black shale and slate"	153–169
"Coal"	169–171
"Slate and black shale"	171–182
"Fire clay"	182–190
"Green and blue shale"	190–227
"Hard pan"	227–230
Mississippian (385 feet thick; top 834 feet above sea level):	
"Brown limestone"	230–250
Shaly limestone	250–292
"Gray shale"	292–300
"Shaly limestone"	300–390
"Hard blue limestone"	390–405
"Marl"	405–430
Limestone, drab, rapid effervescence in cold dilute HCl; much chert, drab and white	422
Chert, gray and white; chips of vein quartz; some pyrite	442
Limestone, dark gray, fine crystalline and crystalline-earthy, rapid effervescence; in flaky chips; 2 samples	465, 476
Limestone, dark gray, saccharoidal, vesicular, rapid effervescence; some gray chert; 3 samples	487–496
Limestone, dark blue-gray, fine-saccharoidal, vesicular, considerable chert at 510, 514, 519; effervescence rapid; 4 samples	505–519
Chert, light blue-gray; some limestone as above	522
Limestone, drab, fine crystalline-granular, argillaceous, rapid effervescence; much blue-gray chert; 3 samples	527–537
Limestone, buff, subcrystalline, rapid effervescence	545, 550
Limestone, buff, pyritiferous, effervescence rapid; much clear quartz in minute irregular grains	556
No samples "limestone"	556–570
"Shale"	570–615
Devonian (155 feet thick; top 419 feet above sea level):	
Shale, dark green and drab, hard, in flakes; limestone, gray, effervescence rapid; limestone, buff, effervescence slow; quartz in small chips; chert; red sandstone in friable chips of poorly rounded grains and minute angular particles of clear quartz	715
Limestone, light gray and whitish, effervescence rapid, in sand; a little fissile light blue-gray shale in flakes, calcareous	750, 760
Silurian (350 feet thick; top 264 feet above sea level):	
Dolomite, light gray, in fine crystalline sand	770, 780
Dolomite, yellow and blue-gray, subcrystalline; limestone, lighter colored, rapid effervescence	790, 800
Dolomite, dark buff, subcrystalline; light gray shale	810
Dolomite, light yellow and blue-gray, subcrystalline, rather slow and slow effervescence; 8 samples	820–890
Dolomite, brownish mottled, a little white gypsum	900

Dolomite, buff and brown, in sand, also in chips at 910; 4 samples 910–940
Dolomite, blue gray 960, 970
Dolomite, light buff, subcrystalline 980, 990
Gypsum, white, in hard concreted masses; somewhat calcareous 1000
Limestone, buff and gray, moderately rapid effervescence; 3 samples....1010–1030
Limestone, brown, or dolomite, rather slow effervescence 1040
Limestone, buff, effervescence rather slow; limestone, buff, rather rapid effervescence 1060
Gypsum, gray, in hard concreted masses; some brownish limestone 1070
Limestone, light buff, moderately rapid effervescence, very fine-grained, in flakes; a little gypsum in white grains 1080
Dolomite, gray, effervescence rather slow; much gypsum in concreted masses and in detached grains and small chips; 3 samples 1090–1110
Dolomite, light yellow-gray, much white chert 1120

Ordovician:

Maquoketa (150 feet thick; top 66 feet below sea level)—
Limestone, blue-gray, highly siliceous; shale 1130
Limestone, as above; chert, blue-gray 1140
Shale, blue-gray, calcareous, plastic 1168, 1224
Limestone and chert as at 1140; 3 samples 1230–1250
(Sandstone, very fine, light gray in mass; hard dark green fissile shale; general facies of St. Peter, probably misplaced ..... 1260)

Galena-Platteville:
Chert, white; a little gray dolomite, no quartz sand or green shale 1280
Dolomite, light buff; in fine sand 1300
Chert, light drab; dolomite 1310
Dolomite, buff and gray, much white chert 1330, 1340
Dolomite, buff, in sand; gypsum in grains 1350, 1360
Shale, light blue-gray, calcareous, in moulded masses 1362–1368
Dolomite, buff, in sand, rather slow effervescence 1370
Gypsum, in concreted gray masses with some dolomite 1380
Dolomite, buff, effervescence rather slow, disintegrating under weak acid into microscopic crystalline particles 1390
Limestone, dark blue-gray, rapid effervescence 1400
Dolomite, gray and buff, cherty at 1430, 1440, 1460, 1470, 1550, 1570, 1580, 1600; 22 samples 1410–1660
Limestone, gray, in flakes and sand, rapid effervescence, earthy 1670, 1680

Glenwood (30 feet thick; top 626 feet below sea level):
Shale, dark blue-green, fissile, with rusty specks from oxidation of pyrite, slightly calcareous; much gray and brown limestone in sand, effervescence rapid; 3 samples 1690–1710

Saint Peter (48 feet thick; top 656 feet below sea level):
Sandstone, fine rounded grains, much shale as above 1720
Sandstone, as above, clean, larger grains up to 0.7 mm. in diameter 1734
Sandstone as above, finer 1745
Sandstone as above, larger grains 1 mm. diameter; considerable green shale 1750
Sandstone as above; 2 samples 1755, 1765

Prairie du Chien—
Shakopee (entered, top 704 feet below sea level):
Gray dolomite in fine sand and much quartz sand as above..... 1768

Driller's Log

	Depth in Feet		Depth in Feet
Given in *Record of strata*	0–430	Shale	1362–1387
Hard blue limestone	430–440	Limestone	1387–1685
Limestone	440–570	Shale	1685–1688
Shale	570–615	Limestone	1688–1723
Limestone	615–1168	St. Peter sandstone	1723–1766
Sandy shale	1168–1224	Hard limestone	1766–1770
Limestone	1224–1362		

*Mineral Content of City Well, Rippey**

	P.P.M.
Bicarbonate	317.2
Chloride	110.
Sulfate	729.0
Silica	3.8
Calcium	153.4
Magnesium	71.0
Na + K as Na	214.9
Total solids	1462.7

RIVERSIDE, WASHINGTON COUNTY

(*Altitude 631 feet*)

This well has a depth of 565 feet and its diameters are from 10 to 6 inches. It is cased within 320 feet of the bottom. When tested it pumped about 40 gallons per minute.

*Record of strata**

	Depth in Feet
Pleistocene:	
Clay and black dirt	0–24
Sand, very fine, gray, clean; "quicksand" of driller	24–30
Sand, fine, gray, with small admixture of clay; "blue clay" of driller	30–80
Clay, yellowish, very smooth and sticky; "clay" of driller	80–110
Sand, gray, fine, some small masses of blue clay, a little lime present shown by effervescence with acid; "sand" of driller	110–235
Mississippian:	
Kinderhook:	
Clay, light blue, very fine and smooth, no grit; "soapstone" of driller	235–410
Devonian and Silurian:	
Limestone, in small chips, mixed with sand, clean clear quartz and other materials. Sand in excess in sample; "rock" of driller	410–455
Limestone in fine sand, with quartz sand in about equal proportions, or perhaps an excess of limestone; "rock" of driller	455–500
Limestone, in very fine sand and mingled with fine quartz grains; "rock" of driller	500–565

SEYMOUR, WAYNE COUNTY

(*Altitude 1066 feet*)

The following log of a diamond drill prospect hole put down for oil at Seymour in 1926 is furnished by the drillers, the Sullivan Machinery Company of Chicago. The assignment to formations is by the writer.

	Depth in feet and inches
Pleistocene and Recent (152 feet thick; top 1066 feet above sea level):	
Soil	0 – 2
Yellow clay	2 – 15
Blue clay	15 – 18

* Analysis by Harry F. Lewis, Chemical Laboratory, Cornell College, 1927.

* By Dr. James H. Lees, Asst. State Geologist.

Fine sand	18	– 20
Hard pan (glacial till?)	20	– 45
Fine sand	45	– 49
Hard pan (glacial till?)	49	– 59
Gravel	59	– 63
Hard pan (glacial till?)	63	–132
Pennsylvanian (490 feet, 10 inches thick, top 934 feet above sea level):		
Gray shale	132	–139- 6
Shaly limestone	139- 6	–147
Gray sticky shale	147	–150
Red and gray shale	150	–154- 6
Gray sandy shale	154- 6	–172
Shaly limestone	172	–174
Blue sticky shale	174	–187
Gray shale	187	–190- 6
Dark shale	190- 6	–191- 4
Coal	191- 4	–192- 9
Bone	192- 9	–192-10
Coal	192-10	–193-10
Fire clay	193-10	–195- 4
Shaly limestone	195- 4	–201- 6
Gray shale	201- 6	–218
Dark shale	218	–222
Soft sticky shale	222	–228
Shaly limestone	228	–229
Sticky shale	229	–240
Dark shale	240	–243
Gray sticky shale	243	–244
Sticky shale	244	–259
Sandstone	259	–300
Shale	300	–301
Sticky shale	301	–314- 7
Coal	314- 7	–315
Dark shale	315	–316
Fire clay	316	–318- 2
Shaly limestone	318- 2	–319- 4
Sticky shale	319- 4	–324- 4
Conglomerate	324- 4	–325- 7
Sticky shale	325- 7	–328
Black shale	328	–338
Blue shale	338	–346- 2
Coal	346- 2	–346- 8
Lime shale with pebbles	346- 8	–355
Shaly limestone	355	–360- 8
Sticky shale	360- 8	–361-11
Coal	361-11	–362- 5
Dark shale	362- 5	–362-10
Sticky shale	362-10	–371- 8
Shaly limestone	371- 8	–373
Sticky shale	373	–381
Sticky shale, lime bands	381	–387
Sticky shale	387	–396
Dark shale	396	–396- 3
Coal	396- 3	–396- 4
Dark shale	396- 4	–398- 6
Shaly limestone	398- 6	–402-10
Limestone	402-10	–407-10
Sticky shale	407-10	–412
Sticky shale, gray	412	–423
Sandy shale	423	–425- 6
Dark shale	425- 6	–437- 4
Bony coal	437- 4	–437- 8

Sandy shale	437- 8–438
Sticky shale	438 –447
Shaly limestone	447 –452
Sticky shale	452 –459-10
Black shale	459-10–463-11
Sandy shale	463-11–481
Sandstone, shale streaks	481 –486- 6
Sandstone and coal, mixed	486- 6–487-10
Sandstone	487-10–496- 2
Coal	496- 2–496- 8
Fire clay	496- 8–499- 4
Dark shale	499- 4–509- 4
Bony coal	509- 4–511- 9
Shaly sandstone	511- 9–517
Dark sticky shale	517 –535- 9
Coal	535- 9–536
Soft sticky shale	536 –538- 5
Coal	538- 5–539- 2
Sandstone	539- 2–540
Limestone	540 –544- 5
Shaly limestone	544- 5–548- 9
Bony coal	548- 9–549- 4
Dark shale	549- 4–551- 1
Bony coal	551- 1–551- 9
Sticky shale	551- 9–560- 4
Limestone	560- 4–563- 1
Dark shale	563- 1–568
Sandy shale	568 –590
Sandstone	590 –614- 7
Dark shale	614- 7–617-11
Sticky shale	617-11–621- 3
Sandstone	621- 3–622-10

Mississippian (penetrated, 377 feet, 2 inches; top 443 feet above sea level):

Hard limestone	622-10–624
Shaly limestone	624 –633
Sandstone	633 –643
Limestone	643 –644
Sandstone and lime mixed	644 –680
Limestone	680 –694
Lime shale	694 –728- 3
Limestone	728- 3–730- 9
Lime shale	730- 9–732- 5
Hard limestone	732- 5–736
Broken limestone	736 –746
Soft shale	746 –747
Limestone	747 –748- 4
Shale	748- 4–749- 9
Limestone	749- 9–750- 6
Shale	750- 6–751- 4
Limestone	751- 4–754- 8
Hard limestone	754- 8–774- 2
White quartz	774- 2–774- 6
Lime shale	774- 6–775- 2
White quartz	775- 2–775- 5
Lime shale	775- 5–779-11
White quartz	779-11–780- 6
Lime shale	780- 6–780- 9
White quartz	780- 9–781- 1
Lime shale	781- 1–782- 8
Hard limestone	782- 8–783- 8
Lime shale	783- 8–784- 4

Hard limestone	784- 4	–785- 6
Lime shale	785- 6	–786- 6
Lime and white quartz	786- 6	–788- 4
Lime shale mixed	788- 4	–789- 9
Hard limestone	789- 9	–807
Hard chert	807	–808
Chert	808	–809- 3
Hard limestone	809- 3	–832
Hard broken limestone	832	–847
Chert	847	–847- 4
Hard broken limestone	847- 4	–957
Hard limestone	957	–974
Hard broken limestone	974	–991
Limestone	991	–1000

Arrangements had been made with the local promoters to save sample drillings. A few were sent to the Survey office for determination while the work was progressing and these are described below by Dr. Lees. After drilling stopped, however, it was impossible to learn anything about samples or to secure any.

	Depth of sample feet
Sandstone, grains fine, clear, fairly well rounded. A few fragments of gray and black noncalcareous shale. A few specks of pyrite	647
Sandstone, similar to above	656
Limestone, dark gray, very finely granular. A few clear quartz grains	671
Limestone, similar to above but with more quartz, some in fine embedded grains	681
Limestone, dark gray, finely granular; and shale, gray. Some limestone chips are only very slightly respondent to acid	690
Shale, dark gray to black, fine texture, noncalcareous; sandstone with dolomitic cement, sand grains fine, clear, also some sandstone chips are dark gray or brown	694
Sandstone and shale mixed. Sandstone is broken up more than in preceding sample, grains are clear but much dark material, perhaps from shale, imparts a dark color to the sample	699

SHELLSBURG, BENTON COUNTY

(Altitude 776 feet)

WELL NO. 1, IOWA CANNING COMPANY

This well, 1160 feet in depth, was drilled by C. D. Nolan of Cedar Rapids. Footing in the Shakopee dolomite, its capacity is from 70 to 80 g.p.m. The static level is 30 feet below the surface, or 30 feet above that of well no. 2, footing in the Jordan. Account must here be taken of the fact that in well no. 1 the upper waters were not effectively cased out.

With the air pipe at 248 feet, the draw-down was estimated as to 110 feet below the surface of the ground. The water is charged with sulphuretted hydrogen gas and is somewhat laxative.

No log or samples of cuttings are available from this well. It is stated that the Saint Peter was reached at 1012 feet and that a "sand" was found at 865 feet. In well number 2, however, the drill at this depth was working in clean nonmagnesian limestones of the Galena-Platteville.

As the supply was insufficient and the well could not be deepened, since a string of drilling tools, fishing tools and a whipstock had been left in it, a second well became necessary.

WELL NO. 2, IOWA CANNING COMPANY

This well, 1519 feet deep, was completed in 1928 by C. W. Varner of Dubuque. The diameters are 10 inches to 1055 feet and 8 inches to the bottom. The principal supply was found in the Jordan sandstone, from 1474 to 1519 feet. Water was found also from 997 to 1028 feet in the Saint Peter sandstone, and from 1195 to 1218 feet in the New Richmond sandstone.

The static level is 50 feet below the surface, 751 feet above sea level. Until the Jordan sandstone was reached the head seems to have been about 90 feet below curb. With the foot piece of the air lift at 320 feet the draw down is estimated at 71 feet. The cost of the well was $7500.

Record of strata, well no. 2, Iowa Canning Co., Shellsburg

	Depth in Feet
Pleistocene and Recent (50 feet thick; top 801 feet above sea level):	
No samples	0–50
Devonian, Wapsipinicon (140 feet thick; top 751 feet above sea level):	
Limestone, buff and light yellow-gray, calcilutite; light buff, crystalline-earthy; blue-gray, earthy, finely laminated, argillaceous, pyritic; all of rapid effervescence in cold dilute HCl; blue-gray powder of shale	50
Limestone, buff, rapid effervescence, some earthy, in small chips; large chips of shale as below	60
Shale, light green and blue-gray, hard, highly calcareous, rapid effervescence, in large chips and concreting powder; limestone, brown-gray, rapid effervescence	60–70
Limestone, yellow-gray, gray and dark gray mottled, crystalline, rapid effervescence; pyrite; gray chert; light brownish unctuous shale; concreting powder of blue-gray shale; cinders	70–80
No sample	80–90
Limestone, buff gray, somewhat mottled, fine crystalline-earthy, rapid effervescence, clean large flakes; calcite; cinders	90–100
Limestone, gray, rapid effervescence; shale, blue-gray and yellow-gray	100–110
Limestone, magnesian, or dolomitic, yellow-gray, rather slow effervescence, crystalline, porous, disintegrating under weak acid into crystalline sand	120–130
Limestone, cream color, soft, fine, earthy	150

Limestone, buff and light gray, rapid effervescence, in fine sand; shale, light bluish, in fine chips; quartz sand, fine to 1.3 mm. diameter, grains mostly ill-rounded, some well rounded, a few secondary enlargements, some small chips of sandstone, fine, secondary enlargements, calcareous, rapid effervescence; pyrite; shale 150–160
Limestone, light cream yellow, calcilutite and very fine-grained, earthy, rapid effervescence 170
Limestone, light buff-gray, fine crystalline-granular and earthy, rapid effervescence; some chips of blue-gray shale 180

Silurian (260 feet thick; top 611 feet above sea level):

Dolomite, buff-gray, vesicular, casts of fossils, cavities lined with drusy spar, facies of Niagaran dolomite 190
Dolomite, buff-gray and light gray, rather slow effervescence; some large chips of fine-grained limestone, rather rapid effervescence; blue and white chert 200, 210
Chert, white, gray and drab; dolomite, very light gray; one chip of calcite and chert; some milky quartz 220, 230
Chert, white; a little dolomite, light yellow-gray; 4 samples 240–280
Chert, white and blue-gray, some pyrite; considerable quartz sand, rounded grains up to about 1 mm. diameter; a little calcite 290
Chert, etc., as above; considerable light gray dolomite 300
Chert, etc., as above; very little dolomite 310
Chert, etc., as above; considerable very light gray dolomite; large chips of blue-gray and drab shale, noncalcareous, arenaceous with quartz sand of rounded grains up to 1 mm. diameter and cherty 320
Dolomite, very light gray, some pink; chert; quartz sand; pyrite; much chert at 340 ..... 330, 340
Dolomite, gray; large irregular fragment of dolomitic sandstone of minute angular grains, pyritic at 360 ..... 350, 360
Dolomite, blue-gray and yellow-gray; large irregular fragment of blue-gray sandstone, minute angular and fine rounded grains, calcareous, highly argillaceous, pyritic 370
Dolomite, gray, light gray and drab; some white chert in small chips; a little quartz sand; 4 samples 380–410
Sandstone, blue-gray, grains minute, some fine rounded, argillaceous, speckled with minute pyrite crystals, calcareous, with rapid effervescence; sandstone chips show included pyritic chert; white and gray chips of chert 420, 430
Sandstone, as above except noncalcareous; dolomite, gray, crystalline, with minutely arenaceous and pyritic residue; much shale in concreting powder 440

Ordovician:

Maquoketa shale (170 feet thick; top 351 feet above sea level)—
Shale, light blue-gray, in hard masses, inclosing chips of sandstone as at 440 feet and white chert 450
Shale, light blue-gray, and blue and green-gray, and drab, plastic; inclosing chips of white chert and dolomite at 480 and 490; 5 samples 460–500
Shale, light gray and gray, hard, siliceous, in chips of slow effervescence, and concreting powder; cherty at 550; 8 samples 510–580
Shale, light blue-gray, calcareous, in moulded masses 590
Shale, gray, in moulded masses and chips 600
Shale, blue-gray, plastic; olive-drab chips, dolomitic 610
Galena-Platteville (367 feet thick; top 181 feet above sea level)—
Dolomite, brown, in clean sand 620
Limestone, magnesian, or dolomite, drab and buff-gray, rather slow effervescence in chips 630, 640
Limestone, drab and brown-gray, argillaceous, rapid effervescence 650
Shale, gray, in moulded masses, inclosing chips of brown-gray, highly argillaceous limestone 660
Shale, light blue-gray, in moulded masses 670
Limestone, brown, rather rapid effervescence, in sand 680

Limestone, gray and light gray, earthy, rapid effervescence, in large flakes	690
Limestone, light gray to buff, rapid effervescence, facies of non-dolomitized Galena-Platteville; 21 samples	700–900
Limestone, blue-gray in mass, rapid effervescence	920
Limestone, yellow-gray	920
Shale, green-gray, plastic, inclosing chips of limestone	925–930
Limestone, blue-gray in mass, rapid effervescence; 4 samples	940–970
Limestone, light brown-gray, rapid effervescence	980
Glenwood shale—	
Shale, buff and drab, plastic	987–990
Saint Peter sandstone (33 feet thick; top 194 feet below sea level)—	
Sandstone, white, grains well rounded, frosted, larger grains about 1 mm. diameter; 4 samples	995–1028
Prairie du Chien (423 feet thick)—	
Shakopee dolomite (160 feet thick; top 239 feet below sea level)—	
Dolomite, light yellow-gray; much quartz sand	1040
Dolomite as above	1045–1050
Dolomite, light gray, arenaceous, with fine to medium well rounded grains, in chips concreted with blue-gray powder of shale	1060
Dolomite, light gray, arenaceous with imbedded grains	1070
Dolomite, gray	1080
Dolomite, with quartz sand in cuttings and showing numerous imbedded grains; occasional secondary enlargements; 11 samples	1090–1190
New Richmond sandstone (40 feet thick; top 399 feet below sea level)—	
Sandstone, fine, dolomitic cement, some chips of dolomite; water, static level rose	1200
Sandstone, fine, clean quartz, grains not well rounded	1210
Sandstone as above, a little dolomite	1220
Sandstone, coarser; dolomite, pyrite	1230
Oneota dolomite (223 feet thick; top 439 feet below sea level)—	
Dolomite, gray of various tints and shades, in places arenaceous with imbedded grains; 19 samples	1240–1400
No samples, cuttings washed away	1405, 1420
Sandstone; some dolomite	1430
Dolomite; some quartz sand	1440
Dolomite, arenaceous, imbedded grains	1450
Cambrian:	
Jordan sandstone (56 feet thick; top 662 feet below sea level)—	
Sandstone, grains rounded, dolomitic cement	1463
Sandstone, white, in sand and chips, grains well rounded and frosted, larger grains slightly over 1 mm. diameter, chips of finer grains, dolomitic cement	1470
Sandstone, white, finer than above, cuttings largely in chips	1480
Sandstone, white, in detached grains, larger grains from 1 to 1.3 mm. diameter	1485
Sandstone, as at 1470	1490, 1500
Saint Lawrence dolomite (?) (entered at 718 feet below sea level)—	
Dolomite, light yellow-gray in chips; quartz sand in cuttings	1519

Notes.—The Devonian cuttings do not include any of a highly fossiliferous limestone, such as the *Spirifer pennatus* beds outcropping at Vinton, or the Cedar Valley limestones cut by the drills at Oakdale and Iowa City. It is somewhat probable that the calcilutite at 50 feet is from the Lower Davenport horizon of

the Wapsipinicon and the shales and limestones beneath will then fall in with the Kenwood and in part the Otis beds. Probably the strata of the Wapsipinicon are here more or less brecciated and intermingled as at Cedar Rapids and at the Aungst and neighboring quarries north of Vinton. The limestones at 120 to 150 feet strongly resemble the basal beds of these quarries, which are referred to the lower beds of the Otis limestone,[63] the equivalent of the Coggon limestone of the Linn county report.[64]

The transition from these limestones to the typical Niagaran dolomite at 190 feet is abrupt. Compared with the Vinton section as shown by the cuttings of the city wells[65] the top of the Niagaran dolomite appears distinctly higher (54 feet) at Shellsburg than at Vinton. But the fewness of the samples taken at Vinton leaves little ground for this conclusion. One sample is supposed to represent 82 feet above the Niagaran dolomite. This sample, composed of chert, quartz sand, pyrite and nonmagnesian limestone, may be compared with the Shellsburg sample at 150 feet.

The Silurian is noteworthy for the heavy beds of chert and cherty dolomite, struck at 220 feet and more than 100 feet thick, and also for the sandstone thirty feet thick at its base. Although the Hopkinton stage of the Niagaran in its outcrops is widely characterized by chert and cherty bands, especially near its base, as at Lyons, no such heavy deposits of chert are known as these at Shellsburg. To be sure the cuttings have been washed, so that chert, commonly in large chips, is more prominent in samples than dolomite and shale crushed by the drill to sand and powder and more easily washed away. But it is believed that this fact does not account for the great excess of chert in a number of the samples, since in others much of the softer constituents of the rock has been left.

The basal sandstone is exceptional in this area and may be compared with the Colmar sandstone which overlies the Maquoketa in the Colmar oil field of Illinois.

The top of the Maquoketa at Shellsburg is placed 114 feet

63 Norton, W. H., Wapsipinicon Breccias of Iowa: Iowa Geol. Survey, vol. XXVII, p. 415.
64 Norton, W. H., Geology of Linn Co., Iowa Geol. Survey, vol. IV, p. 138 seq.
65 Norton, W. H., Thickness of the Paleozoic Strata of Northeastern Iowa: Iowa Geol. Survey, vol. III, pp. 192-194.

lower than at Vinton. This suggests an error in one or the other, or both, of the sections, especially as the upper 194 feet of the Maquoketa at Vinton is determined by only two samples. These samples, however, are expressly stated to represent the entire 194 feet, and in the matter of shale are less likely of error than in the case of limestone. It is hardly possible to consider as Maquoketa the lower beds referred to the Niagaran at Shellsburg, the dolomite from 330 to 410 feet and the sandstone from 420 to 450. The cherts at 220 feet are quite too high to be considered Middle Maquoketa, which in Fayette and Clayton counties is highly cherty and is overlain by about 125 feet of plastic shale.[66]

The more satisfactory explanation of the difference in level of the top of the Maquoketa at the two nearby points is the unconformity between the Niagaran and Maquoketa already known to exist. Indeed the difference in level in this case is about the same as one noted in outcrops in Jackson county by Savage.[67] At Cedar Rapids the top of the Maquoketa is but 35 feet higher than at Shellsburg.

The thickness assigned to the Galena-Platteville-Glenwood at Shellsburg—366 feet—may be compared with that at Vinton, 401 feet, at Cedar Rapids, 305 feet, and at Oakdale 370 feet.

The only typical dolomite of the Galena beds is found in a thin stratum at top. The shales at 660 and 670 have the aspect of the Maquoketa. The limestones they overlie are entirely like the nondolomitized beds of the formation in outcrops and many deep-well sections.

The Glenwood is exceptionally thin, even for a formation whose thickness in its outcrops does not exceed a few feet. The typical green color is absent, perhaps due to oxidation by reason of the thinness of the bed.

The Shakopee, as in some of its outcrops, is distinctly arenaceous. The New Richmond is well defined and water bearing. The Jordan sandstone is easily recognized and is the chief aquifer of the well, although it contains some beds pretty well sealed with dolomitic cement and some fine-grained sandstone whose transmission capacity must be small.

While the dolomite in which the well foots may be an inter-

66 Savage, T. E., Iowa Geol. Survey, vol. XVI, p. 598.
67 Ibid, p. 607.

calated bed of the Jordan, it is more probably the top of the Trempealeau of the Saint Lawrence formation.

SIBLEY

(Altitude 1516 feet, C., St. P., M. & O. Ry.)

CITY DEEP WELLS

The water supply of Sibley is from a shallow well ten feet in diameter and 30 feet deep yielding 82,000 g.p.d., and two deep wells of later installation. Deep well no. 1 was drilled in 1908 by G. J. Savidge of Wayne, Nebraska. The depth is 314 feet, the diameter 10 inches and the well is finished with a Cook strainer. Water stands 112 feet from the surface. On completion the pumping capacity was 125 g.p.m.; in 1914 it was 50 g.p.m.

Deep well no. 2 was drilled in 1914 by E. E. Morrison, of Sibley. The depth is 325 feet, the diameter is 8 inches and the pumping capacity on completion was 35 g.p.m. The static level is the same as in well no. 1.

Log of Sibley deep well no. 1

	Depth in Feet
Gravel and clay	0 – 40
Blue clay and boulders	40 –298½
Gravel, a little water	298½–300
Blue clay, gravel and limestone	300 –304
Gravel, sand and water	304 –310
Blue clay, sand and gravel footing on blue clay	310 –314

Log of Sibley deep well no. 2

Black dirt, stones, sand and water	0 – 14
Blue clay, dark becoming lighter, containing boulders	14 –148
Sand, coarse, furnishes water 20 g.p.m., head 19 feet below curb	148 –148½
Blue clay, light, containing fine sand and some boulders, very hard at bottom	148½–306
Sand, fine	306 –307½
Bluish gray clay	307½–325

The blue clay in which these wells foot may be referred with some probability to the Cretaceous. The general character of the heavy drift of the region is shown by the logs, and its local diversity also.

SIGOURNEY

(Altitude 752 feet, C. R. I. & P. Ry., 785 feet C., M., St. P. & P. R. R.)

In 1882 the town of Sigourney had drilled a well 1888 feet deep and extending 458 feet below the base of the Saint Peter sand-

stone. On account of the quality of the water this well was never used and until 1923 the city depended on a shallow well supply.

Notwithstanding this unfortunate experience the city again, in 1923, had drilled a well for public supply. The depth, 1978 feet, penetrates a water bed not reached by the earlier well. The well is also completely cased to a depth of 1445 feet, presumably excluding all objectionable waters above that level. The main supply was obtained at 1928 feet and the Saint Peter sandstone at 1373 feet, as in the earlier well, was found to be a water bed. The static level is 83 feet below the curb. Under air the delivery of the well is 500 gallons per minute with a draw down of 14 feet.

As the well was being drilled the static level at 655 feet (Devonian) was 40 feet from the top; at 1525 feet (Prairie du Chien), 105 feet from the top; and on completion the static level was found to have risen to 83 feet below the curb. Three casing pipes extend from the surface, a 15½ inch pipe to 102 feet, a 10 inch pipe to 655 feet and a 8¼ inch pipe to 1445 feet.

The driller was Charles P. Brant of Indianapolis, Indiana, and the cost of the well was $18,000.

*Mineral Content of City Well, No. 2, Sigourney**

	P.P.M.
Bicarbonate	312.3
Chloride	93.
Sulfate	857.6
Silica	23.4
$Fe_2O_3+Al_2O_3$	9.4
Calcium	164.9
Magnesium	70.5
Na + K as Na	241.9
Total solids	1616.7

SIOUX CITY

(Altitude 1103 feet)

WELL OF THE MIDLAND PACKING COMPANY (NOW SWIFT AND COMPANY)

A well 615 feet deep was drilled in 1920 by the F. M. Gray, Jr., Company of Milwaukee.

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

Record of strata

	Depth in Feet
No record	0–260
Cretaceous (?) Pennsylvanian (?) (70 feet thick; top 865 feet above sea level):	
Shale, white, kaolinic, noncalcareous, with minute angular particles of quartz and some irregular larger grains	260–265
Shale, red, calcareous, residue of quartz sand as above, color turns to yellow on boiling in HCl	270–280
Shale, whitish, noncalcareous	280–290
Shale, red and white	290–300
Shale, whitish, fine angular grains of quartz; 3 samples	300–330
Mississippian, and Galena-Platteville (260 feet thick; top 795 feet above sea level):	
Sandstone, gray in mass, fine grains of clear quartz, imperfectly rounded, in sand; chips of fine light brownish gray sandstone, hard, grains as remainder of sample; 2 samples	330–350
Sandstone, white, as above	350–360
Chert, white, brown cryptocrystalline silica with minute imbedded angular grains of crystalline quartz	360–370
Dolomite, hard, dark gray, crystalline (effervescence in cold dilute HCl less slow than LeClaire dolomite); limestone, lighter gray, rapid effervescence; limestone, soft, whitish, rapid reaction	370–380
Limestone, blue-gray, rapid reaction; limestone, light yellow-gray, earthy, rapid reaction	380–390
Limestone, as above, much quartz sand and shale as in samples below 360; chemical analysis on basis of silica free rock shows 72 per cent $CaCO_3$ and 11.9 per cent of $MgCO_3$	390–400
Limestone, as above	400–410
Limestone, light yellow-gray, soft, granular, moderately rapid effervescence; most of sample consists of chips of dark ochreous cherty calcareous rock, dark red argillaceous sandstone, hard light green shale, whitish shale, greenish yellow sandstone, calciferous and argillaceous, probably from above	410–420
Limestone, light blue-gray, 61.5 per cent $CaCO_3$, 12.7 $MgCO_3$, on basis of silica-free rock	420–430
Limestone, gray, moderately slow effervescence	430–440
Dolomite, dark blue-gray and blue-gray, crystalline, cuttings heavily rusted and stained ochre yellow, all in small chips; some rounded fragments of a white sandstone with red flecks, fine, argillaceous; and blue and pink shale taken to be from above; 4 samples	440–480
Dolomite, gray and light gray, compact, in small chips, effervescence moderately slow; 5 samples	480–530
Dolomite, grayish buff, crystalline granular, in sharp sand; 2 samples	530–550
Dolomite, drab and grayish buff, compact; 4 samples, that at 570-580 shows 55.24 per cent $CaCO_3$ and 40.10 per cent $MgCO_3$ on basis of silica-free rock	550–590
Ordovician:	
Saint Peter sandstone (penetrated 25 feet; top 535 feet above sea level)—	
Sandstone, white, fine grains rounded and frosted; some light green shale; some chips of greenish argillaceous, pyritiferous sandstone of calcareous cement; 2 samples	590–615

Notes.—At Sioux City and vicinity the Niobrara and the Benton of the Colorado group of the Cretaceous lie entirely above water level of Missouri river and its tributaries. At Prospect Hill within the limits of the city 42 feet of the Dakota formation

is exposed, while at Sargent's Bluff, seven miles south, about 100 feet are shown of the same beds, the lower 43 feet being shale.[68] Hence the upper 260 feet of the above well section can not be correlated with any of the local outcrops.

If this gap can be filled from the section of the waterworks well we may suppose that here also are some fifty feet of Pleistocene and Recent sands and gravels overlying about 210 feet of shales and sandstones probably belonging to the Dakota.

The assignment of the shales 170 feet thick which begin at 260 feet (111 feet below extreme low water in Missouri river) and whose base is 795 feet above sea level is uncertain. They may be compared with the shales beneath the drift at Holstein, 170 feet thick, base 867 feet above sea level, and with the shales with some interbedded sandstones at Cherokee, 270 feet thick, whose base is 903 feet above sea level.

In the log of the waterworks well the place of these shales is held by 31 feet of pyrite and lignite and underlying sandstone[69] which may acceptably be placed with the Dakota. Whether the shales of the Midland Company well are an uneroded remnant of the Pennsylvanian or a local change of the Cretaceous from sandstone to shale is unresolved.

The sandstone underlying these shales is pretty surely Paleozoic, but it is uncertain whether it should be ranked with the Mississippian or the Pennsylvanian. It can hardly be a westward extension of the Saint Peter, for its grains are ill-rounded, and the limestone series beneath it is not wholly dolomitic as is the Prairie du Chien, on which the Saint Peter sandstone rests.

The limestones and dolomites between the shales from 260 to 330 feet and the Saint Peter are referred to the Mississippian and the Galena-Platteville, more on the probability that the intervening formations are here wanting than for any lithologic reasons. Probably all the limestones belong to the Mississippian, and much of the dolomites to the Galena-Platteville.

The sandstone at 590 feet carries all the grain marks of the Saint Peter, and the underlying strata, as shown in the Magee well at Sioux City,[70] confirm this reference. It may be noted that

68 Bain, H. F., Geology of Woodbury Co.: Iowa Geol. Survey, vol. V, pp. 260, 263.
69 Underground Water Resources of Iowa, Iowa Geol. Survey, vol. XXI, p. 1096.
70 Op. Cit., pp. 1097-98.

from Sioux City to Holstein the Saint Peter dips east at the rate of about 11 feet to the mile, and to Cherokee to the northeast, more in the line of the strike of the strata, the dip is about 4½ feet to the mile.

The section may be continued by the Magee well. Beneath the Saint Peter cherty dolomites of the Prairie du Chien extend at least as deep as 345 feet above sea level. And at least as high as 285 feet above sea level begin the beds of the Saint Lawrence dolomites and shales. These become glauconitic at 125 feet above sea level, marking the horizon of the Franconia beds, and are still glauconitic at 35 feet below that datum. The red clastics of the Cambrian were reached according to the log at 125 feet below sea level and samples of the cuttings show that ten feet farther down decayed friable schists of the pre-Cambrian were encountered. Oddly enough this igneous rock was called the Saint Peter sandstone in the driller's log.

This pre-Cambrian floor of schist or granite dips east to Holstein at the rate of 9⅓ feet per mile. And the formations from this floor to the top of the Saint Peter aggregate 590 feet at Holstein and 670 feet at Sioux City.

WELLS OF CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY AT ROUNDHOUSE

In 1917 three wells about 297 feet deep were drilled at the roundhouse of the Chicago, Milwaukee and St. Paul Railway at Sioux City. Each has a drop pipe of 9 inches to the bottom. The chief supply was found at 240 feet and the flow increased from that depth to the bottom. Water rose within 8 feet of the surface. In 1926 the head is reported at 20 feet, but as pumping is going on most of the time at one or more of the wells, this hardly represents the true static level.

On completion the pumping capacity of the wells was found to be 318 gallons per minute, with the pumping cylinder at 60 feet. Under continuous pumping for 30 hours at 233 gallons per minute there was a draw down of 10 feet. The present capacity is 244 gallons per minute. Repairs made in 1924 by repacking and cleaning out resulted in an increased yield.

The wells are cased to 102 feet with 16 inch casing, and with 145 feet of 12 inch casing overlapping 7 feet.

Driller's Log

	Depth in Feet
Clay, sand and shale, dry	0–95
Shale and sand, dry	95–240
Sand rock, water bearing	240–280
Shale	280–297

Chemical analysis

	In grains per U. S. gallon
Calcium carbonate, $CaCO_3$	11.9
Magnesium carbonate, $MgCO_3$	5.6
Calcium sulphate, $CaSO_4$	2.8
Alkali sulphate	3.8
Alkali chloride	0.8

WELL NO. 16 OF THE CITY WATERWORKS

This well was drilled in 1919 by G. J. Savidge of Sioux City. The depth is 338 feet, the diameters are 20, 16 and 10 inches. The principal supply was found from 190 to 297 feet with another water bed from 309 to 332 feet. The static level is about 32 feet below the surface. The pumping capacity of the well on test was 1400 g.p.m. The well is cased with 181 feet 9 inches of 20 inch pipe, 110 feet 9 inches of 16 inch pipe and 60 feet of 10 inch pipe, 14 feet being used in telescoping.

Log of city well no. 16

	Depth in Feet		Depth in Feet
Clay	0–40	Dakota sandstone	190–297
Sand and gravel	40–70	Clay	297–309
Blue clay	70–80	Dakota sandstone	309–332
Sand and coarse gravel	80–190	White clay	332–338

Since 1919 two additional wells have been drilled for the city waterworks, one of 26 inches diameter and 342 feet depth and one of 20 inches diameter and 323 feet depth. Well no. 17, at West 7th and Sioux streets, 323 feet deep, yields three million gallons daily.

Log of city well no. 17

	Depth in Feet		Depth in Feet
Clay	0–40	Hard clay	274–276
Yellow sand and gravel	40–142	Sandstone	276–289
Blue clay	142–145	White clay	289–291
Blue gravel	145–152	Sandstone mixed with small streaks of white clay	291–323
Sandstone	152–274		

SOLON, JOHNSON COUNTY

(Altitude 789 feet)

In 1926 a well was drilled for city supply by Chas. D. Nolan of Cedar Rapids. Before drilling began arrangements were made for a complete set of samples of the cuttings, a matter of special interest because the drill would penetrate the entire Wapsipinicon section. It is understood that the well stopped short of the Maquoketa shale, but nothing can be learned even of its depth and capacity.

STUART, GUTHRIE COUNTY

(Altitude 1205 feet)

The deep well completed in 1916 for the city of Stuart by the Thorpe Bros. Well Company of Des Moines has the distinction of being the deepest well in Iowa, with its depth of 3021 feet. Water was found at 240 feet in glacial sands, and at 550 feet in the Coal Measures, but in inconsiderable amounts. The Saint Peter yielded little water and a test made when the drill had reached its base gave but 8 gallons a minute with a 550 foot pipe.

The chief water beds were found between 2736 and 2800 feet, where the cuttings were washed away by the flow. The head of the Saint Peter water had been 325 below the curb. From 2736 to 2830 feet it stood at 345 feet, rising slightly at the last named depth. No further fluctuations in the static level were observed and there is no evidence that any additional water beds were struck. The final test when the well had reached its present depth, lasting eighty hours with 397 feet of pipe, of which 52 feet were submerged, failed to bring the draw down below the bottom of the pipe and for the last twenty-four hours averaged 212 gallons per minute.

The diameters of the well are indicated by the casings:

12 inch	0–305	8 inch	690–1285
10 inch	260–785	6 inch	1185–1938

Chemical analyses

	Parts per million Deep well*	Old city well 90 feet deep†
Silica (SiO_2)	11.8	.....
Iron and alumina	2.8	.....
Calcium	107.1	90.

*Chemical laboratory, Iowa State College of Agriculture.

†Hendrixson, Iowa Geol. Survey, vol. XXI, p. 190.

Magnesium	65.9	27.
Sodium	343.4	32
Potassium	.....	2
Carbonate radicle (CO_3)	107.4	
Bicarbonate radicle (HCO_3)	.....	408.
Sulfate radicle (SO_4)	826.0	18.
Chlorine radicle (Cl)	257.6	2.
Dissolved solids, by evaporation	1785.0	390.

The cost of the well is reported at about $19,000, and of the pumping machinery at about $3,000.

Record of Strata and Driller's Log

	Depth in Feet
Pleistocene and Recent (251 feet thick; top 1205 feet above sea level):	
"Soil and yellow clay"	0–40
"Sand, fine, mixed with clay"	40–41
"Clay, blue, with many boulders"	41–82
"Sand, medium fine, 10 to 15 gallons of water per minute"	82–86
"Clay, yellow"	86–116
"Hardpan, yellow, cemented"	116–119
"Clay, blue, numerous small pebbles"	119–141
"Sea mud, very fine, drab, no pebbles"	141–196
"Clay, blue, no pebbles"	196–211
"Sea mud, as at 141, some sand mixed"	211–225
"Sand, fine, grading into above"	225–241
"Sand, coarse, 15 to 20 gals. per minute"	241–251
Pennsylvanian (564 feet thick; top 954 feet above sea level):	
"Clay shale, blue"	251–264
"Limestone, blue"	264–271
"Slate, with hard sulphur bands"	271–287
"Boulder formation, very hard"	287–289
"Slate, with limestone bands"	289–321
"Limestone, hard, blue"	321–328
"Slate, hard, black"	328–330
"Boulder formation"	330–331
"Slate, black, very soft"	331–332
"Boulder formation, hard"	332–333
"Slate, hard, black"	333–339
"Coal"	339–341
"Fire clay"	341–342
"Limestone, blue"	342–345
"Slate, blue"	345–353
"Rock, blue"	353–355
"Shale, red"	355–360
"Limestone, blue"	360–368
"Shale, blue"	368–371
"Boulder formation"	371–375
"Shale, blue, with hard bands"	375–401
"Limestone, blue"	401–404
"Slate, blue"	404–410
"Flint rock"	410–411
"Shale, red and blue, hard bands"	411–424
"Limestone, blue, hard"	424–430
"Shale, blue"	430–441
"Shale, red"	441–453
"Hard gray rock"	453–455
"Slate, blue"	455–477
"Blue boulder"	477–481

"Shale, red" 481–487
"Flint band" 487–489
"Shale, gray, sulphur band" 489–505
"Limestone, gray" 505–513
"Shale, gray" 513–533
"Slate, black, mixed with lime rock" 533–541
"Shales with limestones, shales soft and caving" 541–765
"Shale, light colored, calcareous" 765–815

Mississippian (405 feet thick; top 390 feet above sea level):
"Chert and shale" 815–980
"Limestone, brown" 980–1022
"Limestone, gray, effervescence rapid" 1022–1083
"Bands of chert mixed with lime, hard to drill" 1083–1106
"Limestone, brown" 1106–1126
"Lime and chert, mixed gray, bands hard, then soft" 1126–1177
"Shale (Kinderhook) greenish, with hard bands of lime" 1177–1218
Sample of cuttings; shale, blue-gray, calcareous, in plastic concreted masses, with some grains of limestone of rapid effervescence in cold dilute HCl at 1185, 1195, 1203, 1213

Devonian (155 feet thick; top 15 feet below sea level):
Limestone, yellow-gray, soft, rapid effervescence, in sand 1220, 1227, 1234, 1241
Limestone, yellow-gray, some bluish and argillaceous, in sand 1248
Limestone, light yellow-gray, rapid effervescence, in sand 1255
Limestone, light yellow-gray, in flour and powder, argillaceous, rapid effervescence 1262
Limestone, light yellow-gray, in sand, rapid effervescence 1269
Limestone, gray and yellowish, light and darker, rapid effervescence, in sand 1277, 1284, 1291
Limestone, in fine, light gray argillaceous sand and powder 1298
Limestone, brown, dense, hard, rapid effervescence, in sand 1305, 1312
Limestone, light brown and light yellow-gray, rapid effervescence, in sand 1319, 1326, 1333, 1340, 1347, 1354
Limestone, light buff, with considerable argillaceous powder 1361
Limestone, light buff, some greenish, with considerable argillaceous powder, rapid effervescence 1368

Silurian (490 feet thick; top 170 feet below sea level):
Shale, calcareous, gray, in argillo-calcareous powder, a little gypsum 1375
Limestone, light gray, rapid effervescence 1382
Shale, light blue-gray, with some light gray limestone 1389
Shale, whitish, with more limestone than above, rapid and moderately rapid effervescence; a little gypsum 1396
Limestone, light bluish gray, rapid effervescence, in sand, some gypsum 1403, 1410, 1417, 1424, 1431, 1438
Limestone, whitish, crystalline, some light buff, in sand, some gypsum, moderately rapid effervescence 1445, 1452, 1459
Limestone, light buff and gray, rather slow effervescence, some white and rapid, in fine sand, some gypsum 1466
Limestone, light gray, in sand, some moderately rapid effervescence, some rather slow, some lighter colored, rapid; gypsum in white grains and some chips show gypsum and calcite intercrystallized 1474, 1481, 1488, 1496
Limestone, gray, rapid and moderately rapid effervescence, some gypsum 1502, 1509
Limestone, as above, with much highly argillaceous concreted powder 1516
Limestone, buff, argillaceous 1523
Limestone, brownish gray and light yellow, crystalline, rather rapid effervescence, some whitish and rapid, some white chert, some gypsum 1530
Limestone, light gray, rapid effervescence, in coarse sand 1537, 1544, 1551
Limestone as above, heavily rusted, with steel chips of slush bucket 1559, 1567
Shale, deeply rusted, calcareous 1573
Limestone, rusted, rapid effervescence 1579

Limestone, rusted, slow effervescence, in fine meal 1585
Limestone, rusted, slow effervescence, in small chips 1591
Limestone, rusted, effervescence rapid, in meal, some gypsum 1595
Dolomite, light buff, in sand, "hard to drill", some gypsum in rounded grains, with much argillaceous powder 1601, 1609
Dolomite, brown, in chips, some small chips of coal 1615
Dolomite, light buff, in meal and argillaceous powder 1622, 1628
Dolomite, and gypsum, dolomite light buff in sand; gypsum in angular sand 1634, 1640
Shale, grayish brown, calcareous, in concreted powder, with gypsum 1647, 1654
Dolomite, brown, in fine meal, with much gypsum in angular sand 1661, 1668
Dolomite, buff, in fine sand with some gypsum 1675, 1682
Dolomite, buff, with considerable gypsum 1689
Shale, gray, plastic, calcareous 1696
Dolomite, or magnesian limestone, light yellow, argillaceous, with considerable gypsum, in fine meal and concreted powder; 5 samples 1703–1731
Dolomite, buff, in sand, considerable gypsum 1738, 1745
Dolomite, light yellow, in fine crystalline sand, considerable gypsum 1752
Dolomite, as above; chips of blue-gray dense limestone of rather slow effervescence, and a little soft green shale; some gypsum 1759
Limestone and shale, limestone light gray, soft, rapid effervescence, argillaceous; shale, blue, in thin flakes 1766
Limestone, as above, some blue shale, some grains of quartz sand 1773
Limestone, yellow-gray, rapid effervescence, in sand, with much flour of crystalline dolomite and whitish calcareo-argillaceous flour; some quartz sand 1780–1787
Dolomite or magnesian limestone, yellow, rather slow effervescence, in sand and concreted powder 1794
Dolomite, light buff, argillaceous, and arenaceous with rounded grains of clear quartz 1801
Dolomite, light yellow-gray, in fine meal 1808
Dolomite, or magnesian limestone, rather slow effervescence, considerable siliceous residue 1816
Limestone, gray, in small chips, some of rapid effervescence, some moderately slow, argillaceous and cherty residue 1825
Limestone, dark brownish, effervescence moderately rapid, and gray, effervescence slow, in finer grains; poorly rounded quartz sand; flakes of brown chert; 4 samples 1833–1857

Ordovician:

Maquoketa shale (119 feet thick, top 660 feet below sea level)—
Shale, red, highly arenaceous, with fine well-rounded grains of clear quartz and some flakes of pinkish cryptocrystalline silica, 2 feet thick according to log 1865
Shale, in light gray powder, highly calcareous, sandy and cherty residue 1873, 1880
Dolomite, gray, in easily friable concreted masses 1888, 1896
Shale, gray, calcareous; cryptocrystalline silica in minute flakes; some fine white dolomitic meal; a little selenite; 5 samples 1904–1936
Shale, blue-gray; much light gray dolomitic sand; crystals of selenite 1944
Shale, blue-gray, in small chips, siliceous, calcareous 1952
Dolomite, highly argillaceous, in gray powder; cryptocrystalline silica in minute blue-gray chips with imbedded grains of clear quartz, crystals of selenite numerous after digestion in acid; 3 samples 1960–1976

Galena to Glenwood formation inclusive (392 feet thick; top 779 feet below sea level):
Limestone, gray, rather rapid effervescence, in chips with flour of siliceous dolomite as above and a little selenite 1984
Dolomite, buff, light yellow and light gray, in fine meal, at 2137 with large residue of cryptocrystalline silica and fine rounded grains of quartz, at 2220 cherty; 27 samples 1992–2220

Shale, gray, highly calcareous, siliceous with minute grains of quartz and flakes of cryptocrystalline silica, in concreted powder 2230
Dolomite, light yellow, in fine meal 2240
Shale, in light brown concreted powder, calcareous 2250
Shale, gray, highly calcareous 2260
Dolomite, light yellow, in fine meal, with some grains of limestone of rapid effervescence; 3 samples 2265–2281
Limestone, light gray, rapid, in small chips 2291
Shale, dark green, in small flakes, and quartz sand of rounded grains of St. Peter facies, much limestone of rapid effervescence; some pyrite 2296–2301
Limestone, light gray, rapid effervescence, in small chips 2306
Limestone, gray, in small chips, some rapid effervescence, some slow; much fine quartz sand of well-rounded grains and some green shale 2311
Shale, hard, dark green, with some fine quartz sand and limestone of rapid effervescence 2316
Shale, hard, green, in moulded masses, including laminated chips 2321
Shale, light gray, highly calcareous, in concreted powder 2326
Sandstone and shale, sand in rounded grains, fine; shale hard, green, pyritiferous; some fine flour of limestone of rapid effervescence 2334
Limestone, in fine flour, slow effervescence, some grains of limestone of rapid effervescence; some fine rounded grains of quartz 2340
Shale, blue-green, hard, plastic, in concreted masses including laminated chips 2341–2344
Limestone, as at 2340 2348
Limestone, light gray to buff, rapid effervescence, in coarse sand 2356
Shale, gray, highly calcareous, in concreted powder 2360
Sandstone, buff in mass, coloring due to iron oxide in cuttings, grains fine, rounded, considerable dolomite in fine sand 2368
Shale, light blue-gray, highly arenaceous with fine rounded grains of quartz, calcareous 2372

Saint Peter sandstone (38 feet thick; top 1171 feet below sea level)—
Sandstone, in clear white sand, grains well rounded and frosted, larger grains up to 0.5 mm. in diameter ("top of St. Peter") 2376
Sandstone, as above with considerable argillaceous powder 2382
Sandstone, as above, nearly clean 2388
Dolomite, in buff concreted powder 2394
Sandstone, as at 2376 2400
Sandstone, light yellowish from oxidation of cuttings, facies of St. Peter, larger grains up to 0.33 mm. in diameter 2406
Sandstone, light yellow-gray, in minute grains of clear quartz 2410

Prairie du Chien (286 feet thick; top 1209 feet below sea level)—
Shakopee dolomite—
Marl, light gray, argillaceous, minutely arenaceous, somewhat dolomitic 2414
Sandstone, rounded grains, some double-ended crystals; dolomite sand; and some white oölitic chert 2422
"Base of sandstone" 2425
Shale, light brown, calcareous, in concreted powder 2426
Dolomite, light buff, in fine meal 2438
Dolomite, as above, highly siliceous with minute angular particles of quartz and cryptocrystalline silica 2450
Dolomite, light buff, highly arenaceous with imbedded grains 2462
Dolomite, buff and light yellow, in fine meal; 6 samples 2470–2512
New Richmond sandstone—
Sandstone, light cream color, fine rounded grains, some with secondary enlargements, dolomitic 2528
Sandstone, as above, coarser, some sand of dolomite with im-

bedded grains of quartz 2536, 2552
Oneota dolomite—
Shale, in yellow concreted powder, dolomitic, siliceous with fine grains and flakes of crystalline quartz 2560
Dolomite, in fine buff meal, arenaceous, some chips with imbedded grains of quartz sand 2568
Dolomite, in buff meal, highly siliceous with flakes of cryptocrystalline and crystalline quartz 2576
Dolomite, buff, arenaceous with fine rounded grains of quartz sand 2588
Dolomite, light cream color, in flour; 3 samples 2604–2636
Dolomite, buff, residue of cryptocrystalline silica and some crystalline grains and hexagonal pointed crystals 2644
Shale, dark buff, calcareous, siliceous 2648
Sandstone, buff, fine rounded grains, some with secondary enlargements, some dolomite 2656
Shale, in yellow concreted powder, calcareous, siliceous 2664, 2668
Dolomite, light cream color, in flour, fine, siliceous, residue including hexagonal quartz crystals 2672
Marl, in concreted light buff powder, calcareous, argillaceous, siliceous 2680
Dolomite, light yellow, in flour, with fine siliceous and argillaceous residue 2692
Cambrian:
Jordan sandstone (100 (?) feet thick; top 1495 feet below sea level)—
Sandstone, dolomitic, or dolomite, arenaceous, in fine meal and powder, much quartz in minute angular particles and fine rounded grains; 3 samples 2700–2728
Sandstone, fine, rounded grains, stained red, probably from iron in cuttings 2736
"Cuttings washed away" 2736–2800
Saint Lawrence formation (top 1595 (?) feet below sea level)—
Trempealeau beds (120 (?) feet thick)—
Dolomite, light buff, residue of fine particles of quartz; 8 samples 2800–2860
Dolomite, as above, with little glauconite 2888, 2900
Franconia beds (penetrated 101 feet; top 1715 feet below sea level)—
Sandstone, of minute angular particles of crystalline quartz, cement calcareous, of rather rapid effervescence; 5 samples 2920–2960
Limestone, light, rapid effervescence, in fine sand 2972
Sandstone, as at 2920; 4 samples 2980–3021

Notes.—Limestone outcrops of the country rock near Stuart have been correlated with beds deep in the strata of the Des Moines series.[71] As no samples of the cuttings were taken until a depth of 1185 feet the base of the Coal Measures is somewhat uncertain. The cherty shales at 815 feet (390 feet above sea level) seem to correspond to the cherty shales at Des Moines at 374 feet above sea level and may be taken as the summit of the Mississippian; while the shales from 1177 to 1220 feet seem to mark its base.

71 Tilton, J. L., The strata near Stuart, Iowa, Bull. Geol. Soc. America, vol. 33, p. 153, 1922. Also Iowa Geol. Survey, vol. XXIX, pp. 242, 280, 307-312.

As at Des Moines and several other stations the gypsum-bearing limestones (beginning at 170 feet below sea level) are assumed to be Silurian.

The shales from 1865 to 1984 feet occupy the place of the Maquoketa. The thin band of red arenaceous shale at their summit is unusual.

The shales above the Saint Peter, the Glenwood, are present in force, and, as at some of their outcrops in northeastern Iowa and in some well sections, show their affinity with the Saint Peter by their arenaceous layers.

The horizon of the Saint Peter is well marked, and as forecast in the report of 1912 (Plate I) is but slightly lower, some 57 feet, than at Des Moines.

The dolomites, marls and oölitic chert beginning at 2414 are clearly Shakopee, while the sandstone at 2528 feet may represent the New Richmond.

The summit of the Cambrian is probably marked by the dolomitic sandstone at 2700 feet, which perhaps is the far westward extension of the Jordan sandstone. The Saint Lawrence begins then with the Trempealeau dolomite, at 2800 feet or at some point between 2736 and 2800 feet, the cuttings here having been washed away, and the glauconite in the dolomite at 2900 feet may mark the beginning of the Franconia beds. It is noteworthy that the sandstones from 2920 to 3021 feet are free of glauconite, in this differing from the sandstones of the same horizon at Des Moines and from the Franconia beds in the deep wells of eastern Iowa.

The base of the Franconia is usually defined by the clean, saccharoidal sandstones of the Dresbach, but no such sandstones were reached either at Stuart or in the Greenwood Park well at Des Moines, which was sunk 313 feet farther below sea level. Obviously the Stuart well would have gained nothing by going deeper.

The temperature of the water as it is pumped from the well is 63° Fahr. This is forced by air pressure into a reservoir holding 160,000 gallons, and then pumped into a tower the capacity of which is 80,000 gallons. Water from the tower is mixed with exhaust steam in the heater, and the heated mixture is

pumped into the boiler. From the analysis of this mixture the composition of the compound is determined that must be added to water pumped into the boiler. The cost of the well was as follows:

Cost of well, including drilling and casing, completed in the summer of 1917	$17,000
Cost of pumping outfit, including air compressor, drum and pipe	2,500
Cost of reinforced concrete reservoir, 36 feet diameter, 16 feet under ground, 4 feet above ground, capacity 160,000 gallons	3,800
Water tower, capacity 80,000 gallons	4,500
	$27,800

Analyses of water from Stuart well, by the Dearborn Chemical Company, Chicago, November 26, 1917

	Raw Water, Grains per Gallon	Water Pumped Into Boiler, Grains per Gallon
Silica	.250	.140
Oxides of Iron and Aluminum	.090	.163
Carbonate of Lime	Trace	Trace
Suphate of Lime	23.901	21.714
Carbonate of Magnesia	12.953	6.985
Sulphate of Magnesia	Trace	3.904
Sulphates of Sodium and Potassium	59.009	34.029
Chlorides of Sodium and Potassium	18.020	14.790
Loss, etc.	.124	.269
Total soluble mineral solids	114.347	81.994
Organic matter	Trace	Trace
Suspended matter	.350	1.402
Total soluble incrusting solids, grains per gallon	37.194	29.002
Total soluble non-incrusting solids, grains per gallon	77.153	52.992
Total mineral matter, grains per gallon of 231 cubic inches	114.35	81.994
Pounds soluble incrusting solids per 1,000 U. S. gallons	5.31	4.17
Pounds soluble non-incrusting solids per 1,000 U. S. gallons	11.02	.757

TRACY, MARION COUNTY

(Altitude 715 feet)

In 1925 the Chicago, Burlington and Quincy Railroad Company put down a well at Tracy for locomotive supply. The well is 150 feet deep and its original diameters were 12 inches to 125 feet and 6 inches to bottom. When a depth of 125 feet was reached a four hour pumping test raising 70 g.p.m. failed to lower the water level, which was 81 feet above the bottom. At this stage only 20 feet of twelve inch casing had been inserted. However, the water was too hard and was cased off with six inch casing extending the full depth of the well. After the well was completed the six inch hole was filled with concrete, the six inch casing was all with-

drawn and the twelve inch casing was driven to 66 feet. Water then stood 39.5 feet below curb. A test gave 71 g.p.m. for five hours and lowered the water level only eight inches. In 1927 the well was reamed with a twelve inch bit into the concrete filling.

Driller's Log

	Depth Below Grade, Feet
Clay	0–24
Shale, black	24–66
Shale, hard, gray	66–92
Limestone. Reamings are: finely sandy, gray, sparkling facets; fine-grained, gray, black, some concretionary, some lithographic, some with patches of calcite; flint, white and gray; pyrite; sandstone, fine, gray, black films	92–108
Rock, hard, white, with soft streaks	108–116
Limestone, white	116–123
Limestone, soft	123–125
Limestone, hard, creviced. Reamings show chert or flint, dark gray, very fine-grained, some response to acid	125–130
Sandstone, hard	130–138
Sandstone, soft, white	138–139
Sandstone, hard	139–150

URBANA, BENTON COUNTY

(*Altitude 901 feet*)

The public supply of this town is a well 1154 feet deep, its diameters ranging from 8 to 6 inches. The chief water bed, found at the bottom, is probably the Saint Peter sandstone as the well is deep enough to reach that formation. The static level is 125 feet below the surface and with the cylinder hung at 300 feet the pumping capacity is 35 g.p.m., ample to a maximum consumption of 10,000 g.p.d.

*Mineral Content of City Well, Urbana**

	P.P.M.
Bicarbonate	314.7
Chloride	6.
Sulphate	30.2
Silica	9.2
$Fe_2O_3+Al_2O_3$	5.4
Calcium	119.5
Magnesium	40.7
Na + K as Na	26.6
Total solids	394.9

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

VAN BUREN COUNTY

Log of well drilled on farm of A. Nixon, 5½ miles southeast of Stockport. S. Shearard, of Colchester, Illinois, driller.

	Depth in Feet
Surface formation	0–40
Limestone	40–85
Slate (muddy); streak of coal, streak of shale, a little shale oil	85–110
Lime	110–270
Slate	270–272
Limestone	272–320
Slate and shale	320–380
Lime, shelly	380–385
Blue shale	385–430
Brown shale	430–470
Light blue shale	470–635
Salt water sand	635–642

The heavy shale from 320 to 470 feet may be referred to the Kinderhook, and possibly its basal portions to the Devonian. The color and place of the "light blue shale" (470-635) suggests argillaceous limestones of the Devonian, while the "salt water sand" recalls the gypseous beds of the Silurian at Mount Pleasant at this horizon, on account of the frequent association of gypsum and salt.

VAN HORNE, BENTON COUNTY

(Altitude 946 feet)

WELL OF CHICAGO, MILWAUKEE AND SAINT PAUL RAILWAY

After consultation with this office, the Van Horne deep well was drilled in 1915-16 for engine supply. The depth is 2340 feet; the diameters are 16 to 6 inches; the contractor, S. B. Geiger of Chicago. When the well had reached its present depth, advice was sought as to continuing the work. It was pointed out in reply that the drill hole was already one of the deepest in Iowa, measured in the distance below the Saint Peter sandstone. The drill had pierced strata as deep as or deeper stratigraphically than the 3000 foot wells of Boone and Des Moines. The main water beds had been passed through and the Algonkian floor was probably near. There was no probability that more water would be found, and if found it probably would be highly mineralized. In accordance with this advice the drilling was stopped.

The forecast which had been made of the formations through which the drill would pass was proved to have a sufficient degree

of accuracy. The Saint Peter sandstone, the driller's first objective, predicted at 1290 feet, was found at 1270 feet, and the Jordan sandstone within a narrower margin.

The poor quality of the Ordovician and Cambrian waters was unexpected. The nearest deep wells to the east, at Vinton and Cedar Rapids, yield good water at these horizons. Van Horne is situated well to the east of the Mississippian zone of outcrop, and even if the Silurian should be found to carry gypsum, as at Marshalltown, deleterious upper waters could be cased out. But although special efforts were made to effectively case out upper flow, the deep artesian waters were found highly mineralized. The well was therefore abandoned. It has since been leased to the town and the public supply is drawn from it.

It will be noted in table that two water beds supply distinctly better waters than the others: the Galena limestone (906-960 feet) and the Prairie du Chien (1540 feet). The Galena water is free from both calcium and magnesium sulphates and carries little more than one-half the total solids of the rest. The discharge was tested at various depths with the estimated results given in the following table.*

Suitability for boiler use	Depth in feet	Discharge in gallons per hour	Head below surface in feet	Geological formation of water bed
	290	600	150	Devonian
	480	600	140	Devonian (?)
	510	.....	110	Devonian (?)
	Water cased out to 485 feet			
	620	1000	135	Silurian
	Water cased out to 820 feet			
	920	500	200	Galena
Suitable	950	3000	200	Galena
Unsuitable	1000	.....	160	Platteville
Unsuitable	1225	.....	160	Platteville
	1300	12000	200	Saint Peter
Unfit	1400	.....	200	Shakopee
	Water cased out to 1450 feet			
Poor	1485	1200	160	New Richmond
Poor	1710	.....	160	Jordan
Poor	1885	4500†	160	Jordan

It will be noted that the supply from the Galena dolomite and Saint Peter sandstone as tested at 1300 feet, with all water cased

* As reported by officials in charge.

† With pump cylinder 250 feet below surface.

out to 820 feet, reached the ample figure of 200 gallons per minute. With water cased out to 1450 feet, the supply from the New Richmond, Oneota and Jordan combined reached only 75 gallons per minute.

Chemical Analyses of Water of Van Horne deep well, in grains per U. S. gallon

Probable Combination	Depth in feet							
	300-415	485-675	906-960	1000	1400	1540	1770	1855
Calcium carbonate			4.93			1.33		
Calcium sulphate	25.63	14.44	.....	19.16	27.34	20.08	28.37	26.07
Magnesium carbonate	15.28	16.12	7.44	11.15	15.28	12.89	13.05	12.38
Magnesium sulphate	6.14	17.27	.....	6.58	4.90	.....	5.88	6.28
Oxides	0.41							
Incrusting solids	47.46	47.83	12.37	36.89	47.52	34.30	47.30	44.73
Alkali carbonate			3.10					
Alkali sulphate	33.49	32.82	26.80	34.26	35.11	22.22	35.03	35.02
Alkali chloride	1.55	8.46	3.41	2.34	1.46	1.36	1.17	1.46
Non-incrusting solids	35.04	41.28	33.31	36.60	36.57	23.58	36.20	36.48
Total solids	82.50	89.11	45.68	73.49	84.09	57.88	83.50	81.21

Description of Strata and Driller's Log

	Depth in Feet
Pleistocene and Recent (254 feet thick; top 943 feet above sea level):	
"Surface to rock"	254
Devonian (231 (?) feet thick; top 689 feet above sea level):	
Limestone, light yellow and brownish gray, some minutely mottled with dark brown grains, rapid effervescence in cold dilute HCl, in flaky chips; "lime rock"	254–418
Shale, clayey, light blue-gray, some drab, brittle, nonlaminated; "lime-rock and mud caves"	418–485
Unknown, no samples; "lime rock"	485–520
Silurian (195 (?) feet thick; top 423 (?) feet above sea level):	
Limestone, yellow, blue-gray and buff, compact, fine-grained, some minutely pyritiferous, rapid effervescence, in small chips; with much flint, white and drab, no quartz sand; "sandy lime"	520–560
Dolomite, light yellow-gray, cherty; "lime rock"	560–710
Ordovician:	
Maquoketa shales (193 feet thick; top 233 feet above sea level)—	
Shale, blue-gray, somewhat calcareous; "blue shale, caves"	710–785
Shale, light blue-gray, some dark olive green, some blackish; "shale and streaks of lime, 785-960 feet"	785–903
Galena and Platteville limestone (362 feet thick; top 40 feet above sea level)—	
Dolomite, dark brown, some saccharoidal, with greenish shale in water worn lumps	903–960
Limestone, light yellow, Platteville facies, rapid reaction	960–1175
Limestone, light brownish, compact, rapid reaction, in sand; "lime and thin streaks of shale"	1175–1198
Shale, blue-green, in concreted masses, with some sand of limestone, pyritiferous; "blue shale"	1198–1205
Limestone, yellow-gray, earthy, in flakes, rapid reaction	1205–1258
Shale, blue-green, as at 1198; "caves a little"	1258–1265

Saint Peter sandstone (40 feet thick; top 322 feet below sea level)—
Sandstone, light yellow in mass, moderately fine of grain, grains well rounded, and ground 1265–1305
Prairie du Chien (435 feet thick; top 362 feet below sea level)—
Shakopee dolomite (180 feet thick)—
"Shale, caves a little"; no samples 1305–1311
Dolomite, yellow-gray, in fine sand, with some chert, grains of quartz sand, and rounded lumps of green shale; "lime" 1311–1430
Dolomite, as above, with more quartz sand; "sandy lime" 1430–1450
Dolomite, buff, with white oölitic chert, and some quartz sand; "sandy lime" 1450–1485
New Richmond sandstone (50 feet thick)—
Sandstone, calciferous, with considerable calcareous powder, some white chert; "sand" 1485–1535
Oneota dolomite (205 feet thick)—
Dolomite, arenaceous, buff, in fine sand, grains of quartz imperfectly rounded; "sandy lime" 1535–1545
Dolomite, whitish, in fine sand; "lime"; 2 samples 1545–1740
Cambrian:
Jordan sandstone (190 feet thick; top 797 feet below sea level)—
Sandstone, light buff in mass, fine grains, imperfectly rounded; "sand" 1740–1754
"Sandy lime"; no sample 1754–1775
Sandstone, light yellow, fine grained; "sand" 1775–1847
Sandstone, calciferous, fine-grained, larger grains well rounded, much fine angular quartzose material, cement dolomitic; "lime" and "sandy lime"; 2 samples 1847–1930
Saint Lawrence (Trempeauleau dolomite) (120 feet thick; top 987 feet below sea level)—
Dolomite, gray, crystalline 1930–1950
"Lime"; no samples 1950–2050
Saint Lawrence (Franconia shales) (290 feet thick; top 1107 feet below sea level)—
Shale, blue gray, clayey 2050–2145
Shale, bright green, glauconitic 2145–2183
Sandstone, rusted, rather fine of grain, grains moderately well rounded 2183–2194
Marl, light chocolate brown, clayey, with much fine angular quartzose matter, somewhat calcareous, in powder 2194–2220
Marl, darker brown than above, with much fine quartz sand and finest angular quartzose matter, in powder 2220–2250
Shale, and sandstone, shale dark brown and green, noncalcareous, in chips; sandstone, brownish, fine-grained, hard, glauconitic, and white, calciferous, glauconitic; to bottom of well 2250–2340

Notes.—The samples of the cuttings of the Van Horne well are too few for accurate determination of the strata. Thus but two samples of limestone represent the 195 feet assigned to the Silurian. The upper of these samples, 520-560 feet, lithologically is much more like the Devonian, and the presence of flint may be expected from the lower Devonian strata as well as from the Niagaran. But to assign this body of limestone to the Devonian would reduce the thickness of the Silurian to 150 feet, while at Cedar Rapids, Vinton and Belle Plaine the dolomites clearly referable to the Silurian exceed twice that measure. Probably this

sample, if correctly labelled, was taken at or near 520 feet and the change to the Silurian dolomites escaped the driller's notice. To accord with the Cedar Rapids-Belle Plaine section the summit of the Silurian should be placed even above the "lime rock" from 485 to 520 feet, of which no samples were taken.

While the driller's log records "shale with streaks of lime" from 785 to 960 feet, the sample representing the run from 903 to 950 feet is of dolomite. The blue print showing the progress of the well records this run as "brown siliceous dolomite".

The gradient of the summit of the Saint Peter sandstone from Van Horne to Cedar Rapids is little more than one foot to the mile. To the southwest the gradient to Belle Plaine is about 11 feet to the mile.

WACONIA, LINN COUNTY

At this station on the Cedar Rapids and Iowa City Interurban Railway about 4 miles southeast of Cedar Rapids a well was sunk for the Waconia Sorghum Mills Company in 1926 by Chas. D. Nolan of Cedar Rapids.

The well is 384 feet deep and 12 inches in diameter. A fair flow was found at 70 feet. The limestones yielded water all the way to the bottom, with the best flow at 300 feet. Water stands 15 feet below the curb and with the pumping cylinder 60 feet below the curb the capacity is 375 gallons per minute. The well exhausts on pumping 400 gallons per minute. The well is cased to 64 feet and cost $2304.

Record of strata

Pleistocene:	
Sand, orange	5-35
Wapsipinicon and Niagaran (?):	
Dolomite, light buff, fine grained, compact	80–95
No samples	95–220
Niagaran:	
Dolomite, light blue and yellow-gray, cherty at 365; 7 samples	220–370

WALNUT, POTTAWATTAMIE COUNTY

(Altitude 1295 feet)

A well 2510 feet in depth was completed for the town of Walnut in 1919 by the J. P. Miller Artesian Well company of Chicago. The well is cased throughout, the lowest casing, 5 inch, being perforated. The diameters are shown by these casings:

	Feet	Inches
12 inch pipe	302	
10 inch pipe	938	3
8 inch pipe	159	
6 inch pipe	641	3
5 inch pipe	489	6

Water was found at about 300 feet, as reported by the city officials, probably in or just below the "fine sand" (Pleistocene?) of the driller's log occurring from 280 to 290 feet. According to the driller's report water stood at 265 feet below the curb in the "sandy lime" from 1804 to 2050 feet and at 255 feet in the "lime, shale and rock, caving from above" from 2050 to 2137 feet. Here the well pumped on test 125 gallons per minute through an eight inch pipe, but when pumped faster than at the above rate showed a draw down below the cylinder at 335 feet.

The sandstone from 2475 to 2510 was the chief water bed and it is the driller's opinion that water also came in crevices in the limestone below 2400 feet. On completion, the static level was 265 feet below the curb, and with the pumping cylinder set at 335 feet the well delivered through an 8 inch pipe 175 gallons per minute.

At present under air the well delivers without draw down 400 gallons per minute. The water is liked by the consumers and although it scales badly in boilers has no medicinal or injurious physiological effects. The cost is reported at $15,003.

Log of City well, Walnut

	Depth in Feet		Depth in Feet
Drift and shale	0–280	Broken lime and shale	1250–1550
Fine sand	280–290	White limestone, first good rock	1550–1666
Limestone, rotton	290–305	Hard lime	1666–1800
Shale	305–315	Streak light green shale	1800–1804
Red caving material	315–325	Sandy lime	1804–2050
Shale	325–440	Lime, shale and rock caving from above	2050–2137
Lime	440–452	Sandy lime	2137–2185
Yellow and blue shale	452–780	Shale and lime	2185–2200
Streaks lime and shale	780–830	White lime	2200–2250
Coal	830–836	Sandy lime	2250–2300
Soapstone	836–848	Light brown sandy lime	2300–2390
Shale and broken lime	848–1035	Shale, like slate	2390–2400
Mostly lime	1035–1100	Lime, some crevices	2400–2475
Shale	1100–1110	Soft water-bearing sand; finished in lime	2475–2510
Shale, caving badly	1110–1130		
Shale and lime	1130–1150		
Lime mixture	1150–1205		
Shale	1205–1250		

Notes.—In the above section the base of the Coal Measure shales is certainly as deep as 848 feet, and more probably lies at 1035 feet (158 feet above sea level), 290 feet lower than at Audubon, 23 miles northeast, and 142 feet higher than at Oakland, 14 miles southwest. At both Walnut and Oakland the floor of the Coal Measures is considerably lower than had been estimated on the basis of a uniform gradient toward the Council Bluffs-Omaha area.[72]

The depth of the well at Walnut, 1217 feet below sea level, is more than sufficient to reach the Saint Peter sandstone, according to any accepted estimates. At Audubon the top of the Saint Peter is at 745 feet below sea level, and according to the probable spacing of the Saint Peter contours the Saint Peter should be struck at Walnut between 800 and 900 feet below sea level (2093 and 2193 feet from the surface). In the driller's log the "lime, shale and rock caving from above, 2050-2137 feet" may possibly designate the horizon of the Glenwood shale, which usually caves. If this is the case, and the Saint Peter is absent the "sandy lime" describes the Prairie du Chien, whose arenaceous dolomites are commonly thus referred to in logs.

If the summit of the Saint Peter dips to the southwest from Audubon at the same rate as the Coal Measures floor, it would be expected at Walnut at about 1035 feet below sea level, 2328 feet from the surface.

A letter from Mr. C. P. Miller, of the experienced firm of contractors, tends to support the theory that the Saint Peter is here absent, and hence to refer the stratum in which the well foots to the Jordan or some other Cambrian sandstone. "Concerning the Saint Peter sandstone formation, we are under the impression that we never found this stratum, unless it was the short streak of sand we encountered between 2475 and the completion of the well at 2510 feet. However, the writer was on the job at the time and I would not definitely say it was the Saint Peter sand from the fact that it had a different color and a mixture that differed entirely from what we encountered in the eastern part of the state."

72 Underground Water Resources of Iowa: Iowa Geol. Survey, vol. XXI, fig. 7, p. 1100.

*Mineral Content of City Well, Walnut**

	P.P.M.
Bicarbonate	209.8
Chloride	207.
Sulfate	577.2
Silica	114.
$Fe_2O_3+Al_2O_3$	1.2
Calcium	152.2
Magnesium	68.1
Na + K as Na	211.4
Total solids	1336.0

WASHINGTON

WELL NO. 4 OF THE MUNICIPAL WATER AND LIGHT PLANT

This well was drilled in 1924 by the F. M. Gray, Jr., Company of Milwaukee. The depth is 1817 feet, and the diameters are 15½ inches to 256 feet, 12 inches to 620 feet, 10 inches to 1510 feet, and 8 inches to the bottom. The well is cased to 1510 feet.

Water Beds

FORMATION	HEAD IN FEET BELOW CURB	DEPTH IN FEET
Glacial sands		70
Glacial sands		105–120
Glacial sands		230–235
Saint Peter sandstone	130	1200
Oneota dolomite	230	1500
Oneota dolomite	180	1520
Trempealeau dolomite	180	1785
Trempealeau dolomite		1817

The final and present head is reported at 120 feet below the curb, but the log does not make it clear that this was the head of the lower Trempealeau waters at 1817 feet. The well pumps 550 gallons per minute (draw down, 61 feet), pumping cylinder at 150 feet.

*Record of Strata**

Drift (255 feet thick):	
White and blue clay (no samples), till	0–70
Gravel, fine, buff	70–75
Clay, blue, till (no samples)	75–105
Sand and fine gravel, gray	105–120
Clay, blue, calcareous, till	120–235
Sand and fine gravel, gray	235–255
Mississippian (180 feet thick):	
Shale, white (no samples)	255–360
Shale, brown (no samples)	360-385

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

* By F. T. Thwaites, Wisconsin State Geological Survey.

Shale, blue (no samples) 385–435
Devonian (99 feet thick):
Limestone, brown (no samples) 435–475
Limestone, gray (no samples) 475–527
Limestone, brown (no samples) 527–534
Silurian:
Niagaran (31 feet thick):
Dolomite, gray 534–565
Ordovician:
Richmond (Maquoketa) (200 feet thick):
Shale, blue and greenish gray, calcareous 565–605
Shale, brown (no sample) 605–620
Shale, blue, calcareous 620–700
Shale, brown, sandy (no samples) 700–735
Shale, blue, calcareous 735–765
Galena-Black River (Galena-Platteville) (343 feet thick):
Dolomite, gray 765–795
Limestone, light and dark gray, layers of oil shale toward base 795–1050
Lime, dark gray and brown 1050–1080
Sandstone, coarse to fine, light gray, calcareous; much dark gray shale 1080–1108
Saint Peter (102 feet thick):
Sandstone, white, medium to fine, calcareous toward base; with red shale seams 1108–1208
Shale, red and green 1208–1210
Prairie du Chien—
Shakopee (148 feet thick):
Dolomite, gray, much sand; some green shale, and white chert.. 1210–1250
Dolomite, gray, little sand 1250–1353
New Richmond (27 feet thick):
Sandstone, white, medium 1353–1365
Dolomite, pink 1365–1375
Sandstone, white, medium; pebbles of chert 1375–1380
Oncota (205 feet thick):
Dolomite, gray 1380–1410
Dolomite, gray, much white chert, part oölitic 1410–1585
Cambrian:
Jordan (75 feet thick):
Sandstone, light gray, medium, calcareous 1585–1660
Saint Lawrence—
Trempealeau (penetrated 157 feet):
Sandstone, fine, light gray, calcareous; with streaks of gray dolomite 1660–1705
Sandstone, like above; with abundant beds of gray dolomite.... 1705–1735
Dolomite, light gray; some sands 1735–1785
Dolomite, light pink; little fine sand 1785–1817

Driller's log

	Depth in Feet		Depth in Feet
Soil, black, soft	0–3	Slate, white, cavy; hard, top; soft, bottom	245–365
Shale, yellow, hard	3–15	Slate, brown, hard	365–430
Gravel, yellow, soft	15–70	Lime, brown, hard	430–450
Sand and gravel, soft	70–75	Lime, light, hard	450–540
Shale, dark, soft	75–105	Lime, brown, hard	540–565
Quicksand, gray, soft	105–120	Slate, blue, cavy, soft	565–600
Slate, dark, hard	120–135	Slate, brown, soft	600–615
Slate, dark	135–230	Slate, light, soft	615–725
Sand, light, hard at top, soft at bottom	230–235	Slate, dark, soft	725–780
Slate, dark, soft	235–245	Lime, dark, hard	780–795

Lime, light, hard	795–945	Sand, lime, light, soft	1425–1460
Lime, gray, hard	945–1025	Lime, light, hard	1460–1515
Lime, brown, hard	1025–1050	Sand, light, hard	1515–1530
Lime, gray, hard	1050–1080	Lime, gray, hard	1530–1585
Slate, blue, soft	1080–1100	Sand, white, soft	1585–1605
St. Peter sand, white, hard and soft	1100–1195	Sand, white, hard	1605–1655
Slate, blue, soft	1195–1205	Lime, brown, hard	1655–1665
Lime, red, hard	1205–1210	Lime, white, hard	1665–1685
Lime, gray, hard	1210–1355	Sand, white, hard	1685–1725
Lime, red, hard	1355–1365	Lime, gray, hard	1725–1745
Lime, gray, hard	1365–1425	Lime, brown, hard	1745–1785
		Lime, pink, hard	1785–1817

Notes.—In comparing the above section of well 4 with the sections of the earlier wells[73] their substantial agreement will be noted, and as well their mutual supplement as either the earlier or the later sections have the fuller data.

In Calvin's section of one of the earliest of the Washington wells, samples attest a calciferous sandstone at the horizon of the Hoing sandstone of the Silurian, above the Maquoketa shales. Norton's section of well no. 3 gives here a siliceous dolomite with calciferous sandstone. In Thwaite's section of well no. 4 no sandy beds occur at this horizon, and it is perhaps more probable that the Hoing sands were not struck by the drill in this well—for the sands are spotty and lenticular—than that the samples fail to completely represent the rock.

The Maquoketa in well no. 3 is represented by samples extending from 563 to 620 feet, and the first sample of the Galena dolomite occurs at 710 giving a thickness to the shales of 147 feet. Calvin's data, however, led him to place the summit of the Maquoketa at 632 feet and its base at 793 feet—giving a thickness of 161 feet. In well no. 4 the top is placed at 565 and the base at 765 feet giving the formation a thickness of 200 feet. These differences seem due to difference in the interpretation of transitional beds as well as to difference in the data at hand.

In well no. 4 the Saint Peter is overlain by a "blue shale" according to the log—"sandstone, much dark gray shale", of the record. Calvin also found here an "arenaceous shale", and Norton records "shale, hard, green, fissile; and sandstone." While placed with the Galena-Platteville in the sections, the affinities of this shale, the Glenwood, are with the Saint Peter.

73 Underground Water Resources of Iowa, Iowa Geol. Survey, vol. XXI, pp. 743-46.

The "sandstone with streaks of dolomite" from 1660 to 1705 and the 30 feet of underlying "sandstone with abundant beds of dolomite" in the section of well no. 4, classified as Trempealeau, were placed with the Jordan sandstone in the section of well no. 3.

WATERLOO

(Altitude 849 feet, I. C. R. R.)

CITY WELL NO. 4

The fourth well of the city of Waterloo was completed in 1914 by the J. P. Miller Artesian Well Company of Chicago. The depth is 1378 feet and the diameters are from 16 to 9 inches. The principal supply was struck at about 850 feet (St. Peter sandstone). Other water beds were found at 800 and from 1200 to 1350 feet.

On completion of the well the water flowed over the top. In 1927 the head had fallen to 34 feet below the surface. The pumping capacity with the cylinder set at 128 feet continues to be 750 gallons per minute, and under capacity pumping in all wells the static head is lowered 62 feet. The cost of this well was $8,365. The following log is reported by the superintendent of waterworks:

	Depth in Feet
Loam, clay, sand and gravel	0–20
Cedar Valley limestone	20–100
Wapsipinicon limestone	100–150
Shale	150–200
Niagaran dolomite	200–300
Maquoketa shale	300–575
Galena limestone	575–850
Platteville shale and limestone	850–900
Saint Peter sandstone	900–950
Shakopee dolomite	950–1100
New Richmond sandstone	1100–1150
Oneota dolomite	1150–1275
Jordan sandstone	1275–1375
St. Lawrence sandstone	1375–1378

CITY WELL NO. 5, WATERLOO

This well was completed in 1922 by the F. M. Gray, Jr., Company of Milwaukee. The depth is 1409 feet and the diameters are from 20 to 10 inches. The well is cased to 876 feet. The Saint Peter is the chief water bed. In well no. 1 the main flow was found in the Jordan or the Trempealeau. The static level is

50 feet below curb with a draw down of 100 feet when pumping up to capacity of 1350 gallons per minute. The pumping cylinder is set at 156 feet.

*Record of strata**

	Depth in Feet
Devonian (165 feet thick);	
Limestone, light brown	0–10
Limestone, gray, mottled brown at top	10–40
Limestone, gray, sandy, cherty	40–55
Limestone, gray	55–90
Limestone, gray, sandy, cherty	90–110
Limestone, gray and blue, brecciated	110–125
Limestone, light brownish gray	125–135
Limestone, bluish gray, sandy	135, 165
Silurian:	
Niagaran (75 feet thick):	
Dolomite, mottled blue and light gray; no samples from 195-210	165–240
Ordovician:	
Cincinnati (Maquoketa) (230 feet thick):	
Shale, blue, calcareous	240–295
Shale, no sample	295–310
Shale, blue, calcareous	310–425
Dolomite, dark gray, shaly	425–445
No sample	445–455
Dolomite, dark gray, shaly	455–470
Galena—Platteville (371 feet thick):	
Limestone, gray (Galena ?)	470–485
No samples, limestone	485–698
Limestone, gray	698–745
Shale, bluish gray, calcareous (Decorah)	745–760
Limestone, light bluish gray	760–775
Shale, blue, calcareous	775–780
Limestone, bluish gray (Platteville)	780–785
Limestone, light gray	785–835
No sample	835–841
Saint Peter (38 feet thick):	
Sandstone, medium gray, calcareous	841–879
Lower Magnesian (Prairie du Chien) (365 feet thick):	
Dolomite, gray and blue; pyrite and sand	879–895
Sandstone, fine, gray, calcareous	895–910
Dolomite, gray, sandy	910–955
Dolomite, light pink, sandy	955–985
Dolomite, gray	985–1000
Dolomite, gray, sandy	1000–1030
Dolomite, light pink, sandy	1030–1045
No sample	1045–1050
Sandstone, fine, white, calcareous	1050–1060
Dolomite, gray, very sandy	1060–1135
Dolomite, dark gray, cherty, sandy	1135–1150
Dolomite, light pink, cherty, sandy	1150–1165
Dolomite, gray, cherty, sandy	1165–1255
Cambrian:	
Jordan (145 feet thick):	
Sandstone, fine, gray, calcareous, part breaks in chips	1255–1300
No sample	1300–1315

* by Prof. F. T. Thwaites, University of Wisconsin.

Sandstone, medium to fine, white, calcareous, no sample from 1330 to 1345 1315–1380
Sandstone, very coarse to very fine, gray, calcareous 1380–1390
Sandstone, fine, gray, calcareous 1390–1400
Saint Lawrence (Trempealeau) (9 feet penetrated):
Sandstone, very fine, gray, exceedingly calcareous 1400–1409

*Chemical analysis of sample of water from the Waterloo City wells**

	Parts per million
Calcium oxide (CaO)	72.0
Magnesium oxide (MgO)	19.5
Chlorine (Cl)	10.6
Sulphur trioxide (SO_3)	19.0
Carbon dioxide (CO_2), free	13.2
Carbon dioxide (CO_2), bound	59.9
Iron and alumina (Fe_2O_3 and Al_2O_3)	.7
Silica (SiO_2)	8.9

	Probable combination in grains per U. S. gallon
Calcium carbonate ($CaCO_3$)	4.16
Calcium sulphate ($CaSO_4$)	1.89
Calcium chloride ($CaCl_2$)	1.25
Magnesium carbonate ($MgCO_3$)	2.38
Carbon dioxide, free	.77
Iron and alumina	.04
Silica	.52
Incrusting solids	11.05

CITY WELL OF 1928

The sixth deep well of the city of Waterloo was completed in June, 1928, by the Thorpe Bros. Well Co. of Des Moines. The depth is 1407½ feet, about the same as that of the other wells. The diameters are from 16 to 12 inches. The elevation of the curb is 876 feet above sea level. The static level is within 40 feet of the surface. The well has not yet been fully tested. This well is located in the same alignment on the flood plain of Cedar river as are the other city wells and about three-quarters of a mile northwest of well no. 5.

With the cylinder placed at 156 feet the yield is approximately 1,000,000 gallons per day, but it is expected to lower the cylinder to 188 feet. The cost of the well was $20,400, and of the pumping machinery $3500. The geologic section of well no. 1[73a] will give the formations penetrated by well no. 6 with sufficient accuracy.

* American Water Softener Co., Philadelphia, 1919.

73a Norton, W. H., Underground Water Resources of Iowa: Iowa Geol. Survey, vol. XXI, pp. 310-311.

	Thickness	Depth in feet
Pleistocene and Recent	30	0–30
Devonian:		
No samples	70	30–100
Wapsipinicon limestone	58	100–158
Silurian:		
Niagaran limestone	107	158–265
Ordovician:		
Maquoketa shale	215	265–480
Galena-Platteville limestone	335	480–815
Saint Peter sandstone	47	815–862
Prairie du Chien stage—		
Shakopee dolomite	168	862–1030
New Richmond sandstone	30	1030–1060
Oneota dolomite	145	1060–1205
Cambrian:		
Jordan sandstone	48	1205–1253
Saint Lawrence, Trempealeau dolomite	120	1253–1373

WAUKON

(Altitude 1216 feet)

CITY WELL NO. 3

In 1913 it was found necessary to obtain a larger water supply for the city of Waukon on account of increase in consumption due in part to the installation of a sewer system. Neither of the two deep wells of the city, both 577 feet deep, had shown signs of failure, but well no. 1 on account of defective casing which allowed leakage into the well, had largely fallen in disuse, while the drill hole was so crooked that repairs would probably be expensive.

On consultation with this office as to the depth to which a new well should be drilled, the city officials were advised that the well if necessary should be sunk through the Dresbach sandstone, and a well 1450 feet deep probably would tap the water beds of the Cambrian which yield the supply at Lansing and McGregor.

In 1914 a third well was drilled by W. H. Gray and Brother of Chicago to the depth of 910 feet, where work was stopped on account of tools lodging at the bottom of the drill hole. The diameter was 16 inches to 510 feet, where it was reduced to 12½ inches. The static level is 308 feet below the surface—971 feet above sea level. Three tests were made of the capacity of the well. In the first, a so-called "drinking test", 200 gallons per minute were discharged for thirty minutes into the well from a hose connected with a fire hydrant. The water level during this

time rose 14 feet and ceased to rise any higher. This was taken to indicate that 200 gallons per minute could be pumped continuously with a draw-down of only 14 feet. A pumping test was also made with the working barrel set 112 feet below the surface of the water. A discharge of 265 gallons per minute was maintained for three hours with a draw-down of 17 feet during the first 12 minutes of the test, the water level remaining constant during the remainder of the time. Another pumping test was made while the pumps of the old well were in operation. The discharge from the new well was 350 gallons per minute for one hour and ten minutes, while the pumps of the two old wells each lifted 60 gallons per minute. The draw down of the new well was 26 feet, and was all effected in the first ten minutes. In the first pumping test the pump speed was 26 strokes per minute; in the second, 34.

Record of strata

	Depth in Feet
Pleistocene and Recent (20 feet thick; top 1279 feet above sea level):	
Loess, yellow, calcareous	10
Clay, buff, friable, calcareous, an occasional quartz pebble	18
Ordovician:	
Galena limestone to Glenwood shale inclusive (175 feet thick; top 1259 feet above sea level)—	
Limestone, yellow, (in large chips, at 20 feet), rapid effervescence in cold dilute HCl; 3 samples	20–35
Limestone, blue-gray, crystalline-earthy, rapid reaction	40
Limestone, blue-gray and yellow, argillaceous, residue minutely quartzose	45, 50
Limestone, light yellow-gray, in flaky chips	55
Limestone, blue-gray, crystalline-earthy, some whitish	60
Limestone, gray, in chips; with bluish calcareo-argillaceous powder	65
Limestone, light buff and yellow, crystalline-earthy, fossiliferous at 110, reaction rapid; 8 samples	70–110
Limestone, blue, mottled, highly argillaceous; green calcareous shale intercrystallized with limestone; in chips, with much bluish argillo-calcareous powder; residue siliceous with crystalline and cryptocrystalline quartz; pyritiferous	115
Limestone, blue and green-gray, fossiliferous, earthy; in large chips and powder as above	120, 127
Limestone as above, highly argillaceous; 3 samples	132, 140
Shale, green, fissile, with a little limestone as above, fossiliferous	145, 150
Shale, and limestone, as above; unfossiliferous	155
Limestone, gray, fossiliferous, crystalline-earthy, in flakes	157
Limestone, yellow gray, highly argillaceous; at 185 speckled and fossiliferous; 6 samples	160–185
Shale, green, plastic (Glenwood shale)	190
Saint Peter sandstone (65 feet thick; top 1084 feet above sea level)—	
Sandstone, moderately fine (fine at 250 feet), light gray in mass or buff from rusted grains, grains of clear quartz well rounded; 11 samples	195–255

Prairie du Chien (290 feet thick; top 1019 feet above sea level)—	
Dolomite, blue-gray (buff at 260, 270); 7 samples	260–295
Dolomite, gray, crystalline, porous; 3 samples	300–310
Sandstone and dolomite, sand grains moderately fine, well rounded	315
Dolomite, yellow-gray, in chips, with much quartz sand	320
Dolomite, gray, arenaceous	325
Dolomite, blue-gray	327
Dolomite, arenaceous and minutely quartzose, in yellow powder and small chips; much quartz sand	330, 340
Sandstone, buff, moderately fine	350
Dolomite, blue-gray, in chips	360
Shale, light yellow, calcareous, plastic	365
Dolomite, blue-gray, cherty at 410, 420; 14 samples	370–510
Dolomite, highly arenaceous, gray	520
Dolomite, gray	525, 530
Dolomite, buff, arenaceous	540
Cambrian:	
Jordan sandstone (120 feet thick; top 729 feet above sea level)—	
Sandstone, buff in mass, fine grains moderately well rounded; 4 samples	550–580
Sandstone, white, grains well rounded and up to 1 mm. in diameter (at 620 up to 1.5 mm. in diameter)	590, 620
Sandstone, buff, fine	640
Sandstone, buff, grains up to 1 mm. in diameter, with chips of buff, fine-grained calciferous sandstone	660
Saint Lawrence, Trempealeau beds (90 feet thick; top 609 feet above sea level)—	
Marl, blue, cuttings in sand and powder, chiefly of microscopic angular quartzose particles, argillaceous, calcareous	670
Dolomite, blue-gray, highly siliceous as above, in small chips	680–690
Sandstone, blue-gray, hard, of fine grains and quartzose particles, calciferous (coarser with rounded grains at 720); 3 samples	700–720
Dolomite, blue, highly siliceous with quartzose particles and fine grains, in chips; 3 samples	730–750
Saint Lawrence, Franconia beds (penetrated 150 feet, top 519 feet above sea level)—	
Sandstone, in powder and some chips, of very fine grains and microscopic particles, glauconitic	760
Shale, green, in powder, highly siliceous with fine grains and quartzose particles, glauconitic, slightly calcareous; 3 samples	770–790
No samples; "green clayey shale" of driller's log	800–870
Sandstone, light gray, fine rounded grains, some dolomite and shale	880
Sandstone, as above, color of cuttings greenish; dolomite and shale in powder; numerous black opaque nonmagnetic grains	890
Sandstone as at 880	900
Sandstone, light yellow, fine grains of clear quartz, well rounded	910

Driller's log

	Depth in Feet
Surface clay	0–20
Limestone, grayish	20–115
Shale	115–155
Limestone	155–185
Shale	185–190
Saint Peter sandstone	190–260
Limestone, brownish	260–315
Sand	315–320
Limestone	320–335
Sandstone, hard, changing from white to brown	335–350
Limestone, hard, blue, many crevices	350–450
Limestone, whitish	450–520

Jordan sandstone	520–665
(Sand caved at 585 feet, cased off with 59 feet of 10 inch pipe. Bottom of pipe seated in hard sandstone at 600 feet. Hard sand 5 feet thick, then 60 feet of softer water-bearing sandstone. At 575 feet water level dropped from 120 feet to 300 feet from the surface.)	
Limestone, bluish	665–685
Limestone, grayish	685–745
Limestone, blue	745–760
Shale, green, clayey	760–880
Sandstone, white, very hard	880
(Work stopped at 910 feet, with 67 feet of tools stuck.)	

Notes.—It will be seen from the above record of strata that the entire 175 feet of the Galena-Platteville beds of this well section completely escaped dolomitization. No limestone cuttings contain enough magnesium carbonate to retard brisk effervescence in cold dilute HCl. The shales and highly argillaceous limestones from 115 to 157 feet probably represent the Decorah shale, and the underlying limestone is the Platteville. The Glenwood shale is here only five feet thick.

The Prairie du Chien is not clearly tripartite here, although the arenaceous beds from 300 to 360 feet may be taken in whole or part to represent the New Richmond sandstone.

The Trempealeau beds—the "dolomite" of the "Saint Lawrence dolomite and shale"—correspond lithologically with the outcrops of the formation to the east in the Mississippi bluffs, but are less dolomitic than in many well sections to the west and south.

The Franconia beds are marked by their usual glauconitic and argillaceous content, and by the ambiguous strata which often leave the observer in doubt as to whether they should be called shale or sandstone or even dolomite.

The sandstone at 880-900 feet is probably transitional to the Dresbach sandstone, as the dolomite and shale of the cuttings may possibly be from higher levels. The clean sandstone at 910 in which the drill stopped may easily be the uppermost of the Dresbach beds. Certainly the Dresbach was to be expected a few feet deeper at the most. Truly it would have been highly unfortunate that the drilling was compelled to stop so near or even at the top of a generous water sand, were it not for the fact that the supply already obtained was later found by tests to be ample for the needs of the city.

WEBSTER CITY

(Altitude 1050 feet, I. C. R. R.)

In the Report of the Iowa Geological Survey for 1912 mention is made of the city supply then drawn from 13 drift wells, and of a well sunk by the Gas Company to a depth of 1250 feet. The water of this deep well was found so highly corrosive that it was never used except for a public watering trough. Lest the failure to obtain good water at this depth might discourage further efforts, the following forecast was made by Norton.[74]

"Had the drilling been continued 150 feet deeper, the Saint Peter sandstone probably would have been struck, and 400 to 600 feet deeper the creviced limestones and sandstones which yield the chief supply for the Iowa wells would have been tapped. A well about 1850 feet deep could have given a largely increased yield of much better water, the sulphate content being greatly lessened."

As the supply from the wells in drift had become inadequate a deep well was contracted for with Thorpe Brothers of Des Moines, who completed the well Jan. 1, 1925. Saint Peter sandstone was reached at the depth of 1420 feet (depth predicted 1400 feet) and an abundant supply was found in the underlying formations well within the recommended depth of 1850 feet.

The depth of the well is 1805 feet; diameters, 16 inches to 560 feet, 12 inches to 1420 feet, 8 inches to bottom of the well. The casing of heavy wrought iron was set and packed so as to exclude upper waters, which might be expected to be heavily mineralized: 16 inches, 105 feet to rock; 12 inches to 560 feet with 25 feet of concrete filling between the 12 inch and 16 inch casings, 10 inches to 1420 feet, 8 inches from 1400 to 1520 feet, the remainder of the boring uncased.

Small flows at 600 and 1100 feet were cased out. The Saint Peter sandstone is reported as dry. The supply was obtained from the New Richmond sandstone and the Oneota dolomite, the main flow being struck in the former at 1620 feet.

The well had flowed until the depth of 1620 feet was reached when the water fell to the present static level of six or seven feet below the curb. The pumping capacity is rated at 2,500,000 gal-

[74] Underground Water Resources of Iowa, Iowa Geol. Survey, vol. XXI, Des Moines, 1912, pp. 844-45.

lons a day, and under protracted capacity pumping the head is drawn to, but not below, 32 feet below the curb.

The water from these deep horizons is of the sodic-magnesic sulphated class as is seen from the following:

Analysis of water, by Graver Corporation

	GRAINS PER U. S. GALLON
Calcium carbonate	17.60
Calcium sulphate	4.08
Magnesium sulphate	18.10
Sodium sulphate	16.90
Sodium chloride	4.21
Silica	0.44
Iron and aluminum oxide	0.15
Suspended matter	0.78
Incrusting and corrosive solids	41.15
Nonincrusting solids	21.11
Total solids	62.26
Hardness	35.68
Alkalinity	17.60

Special acknowledgements are due the City Manager, Mr. G. J. Long, who secured and supplied the above information and also furnished to the Survey a very complete set of samples of the cuttings.

Record of strata in City well (1925) of Webster City

Recent and Pleistocene (103 feet thick; top 1030 feet above sea level):	
"Earth and clay"	
"Gravel"	
"Clay"	
Mississippian, Kinderhook stage (467 feet thick; top 927 feet above sea level):	
"Rock"	103–120
Limestone, whitish and light yellow-gray, soft, earthy, with calcite crystals, rapid effervescence, in large flakes, some samples in smaller chips. At 150 feet cherty and with some imperfectly rounded quartz sand. At 200 feet with some reddish chalcedony; 12 samples	120–230
Limestone, dark brown, argillaceous, crystalline, rapid response; and some white cherty limestone	240
Limestone, greenish gray, minutely crystalline-earthy, argillaceous, effervescence moderately rapid, in flaky chips with much argillo-calcareous powder; 4 samples	240–280
Chert, blue and white, with argillaceous limestone as above	290
Limestone, as at 240-280; 5 samples	300–340
Shale, light greenish grey, plastic, in concreted masses; 2 samples	350, 360
Limestone, dark blue-gray, fine crystalline-granular, vesicular, some mottled with flint, moderately slow effervescence, in chips	370
Limestone, light yellow-gray, in sand, rapid effervescence, and light blue-gray, in chips, less rapid	380
Limestone, whitish, crystalline, effervescence rapid, with some flakes of light blue-gray shale	390
Shale, light green-gray, in concreted masses	400

Limestone, whitish, and light yellow-gray, crystalline, reaction rapid.... 410
Shale, greenish; with white limestone, rapid effervescence 420
Limestone, blue and yellow-gray, a calcilutite, rapid effervescence, in small flaky chips, with some white, macrocrystalline; 2 samples 430, 440
Limestone, blue-gray, some white, some yellow gray calcilutite, some mottled, in small chips, rapid effervescence 450
Limestone, blue-gray and brown, some mottled, effervescence moderately rapid, fine crystalline-granular 460
Limestone, light gray-buff, fine crystalline-granular, reaction moderately slow, with a little green fissile shale; 2 samples 470–480
Limestone as above, and shale, blue-gray, calcareous; some dark drab limestone, highly argillaceous, soft, with minute nonsiliceous balls resembling oölite 490
Limestone, drab, compact, reaction moderately slow, residue argillaceous and with much microscopic crystalline and cryptocrystalline quartz; some shale; 2 samples 500, 510
Limestone and considerable shale; limestone in fine sand, light gray, response rapid; and dark gray and light yellow, rather slow response 520
Shale, gray, calcareous, in chips, some drab, with minute calcareous balls as at 490 530
Limestone, gray, moderately slow response, hard, compact, fine-grained; some shale 540
Limestone, blue-gray, soft, fine crystalline-granular, argillaceous 550
Limestone, iron gray, fine crystalline-granular, slow response; some microscopic quartzose residue 560
Limestone, blue-gray, soft, argillaceous 570

Devonian (100 feet thick; top 450 feet above sea level):

Dolomite, light yellow-gray, fine-granular; and shale, blue, calcareous, in chips; 2 samples 580, 590
Dolomite, yellow-gray, fine granular-crystalline, in clean chips 600
Dolomite, light buff, in fine crystalline sand, with some irregularly rounded grains of quartz 610
Dolomite, brownish buff, in fine crystalline sand 620
Limestone, blue-gray, hard, fine-grained, argillaceous; with some chips of shale of same color 630
Limestone, dark gray, in flaky chips, some porous 640, 650
Shale, some brown, inflammable, some lighter color, giving empyreumatic odor when heated 660
Limestone, blue-gray, argillaceous, response moderately rapid; and brown crystalline dolomite; also light blue shale 670

Silurian (290 feet thick; top 250 feet above sea level):

Limestone, light brown, crystalline-granular, porous, with white calcite; some drab and argillaceous, both moderately slow in reacting to acid, in flaky chips 680
Limestone, brown, as above 690, 700
Limestone, light blue-gray, argillaceous, rapid reaction 710
Limestone, light gray, soft, response rapid, with a little white gypsum in rounded chips 720
Dolomite, brown, in flaky chips 730
Dolomite, light yellow-gray, crystalline-granular, with some gypsum 740
Limestone, blue-gray, moderately slow reaction; shale, and some gypsum 750
Limestone, brown, crystalline, reaction moderately slow; with hard blue calcareous shale in chips, and some gypsum in rounded grains 760
Shale, blue 770
Limestone, dark drab, reaction rapid, fossiliferous, in flakes 780
Limestone, drab, earthy, argillaceous, reaction slow, a little gypsum 790
Limestone, dark drab, reaction rapid, in flaky chips, some gypsum in rounded grains 800
Limestone, drab, moderately slow response, some gypsum 810
Limestone, drab, response rapid, some gypsum 820

Gypsum, white, with some limestone 830
Limestone, brown and blue-gray, moderately slow reaction; with gypsum; 4 samples 840–870
Gypsum, with light blue limestone of rapid effervescence 880
Gypsum, in hard white concreted masses, slightly calcareous 890
Limestone, brownish, in small chips and flakes, rapid effervescence 900
Limestone, brownish, in small chips, moderately slow effervescence 910, 920
Limestone, gray, rapid effervescence 930
Limestone, light gray, rapid response, fossiliferous, with fragments of brachiopods, shell material preserved 940, 950
Limestone, light brownish gray, rapid response 960
Ordovician:
Maquoketa shale (70 feet thick; top 60 feet above sea level)—
Shale, blue and drab, calcareous; 6 samples 970–1020
Limestone, gray, highly argillaceous, moderately rapid effervescence 1030
Galena and Platteville formations (380 feet thick; top 10 feet below sea level)—
Limestone, gray, rapid effervescence 1040
Limestone, light gray, argillaceous, with a little olive green shale with bituminous odor when heated 1050
Limestone, gray, crystalline, rapid effervescence 1060, 1070
Dolomite, light gray, in fine crystalline meal 1080
Dolomite, gray and buff, in crystalline meal, with much gray and blue gray flint; 6 samples 1090–1140
Dolomite, as above, with limestone, gray, in flaky chips 1150
Limestone, gray, earthy, rapid reaction, in flaky chips, with some dolomitic meal 1160
Limestone, light yellow-gray and blue-gray, earthy, reaction rapid, in flaky chips; crystalline-granular and moderately rapid response at 1240, with flint at 1250 and 1270-1290 1170–1360
Shale, light blue-gray and dark green, with some limestone meal, pyritiferous 1370
Limestone, dark drab, in meal, reaction rapid; with shale 1380
Shale, bright green, fissile; 3 samples 1390–1410
Saint Peter sandstone (50 feet thick; top 390 feet below sea level)—
Sandstone, fine, light yellow-gray in mass, grains of pure quartz, well rounded, some rusted 1420
Sandstone, as above, white, coarser, a little hard bright green shale from above; 4 samples 1430–1460
Prairie du Chien—
Shakopee dolomite (120 feet thick; top 440 feet below sea level)—
Dolomite, gray, light drab and light buff, in chips, in places with imbedded grains of quartz; quartz sand and green shale in drillings; 6 samples 1470–1520
Dolomite, as above, in flour, with much fine sand in drillings; 6 samples 1530–1580
New Richmond sandstone (80 feet thick; top 560 feet below sea level)—
Sandstone, in minute, irregular grains, with considerable dolomite 1590
Sandstone, light gray, fine, grains rounded, with some dolomite with imbedded grains of quartz sand 1600, 1610
Sandstone, gray, fine, grains moderately rounded, some dolomite 1620
Sandstone, yellow-gray, dolomitic (or dolomite, arenaceous), grains moderately well rounded, much cryptocrystalline silica at 1640; 3 samples 1630–1650
Sandstone, fine, drillings much rusted, moderately well rounded grains 1660
Oneota dolomite (135 feet thick to bottom of well; top 640 feet below sea level)—

Dolomite, light buff or gray, in fine sand, with a few irregular grains of quartz sand, large residue of cryptocrystalline silica in fine sand at 1670; 11 samples 1670–1770
Dolomite, reported at bottom of well, no samples 1780–1805

Notes.—No attempt is made to subdivide the Kinderhook, although the upper whitish limestones probably represent the Alden beds. The shale struck at 350 feet might plausibly be taken as the Sheffield, but on the whole considering the sections of other deep wells of the territory it has seemed best to draw the base of the Kinderhook as low as the bottom of the argillaceous limestones at 570 feet. The Devonian is presumed to be thin, as it is found to be over its area of outcrop to the east, and is assigned but 100 feet. Both its summit and base are arbitrarily drawn, the latter to include an inflammable shale, since such thin shales occur in the Otis and Independence of the Devonian outcrops. A similar shale occurs at Fort Dodge 97 feet lower than at Webster City, denoting a dip, if the two shales are of the same horizon, of some five feet to the mile. The summit of the Saint Peter sandstone, however, lies at about the same level at both localities.

Beneath the bituminous shale just mentioned occur magnesian limestones containing gypsum. As at Marshalltown, Des Moines, Grinnell, Pella and Mount Pleasant, the presence of gypsum in limestones lying between the Kinderhook and the Maquoketa is taken to mark the Silurian horizon, but more probably the Salina, than the Niagaran of the Iowa outcrops.

The Maquoketa shale and the Saint Peter sandstone are here reliable markers and determine clearly the Galena-Platteville limestones and basal shales.

All the strata below the Saint Peter are assigned to the Prairie du Chien, with its three component formations, the Shakopee dolomite, the New Richmond sandstone and the Oneota dolomite. This assignment agrees with that of the deeper Fort Dodge section, where the corresponding dolomites are found to be underlain by a sandstone best referred to the Jordan. If the water-bearing sandstones below 1590 feet represent the Jordan, the Prairie du Chien is here abnormally thin, as compared, for example, with the section of the deep well at Ames.

WEBSTER COUNTY

WELL OF J. C. RITCHIE, SW. ¼ SEC. 23, HARDIN TP.*

The altitude of the well curb is about 1125 feet above sea level. The depth of the well is 552 feet. Water was found from 330 to 375 feet and at 527 feet. The water heads 150 feet below the curb.

Record of strata of Ritchie well

	Depth in Feet
Clay, yellowish, calcareous; limestone pebbles; glacial till; 3 samples	20–40
Clay, gray, limestone pebbles; glacial till	50, 60
Clay, dark gray and buff, pebbly, many limestones, calcareous	70, 80
Clay, mostly yellowish, pebbly, calcareous	90
Sand, very fine, yellow	100
Clay, gray, blue-gray and dark gray, pebbly, calcareous; 16 samples	110–260
Clay, some dark gray, some yellowish, some pebbles; dark fragments calcareous; yellowish parts noncalcareous and probably a shale. The pebbles seem to be in the darker portion and the lighter parts are somewhat laminated	270
Gravel and sand, rather rusty yellow, very little limestone	280
Sand, yellow like preceding, finer	290
Clay, dark gray, with some fragments of lighter gray, noncalcareous; few small dark pebbles	300, 310
Clay as above, rather abundant quartz and dark pebbles	320
Clay, light blue-gray, some dark pebbles and some of white chert, no response to acid	330
Sand, dark gray, in angular chips and rounded grains; white chert	340, 350
Clay, dark gray, slight response to acid, some dark pebbles; some sand from 340, 350	360
Limestone, light gray, in small chips and powder, brisk effervescence; 4 samples	370–400
Limestone, medium dark gray, fine grains and larger chips, chips show subcrystalline structure; some chips of limy shale, dark gray	410
Limestone, as above; 4 samples	420–450
Limestone as above, some chips of very dark gray, noncalcareous shale	460
Shale, blue-gray, fine textured and soapy	470, 480
Limestone, in rather fine powder, rather dark gray; as with all limestones above brisk effervescence; chips of noncalcareous shale	490
Shale, dark gray, with some fragments of lighter gray color; fine shiny specks probably quartz scattered through the shale	500
Limestone, gray, in small chips, and fine powder, brisk effervescence; 5 samples	510–552

WESLEY, KOSSUTH COUNTY

(*Altitude 1252 feet*)

CITY WELL NO. 1

This well, drilled in 1921 by Jas. Lee of Algona, is 1100 feet in depth, and its diameters are 8 and 5 3/10 inches. Some water was found at 275 feet and the main supply was reached at 1030 feet, 227 feet above sea level, a depth at which the Saint Peter

* By Dr. Jas. H. Lees, Assistant State Geologist.

sandstone should be encountered. The static level is 215 feet below the surface. With the cylinder set at 250 feet the pump delivers 35 g.p.m., an amount sufficient for the town of 440 inhabitants with a consumption of 7,000 to 10,000 g.p.d. There is no draw down under pumping. The casing is 8 inch to 215 feet, 5⅝ inches from the top to 1007 feet, and at bottom 40 feet of 5 3/16 inch casing with 14 feet of overlap.

The quality of the water is described as very hard with much iron and pronounced rusting. This is borne out by a sanitary water analysis of February, 1927, which finds the sample of very red iron color, very decided turbidity, and with a heavy iron flocculent sediment. The cost of the well was $8,000.

*Mineral Content of City Well, Wesley**

	P.P.M.
Bicarbonate	495.3
Chloride	7.
Sulfate	77.0
Silica	10.4
$Fe_2O_3+Al_2O_3$	7.6
Calcium	65.4
Magnesium	27.6
Na + K as Na	74.2
Total solids	516.8

WINFIELD, HENRY COUNTY

(Altitude 704 feet)

The city well of Winfield was completed in 1921 by the McCarthy Well Company of Saint Paul. The depth reached was 1268 feet. The work was accomplished "in 63 days, excluding Sundays and one day on account of a break of machinery, making an average of 20 feet a day." Casing was put down to rock and through the heavy Kinderhook and Maquoketa shales.

The pumping test of 24 hours showed a capacity of 150 gallons per minute with a draw down of 84 feet. The static level is 73 feet below the surface. The chief water bed was the Shakopee dolomite from 1180 to 1268 feet.

Record of strata and driller's log

	THICKNESS IN FEET
Pleistocene and Recent (80 feet thick; top 698 feet above sea level):	
"Clay"	3–80

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

Mississippian (110 feet thick; top 618 feet above sea level):	
"Limerock, hard, many seams or layers"	80–190
Kinderhook shale (320 feet thick, top 508 feet above sea level)—	
Shale, plastic, blue	190–510
Devonian and Silurian (108 feet thick; top 198 feet above sea level):	
Limestone, magnesian, or dolomite, as tested by slow response to cold dilute HCl, drab; some lighter colored limestone of brisk effervescence	510–618
Ordovician:	
Maquoketa shale (210 feet thick; top 80 feet above sea level):	
Shale, light blue, plastic, "in streaks of color running from green to brown"	618–808
Shale, brown, hard, in chips, feebly inflammable, slightly calcareous	808–818
Shale, brownish drab, plastic	818–828
Galena to Glenwood inclusive (315 feet thick; top 130 feet below sea level)—	
Limestone, blue, earthy, rapid effervescence, in flaky chips	828–1114
"Sandrock, white, very hard and fine-grained" (no sample, Glenwood beds)	1114–1128
Shale, green and drab, hard (Glenwood)	1128–1143
Saint Peter sandstone (37 feet thick; top 445 feet below sea level)—	
Sandstone, white, fine, well rounded and frosted grains	1143–1180
Prairie du Chien:	
Shakopee dolomite (penetrated 88 feet; top 482 feet below sea level)—	
Dolomite, dark gray; white chert; drab shale	1180–1268

*Mineral Content of City Well, Winfield**

	P.P.M.
Bicarbonate	280.6
Chloride	80.
Sulfate	434.6
Silica	13.8
$Fe_2O_3+Al_2O_3$	3.2
Calcium	201.6
Magnesium	36.1
Na + K as Na	152.1
Total solids	1061.7

WOODWARD, DALLAS COUNTY

(Altitude 1060 feet)

In 1916 a deep well was drilled by Chas. Nolan of Cedar Rapids for the State Hospital and Colony for Epileptics near Woodward. The well is located in the Ne. ¼, sec. 31, Cass Tp., Boone county, at an elevation of about 1060 feet. The depth of the well is 1800 feet and the diameters are from 12 to 6 inches. The static level is 110 feet below the surface of the ground. The pumping capacity on completion was found to be 220 g.p.m.

The quality of the water, however, was unsatisfactory and in 1922 the well was abandoned in favor of a supply drawn from Des Moines river. The following log is from a blue print by H.

* Analysis by Dr. Harry F. Lewis, Chemical Laboratory, Cornell College, Mount Vernon, 1927.

F. Liebbe, State Architect. The assignment to formations is by the writer:

Log of well at Epileptic Colony

	Depth in Feet
Pleistocene (145 feet thick; top 1060 feet above sea level):	
Clay, yellow, soft, sticky	0–27
Sand, very fine, some water	27–46
Clay, yellowish gray, containing wood	46–51
Clay, light blue	51–69
Clay, grayish yellow, containing sand and gravel	69–110
Clay, deep brown	110–140
Sand, quartz, fine uniform grains	140–145
Pennsylvanian (380 feet thick; top 915 feet above sea level):	
Rock, hard, blue	145–150
Shale, blue, hard, brittle	150–210
Slate, sandy; some coal	210–230
Shale, light blue	230–305
Shale, bituminous, mixed with ash-colored fine clay, coal and iron	305–375
Shale, black and sandy	375–410
Shale, gray and blue	410–445
Flint rock, streaked with shale	445–452
Shale, gray, blue	452–485
Shale, sandy	485–493
Lime rock, hard, brown	493–495
Sand rock, white, testing 35 g.p.m.	495–525
Mississippian (315 feet thick; top 535 feet above sea level):	
Shale, blue	525–528
Sandstone, white	528–534
Shale, blue, sandy	534–560
Limestone, gray	560–720
Limestone, white, brittle	720–790
Shale, light blue, fine texture (Kinderhook)	790–840
Devonian and Silurian (505 feet thick; top 220 feet above sea level):	
Limestone, blue	840–865
Limestone, gray, hard	865–970
Shale, brown, hard, cavy	970–983
Limestone, sandy; some water	983–995
Limestone, soft, light color	995–1040
Shale, yellow	1040–1045
Limestone; some quartz	1045–1110
Shale	1110–1113
Limestone, gray, hard	1113–1240
"St. Peter sandstone"	1240–1285
Shale, bluish	1285–1290
Limestone, hard, brown	1290–1345
Ordovician (penetrated 455 feet):	
Maquoketa shale and Galena-Platteville limestone (378 feet thick; top 285 feet below sea level)—	
Shale	1345–1350
Limestone, blue; granite streaks (blue chert?)	1350–1410
Limestone, light color	1410–1475
Shale, light blue	1475–1530
Lime, brown, hard, fine-grained	1530–1650
Sandstone, white, round shape	1650–1655
Limestone, brown, very hard	1655–1723
Glenwood shale (2 feet thick; top 663 feet below sea level)—	
Shale, green	1723–1725
Saint Peter sandstone (penetrated 75 feet; top 665 feet below sea level)—	
"Jordan sandstone"	1725–1800

WORTHINGTON, MINNESOTA

A test well at Worthington, Minnesota, was drilled in 1928 and is here placed on record because, situated but eight miles north of the Iowa state line, it gives, no doubt, authentic information as to conditions of water supply in northern Osceola county. The country rock in both the southwestern corner of the county and in the northeastern corner is the Sioux quartzite.[75] The elevation is about 1575 feet above sea level.

Driller's log, A. Engerbretsen

	Depth in Feet	
Mixture of blue and yellow clay	0	–125
Yellowish gray sand, water to within 50 feet of top	125	–167½
Gray sand, quite coarse, water sand	167½	–172
Yellow and gray sand	172	–295
Gray sand	295	–300
Yellow and gray clay	300	–354
Gray sand	354	–387
Yellow and gray clay	387	–395
Gray sand	395	–398
Yellow and gray clay	398	–440
Hard sand rock	440	–470
Hard rock	470	–478
Soft rock and sand, mixed with yellowish clay	478	–508
Hard rock, but not so hard as the stratum between 470 and 478	508	–513

Driller's log, continued, C. W. Varner, Dubuque

Sand rock	513	–535
Clay or hard pan, caving	535	–553
Sand rock, caving at 583	553	–601
Hard sandstone	601	–604
Fissure of one foot	604	–605
Softer sandstone	605	–610
Hard sand	610	–612
Softer sand	612	–617
Hard sand	617	–630
Clay, caved in presumably from about 550 feet	630	–641
Hard sand rock	650	–705
?	705	–750

Record of strata, Worthington test well, 1928

The following determinations were made of samples preserved by Mr. Varner. No cuttings had been kept previously to his taking over the work.

	Depth in Feet
Sandstone, gray in mass, speckled grains irregular, mostly of colorless quartz, up to 2 mm. in diameter, secondary enlargements, sparkling, some greenish yellow grains, some black, some of pink quartz; a little gray shale; 2 samples	510–520

75 O. E. Meinzer, Underground Waters of Southern Minnesota, p. 288.

Sandstone, gray, speckled, coarser than above, grains up to 2 mm. diameter, mostly clear, colorless quartz, some yellow, red, rose red and greenish; greenish yellow grains showing cross-hatching and high polarization colors; blackish grains (streak brown) yellowish by transmitted light, isotropic; grains mostly broken, a few well rounded	520–525
Sandstone as above, finer	530–535
Shale, light drab, noncalcareous, micaceous (white mica), microscopically quartzose	535–553
Sandstone, light gray, and light yellow-gray, fine, form of grains and mineral constituents as at 520, also micaceous (white mica), and biotite mica at 590, pink grains rather common at 615; 11 samples	553–620
Sandstone, yellow-gray, fine, cuttings mostly in angular fine fragments, some rounded grains, secondary enlargements, a little feldspar, black grains rare, vari-colored quartz rare, micaceous; 6 samples	615–645
Sandstone, coarse to fine, grains up to 2 mm. and 3 mm., much fine quartzose material, grains largely of colorless quartz, a few pinkish, many whitish, in part of feldspar, irregular, broken, secondary enlargements, some rounded, not frosted; 3 samples	645–660
Sandstone, gray, very fine, micaceous, grains irregular	660–665
Sandstone, light yellow, slight pink tinge from grains of this color, micaceous, almost wholly of quartz; ball of pyrite, size and form of grains as at 645	665–670
Sandstone, light yellow, medium to fine, micaceous, some pink grains, irregular, broken	670–675
Sandstone, fine to medium, light gray, as above	675–680
Sandstone, light gray, slight pinkish cast, fine to medium as above; 2 samples	680–690
Sandstone, yellow-gray, fine to coarse, some greenish, pink and yellow grains	690–695
Sandstone, light pinkish, terra cotta colors, argillaceous, in friable masses, a few yellow, pink and bright red grains	700–705
Crystalline rock, minerals: quartz, orthoclase, plagioclase, biotite, other ferro-magnesian mineral, masses of kaolinitic material from rock decay; 8 samples	705–750

Notes.—Water, it is said, was found at 125 feet in considerable amount, and continued to come in to a depth of about 300 feet. A larger supply was struck at 400 feet, rising to nearer the surface. This vein is probably the "gray sand" of the log at 395-398 feet. Below 400 feet it is not known that any water was found.

This section is noteworthy because it gives here the elevation of the Paleozoic floor of the crystalline rocks of the Archean, about 870 feet above sea level, and because two bodies of rock which might have been expected—the Sioux quartzite and the Red Clastics of the Cambrian—are entirely absent. Yet the Sioux quartzite occurs both to the north and to the west of Worthington within the county limits; and in a number of deep well sections in Minnesota and Iowa the sandstones and shales of the Red Clastics overlie the crystalline Archean rocks. Nor

is there a trace of the glauconitic sandstones and "marls" of the Cambrian.

Probably drift deposits extend to at least 172 feet. And to the Cretaceous may safely be referred the 268 feet of "yellow and gray sand", "gray sand", and "yellow and gray clay" of the log.

The upper gray and speckled sandstone of the cuttings is said to have begun at 465 feet. The variety of minerals present, the lack of assortment and the irregular form of the grains indicate a near shore of crystalline rocks, but of course do not record any particular geologic period of time. The lower sands, separated from the upper sands by 18 feet of drab shale at 535 feet, in large part finer, and more predominantly of colorless quartz, though also poorly rounded of grain, record a more distant source of supply, with a longer period of effacement of the weaker minerals by wave work. Yet the two sandstones are on the whole much alike in mineral composition and shape of grains.

It is not determined whether these sands are Cretaceous or Cambrian.

Although these sands of the cuttings below 510 feet at Worthington seem to have been found dry, it does not follow as a sure conclusion that they would be found everywhere dry across the Iowa line. They do not encourage drilling, but they do not forbid it. Their texture, caving at one horizon, suggests that in places they may perhaps be water-bearing.

QUITMAN, MISSOURI

(Altitude 906 feet)

Mr. Gerald Bednar, President of Iowa's First Oil Development Company, which drilled the oil prospect south of Clarinda, has furnished a log of a prospect which was drilled near Quitman, Nodaway county, Missouri, by G. H. Rose and Son of Maryville, Missouri. This well is in the hills one mile south and two miles east of town, in the southeast corner of SE. ¼ NE. ¼ Sec. 15, T. 64, R. 37, at an elevation of 953 feet above sea level, and was completed June 6, 1927. It is about 40 miles south of the Clarinda boring and nine miles south of Maryville.

Driller's log of prospect in Cardin Lease, Quitman, Nodaway County, Missouri, well no. 2

	Depth in Feet
Soil	0–10
Yellow clay	10–25
Gravel (water)	25–35
Blue shale	35–45
Lime	45–48
Light shale	48–52
Lime	52–53
Light shale	53–55
Lime	55–60
Light shale	60–62
White lime	62–74
Light shale	74–82
Lime	82–89
Shale	89–90
Lime	90–105
Shale, dark	105–108
Lime	108–112
Shale, dark	112–114
Lime	114–116
Shale, dark	116–126
Lime	126–128
Shale, light	128–129
Lime	129–132
Shale, light	132–177
Lime	177–190
Shale, dark	190–193
Lime	193–198
Shale, light	198–210
Lime	210–214
Lime, broken	214–217
Lime	217–230
Shale, dark	230–233
Lime	233–248
Shale, dark	248–260
Shale, light	260–273
Red bed	273–285
Shale, light	285–424
Lime	424–429
Shale, broken	429–443
Lime	443–447
Shale, light	447–452
Lime	452–457
Shale, light	457–461
Lime	461–467
Shale, dark	467–475
Lime	475–485
Shale, light, sandy	485–487
Lime, hard	487–488
Shale, light	488–500
Lime	500–515
Shale, light	515–518
Lime	518–522
Shale, light	522–524
Lime	524–526
Shale, sandy	526–530
Lime	530–535
Shale, dark	535–555
Shale and broken sandstone	555–560
Lime	560–570
Shale, dark	570–575
Shale, brown	575–585
Lime, brown	585–588
Red bed	588–593
Shale, sandy	593–600
Lime	600–604
Shale, dark	604–606
Lime, hard	606–632
Shale, dark	632–635
Lime	635–642
Shale, sandy	642–644
Lime	644–668
Shale, black	668–676
Lime, very hard	676–696
Shale, black	696–700
Lime	700–702
Shale, dark	702–707
Lime	707–718
Shale, dark, broken	718–720
Lime	720–732
Shale, broken	732–737
Lime	737–739
Shale, broken	739–746
Lime	746–748
Shale, dark	748–752
Lime	752–757
Shale, blue	757–762
Lime	762–770
Shale, blue	770–777
Lime	777–779
Shale, blue	779–784
Red bed	784–788
Shale, light	788–803
Lime	803–808
Shale, dark	808–837
Lime	837–844
Shale, light	844–848
Shale, dark	848–860
Lime	860–862
Shale	862–865
Lime	865–870
Shale, dark	870–873
Lime	873–876
Shale, dark	876–882
Lime	882–885
Shale, dark	885–889
Lime	889–897
Shale	897–902
Lime	902–903
Shale, black	903–904
Lime	904–905
Shale, dark	905–910
Lime, gray	910–914
Shale, light	914–918
Lime, gray	918–922
Shale, dark	922–929
Shale, green	929–954

Shale, dark	954–1016
Lime	1016–1020
Shale, black	1020–1028
Lime, hard	1028–1030
Shale, black	1030–1037
Shale, blue, sandy	1037–1044
Lime	1044–1045
Shale, dark	1045–1047
Lime	1047–1048
Shale, dark	1048–1066
Lime	1066–1070
Shale, dark	1070–1080
Lime	1080–1082
Shale, dark to black	1082–1104
Lime	1104–1105
Shale, dark	1105–1116
Lime	1116–1118
Shale, dark	1118–1125
Shale, yellow	1125–1132
Shale, dark	1132–1151
Lime	1151–1153
Shale, dark	1153–1160
Shale, sandy	1160–1165
Shale, dark	1165–1172
Lime	1172–1173
Shale	1173–1176
Lime	1176–1178
Shale, dark	1178–1195
Shale, light, sandy	1195–1211
Lime, gray	1211–1213
Shale, light, sandy	1213–1218
Shale, dark	1218–1300
Sand, water (oil showing)	1300–1305
Shale, dark	1305–1308
Lime	1308–1311
Shale, black	1311–1313
Shale	1313–1314
Lime	1314–1316
Shale, black	1316–1332
Water sand (oil showing)	1332–1337
Shale, light	1337–1357
Shale, dark	1357–1367
Shale, black	1367–1370
Shale, dark	1370–1387
Shale, black	1387–1390
Shale	1390–1391
Shale	1391–1395
Lime and particles of iron	1395–1400
Shale, black	1400–1404
Shale	1404–1410

Deep Wells Abandoned Since 1912 (Compiled in 1925)

Location	Depth in feet	Year completed	Remarks
Amana			
Woolen mill well	1640	1883	Heads now 2 feet above curb, discharge 100 g.p.m.
Belle Plaine			
City well	1503	1907	Soon after completion superseded by artesians 200 feet deep. Supply now from shallow wells in gravel on Salt creek
Burlington			
Iowa Soap Co.	509	1904	Cost of chemical treatment as much as that of city water
Sanitary Milk Co.	487	1905	Plant moved to other location
Cedar Rapids			
City wells nos. 2 and 3	1450	1888	Cost of pumping, due to lowered static level
Y. M. C. A. well	.....		Building now used for other purposes
Centerville			
City well no. 2	1540	1895	Replaced by impounding reservoir. Quality of well water poor
City well no. 3	2054	1904	Replaced by impounding reservoir. Quality of well water poor
Cherokee			
State Hospital for the Insane	1070	1902	Replaced by 4 wells 200 feet deep
Clinton			
C. & N. W. Ry. Shops	1159	1896	Supply now pumped from Mississippi River
C. & N. W. Ry. Shops	?	1900	
Clinton Paper Co.	1076	1883	Property sold
Excelsior Laundry Co.	737	1910	Plant moved. Present head + 16 feet. Increased flow when City well no. 6 was drilled
Council Bluffs			
Hurd Creamery Co. (Bloomer Ice Co.)	1280	1906	Cessation of flow and cost of pumping
State School for Deaf, well no. 1	1012	1885	
State School for Deaf, well no. 2	1080	1889	Rusting of casing and fill
Dubuque			
City well, 6th Ave.	1927	1900	
Consumers' Steam Heating Co.	802	1884	
Cushing factory	965	1888	
Schmidt Brewery	886	1891	
Linwood cemetery well no. 1	1765	?	City water found cheaper than cost of pumping
Linwood cemetery well no. 2	1954	1891	City water found cheaper than cost of pumping
Steam Heating Co.	802	1884	
Dunlap			
City well	1500	?	Superseded by four 5 inch sand points

Deep Wells Abandoned Since 1912 (Continued)

Fort Madison			
Atlee Lumber Co.	720	?	
Hinde and Dauch Paper Co., no. 1	689	1888	Replaced by 5 wells from 130 to 145 feet deep
no. 2	689	1903	
Jefferson			
City well	2026	1886	
Keokuk			
Hubinger Tile and Brick Co.	800	?	Plant abandoned
Hubinger house wells	2000-2230	?	Property sold, lakes fed by wells drained, and houses built on site
Keokuk Pickle Co.	710	1892	Company out of business
Rand Park	1800	?	
Mallard			
City well	1050	1903	Fill with sand
Mason City			
City wells nos. 1, 2, 4, 5	651-616	1892	Supply now drawn from 4 wells 1200 feet deep
Onawa			
City well	863	1905	Infection
Ottumwa			
Y. M. C. A.	800	?	
Waterloo			
City well no. 1	1373	1905	Adequate supply from later wells, soil infected
Waukon			
City well no. 1	577	1896	Supply from wells nos. 2 and 3

Deep Wells of Diminished yield, reported in 1925

	Depth	Date of Completion	Date of first notice of diminution	Head above or below curb		Yield		
				Original	Present (1925)	Original	Present (1925)	
	FEET	YEAR	YEAR	FEET	FEET	GALS. PER MINUTE	GALS. PER MINUTE	ALLEGED CAUSE, REPAIRS
Burlington								
Ice Company	852	1911		+51		500	75	Rusted casing
Murray Iron Works	831	1903		+92	=	300	50	Repacked, recased
Bettendorf								
Water works well no. 1	1650				—3	1000	600	
Bloomfield								
City well	1817	1900		—130	—172	300	300	No repairs
Cedar Rapids								
City well no. 1	1450	1894		+28	—18	250		
Clinton								
Corn Syrup Refining Co.	1226	1908			—14	400	275	No repairs
Curtis Bros. & Co.	1150	1911			—7		150	No repairs, draw down of 14 feet when pumping at capacity
Gas and Electric Co.	1605	1911		+2	—14	500	250	No repairs
Davenport								
Independent Produce Co. (Malting Co.)	1285	1896 1904	1917					Interference from other wells
French & Hecht (Metal Wheel Co.)	1539	1909	1919-25	+21	=	200	65	Recased and repacked in 1921
Independent Baking Co.	900		1920		+2		17	No repairs
Kohr's Packing Co. (Tri-City)	1100	1893	1922	+46	—35	250	300	No repairs
Nichols Steel & Wire Co. (Corn Products Co.)	1500 2007	1876 1892		+58 +81	+10 =			No repairs
Schmidt Bldg.	1200	1892	1922	+30	—30	45	40	Recased and cleaned in 1924
Witts' Bottling Works	780	1891	1899	+82	—6	300	20	Cleaned and repacked in 1905; loss sudden in 1899

	Depth	Date of Completion	Date of first notice of diminution	Head above or below curb		Yield		
				Original	Present (1925)	Original	Present (1925)	
	FEET	YEAR	YEAR	FEET	FEET	GALS. PER MINUTE	GALS. PER MINUTE	ALLEGED CAUSE, REPAIRS
Dubuque								
Bank & Insurance Bldg.	1380	1900	1920	+10		125		Repaired in 1925, effect, 35 per cent increase in flow
Jas. Beach & Sons	965	1897		+34	=			Recased in 1908 and 1912
Elkader								
City wells 1 and 2	180	1896	1913	+20		500	145	Dynamited, cleaned, recased, repacked
Fort Madison								
Santa Fe Ry. Shops	700	1906	1922	+69	=	300		Filling with sediment
Hampton								
City well no. 1	1709	1900	1923	—50	—123		366	Filling, rusting of casing, no repairs
Homestead								
City well	1895		1914	—90	—155			No repairs
Keokuk								
Y. M. C. A. well	769	1902	1921	+50	+20	350		Cleaned in 1919
Ottumwa								
John Morrell Co. Well no. 1	1110	1888	1895				100	Rebored in 1892
John Morrell Co. Well no. 2	1554	1892	1895				50	No repairs
John Morrell Co. Well no. 3	1702	1897	1902				450	No repairs
John Morrell Co. Well no. 4	2205	1904					1000	
Rockwell City								
City well no. 1	1475		1920	—115	—160			No repairs
Sabula								
City well	973	1895		+74	+27	720		Repacked and recased in 1913 without effect
West Liberty								
City well	1768	1888		+9	—23	120	250	No repairs
Condensed Milk Co. (Bought by City)	1721	1904				300	325	Recased and cleaned in 1923

WELL WATER RECESSIONS IN IOWA[1]

JAMES H. LEES

Well waters of Iowa may be grouped into two classes, so far as their origin is concerned. These are waters derived from the glacial drift, with its interbedded sands and gravels, and those obtained from the underlying bed rock. The great body of the glacial drift consists of more or less pebbly compact clay which absorbs water rather slowly, hold but little and yields it grudgingly. Associated with the mass of this clay, or till, however, are bodies of sand and gravel, some of them more or less lenticular and of limited size, some of them with more uniform dimensions and of very considerable extent, either as widely distributed layers or as long narrow accumulations filling channels in glacial drift or in rock. Such bodies make excellent reservoirs and yield their stores of water readily enough, except in cases where the sand is very fine. Another type of material which is associated with the glacial till, although it is of eolian rather than strictly glacial origin, is the loess—a very fine-textured clay or silt, typically without sand or pebbles, although these are found locally, especially near the base of the loess deposit. Despite its fine grain and texture the loess is very porous and transmits water quite freely, hence it, and especially its sandy base, forms an aquifer of some importance.

FIVE DRIFT SHEETS

Five glacial drift sheets have been recognized in Iowa. The oldest of these, the Nebraskan, covered the entire state and apparently it still constitutes the major fraction of the glacial deposits of western Iowa at least. A basal sand seems to be widely present and supplies a number of wells which penetrate the overlying beds. A second drift sheet, the Kansan, covered all of

1 Reprinted by permission and with additions from the Journal of the American Water Works Association, Vol. 18, No. 3, September, 1927. Presented before the Chicago Convention, June 9, 1927.

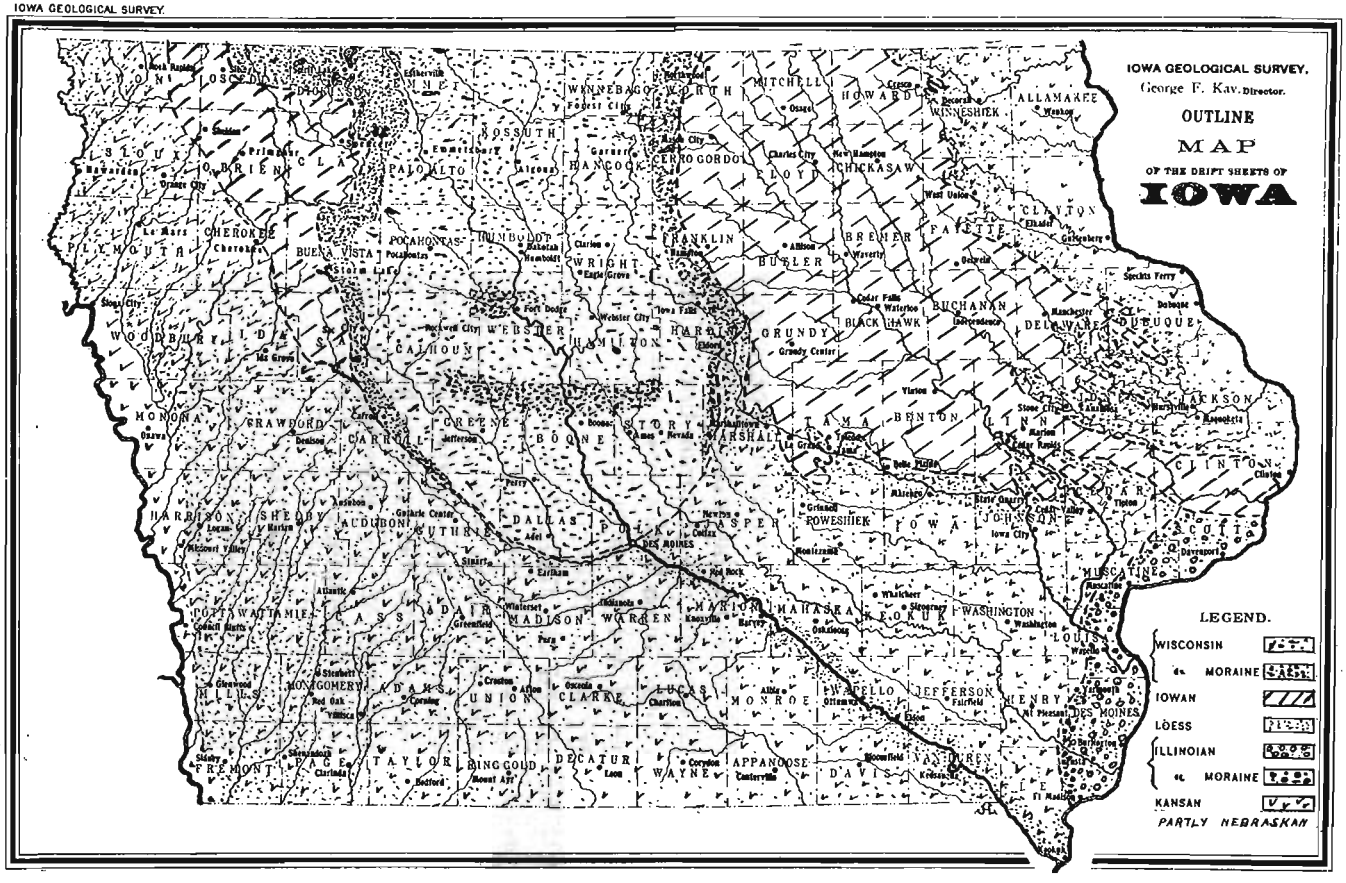

Fig. 1.—Glacial drift sheets of Iowa.

Iowa except the northeast corner and forms the surface drift of southern and northwestern Iowa. It is separated from the Nebraskan by a generally distributed gumbotil, a dark gray, very fine-textured gumbo clay which is residual from chemical weathering of the underlying till and which forms a floor for the basal sands which are related to the Kansan drift. A narrow strip of southeastern Iowa between Davenport and Fort Madison is covered by Illinoian drift, which resembles the older drifts in general character, in the presence of embedded and basal sands and in being overlain by gumbotil. Most of the northeast quarter of the state is covered by Iowan drift, which is notable for its exceptional thinness and for the great deposits of loess which mark its boundaries and spread in an ever-thinning blanket over the older drifts. Loess of approximately the same age is piled up also in thicknesses of thirty to a hundred feet or more along the bluffs of the two bordering rivers of the state and in lesser quantities along the Des Moines and over the intervening territory. In north-central Iowa, however, the Des Moines valley loess is mantled by the Wisconsin drift, the youngest of the glacial deposits of the state. Within recent years the Iowa Geological Survey has determined the presence in northwestern Iowa of a strip of Iowan drift west of the margin of the Wisconsin lobe. This is shown on the map, figure 1.

TOPOGRAPHY OF DRIFT AREAS

The topography of the northeast corner of Iowa, the only part of the state uninvaded by glaciers later than the Nebraskan, is exceedingly rugged, the drift is almost entirely eroded away and the only unindurated materials are alluvium and coarser filling in the valleys and residuum from rock wastage and loess on the uplands. The valley filling furnishes an abundant and permanent supply of water to wells sunk therein, but the upland covering is thin and over much of the area is well drained so that comparatively few wells find sufficient water in it, but are compelled to enter the underlying rocks. The thickness of the Kansan and Nebraskan drifts of southern Iowa is much greater than that of the northeast corner and reaches a maximum of 500 feet or more in some of the western counties. The topographic features are

markedly erosional, although some upland tabular divides still indicate the level character of the original drift plain. Near the "breaks" water is likely to be found only at considerable depths and this is true of some parts of the uplands, as where no gravel beds have been penetrated and hence wells must be sunk through the entire thickness of the drift to search for the sand bed at its base. The deep, wide valleys of this province supply many town and farm wells although even here some failures are to be noted and recourse must be had to ponded surface supplies. The characters of the Illinoian drift plain are similar to those of the province just described except that here are three drifts with their contained gravels and sands from which water may be drawn.

The loess overlying the three older drifts in southern and northwestern Iowa has always been utilized as a source of water for shallow wells, which generally have been sunk to the basal sand layer. In some parts of western Iowa a good many wells are supplied from a layer of gravel which lies immediately under the loess, but which seems to be residual from the wastage of the drift rather than depositional, as a part of the loess. The Iowan drift plain of northeast Iowa has typically a rather gently rolling surface, which, where the drift is thin, permits of fairly free natural drainage of the ground water. Where the thickness of the drift is greater, ranging up to 200 to 300 feet, the water content is much larger. The topography of the Wisconsin drift sheet is very immature so that except near the few larger streams the glacial materials are water-logged and the head of water is high, permitting the use of many shallow wells.

INTERMEDIATE WATER SUPPLIES

It is impossible of course to distinguish sharply between the waters of the glacial drift and those of the country rock, as there is naturally a continuous interchange, especially where the rock under the drift is limestone or sandstone. Not only are these rocks sufficiently porous to permit absorption of the overlying water, but wherever the solid strata are overlain by broken or residual materials these latter hold a supply of water and in many cases serve as a valuable aquifer. Where the country rock

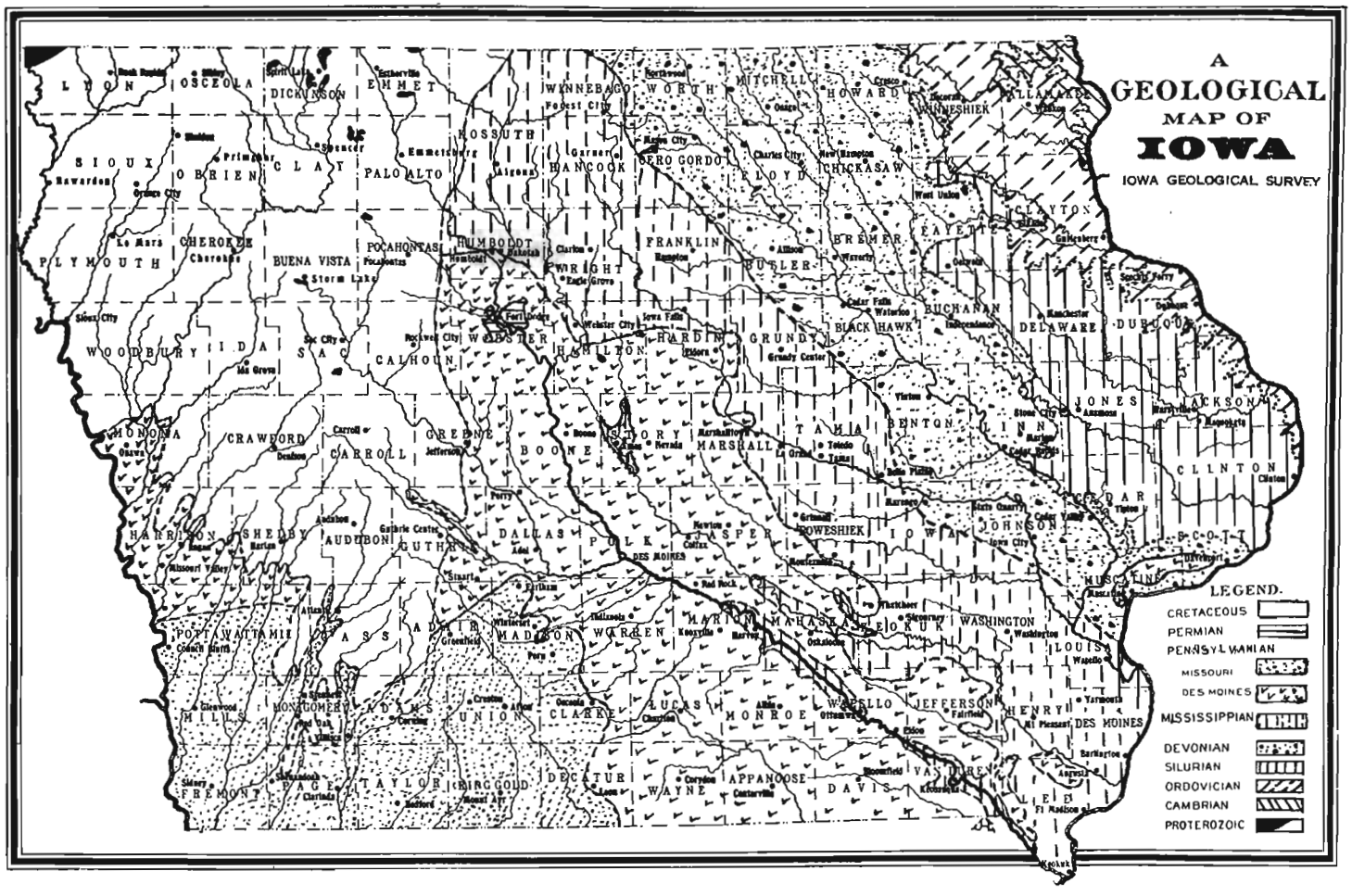

Fig. 2.—Geological map of Iowa

is shale, however, it acts as a confining rather than a contributing agent.

DISTRIBUTION OF STRATIFED ROCKS

The stratified rocks come up to the glacial beds in a series of broad irregular belts with a general northwest-southeast trend, as is shown on the geological map, figure 2. The series includes sandstones, shales, limestones and intergradations of these three types. There are no eruptive rocks to break the sedimentary succession and very little faulting and comparatively little warp-

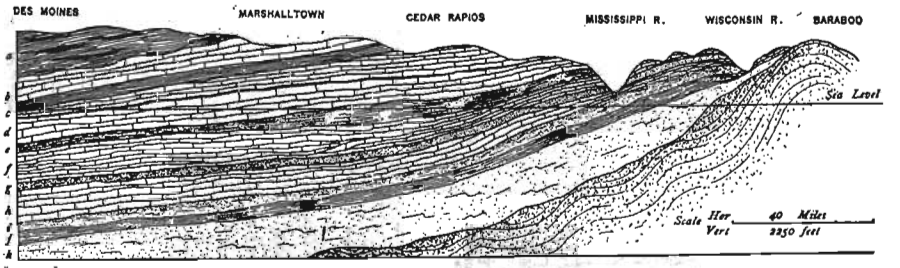

Fig. 3.—Geological section from Barahoo, Wisconsin, to Des Moines, Iowa, showing the general stratigraphy of the region. The drift is not shown. The chief aquifers are the Saint Peter, the Jordan and the Dresbach sandstones. The line of juncture of the Cambrian sandstones and the underlying Huronian is hypothetical. *a* Des Moines; *b* Mississippian; *c* Devonian; *d* Niagaran; *e* Maquoketa; *f* Galena-Platteville; *g* Saint Peter; *h* Prairie du Chien; *i* Jordan sandstone; *j* Saint Lawrence; *k* Dresbach and underlying Cambrian. By W. H. Norton.

ing have occurred to rupture or deform the beds. In age the strata range from Upper Cambrian to Upper Cretaceous, with the older rocks exposed in the northeastern part of the state and the younger ones to the west, southwest and south. From their outcrops the strata have a general dip toward the southwest of about ten feet per mile, hence the older beds lie within reach of the drill over most of the state, exception being made of the northwest corner, where some of them are absent, and of the southwest, where search for them is hardly practicable. Exception should be made also of the disposition of the Upper Cretaceous beds in western Iowa, which instead of being arranged conformably with the older strata of that region lie upon the upturned eroded edges of these older beds. The entire series of sedimentary rocks rests on a substructure of quartzite known in Iowa as the Sioux quartzite, which is practically impervious to water and hence marks the lowest limit of efforts to obtain supplies in wells. Its surface forms a great trough which rises above the

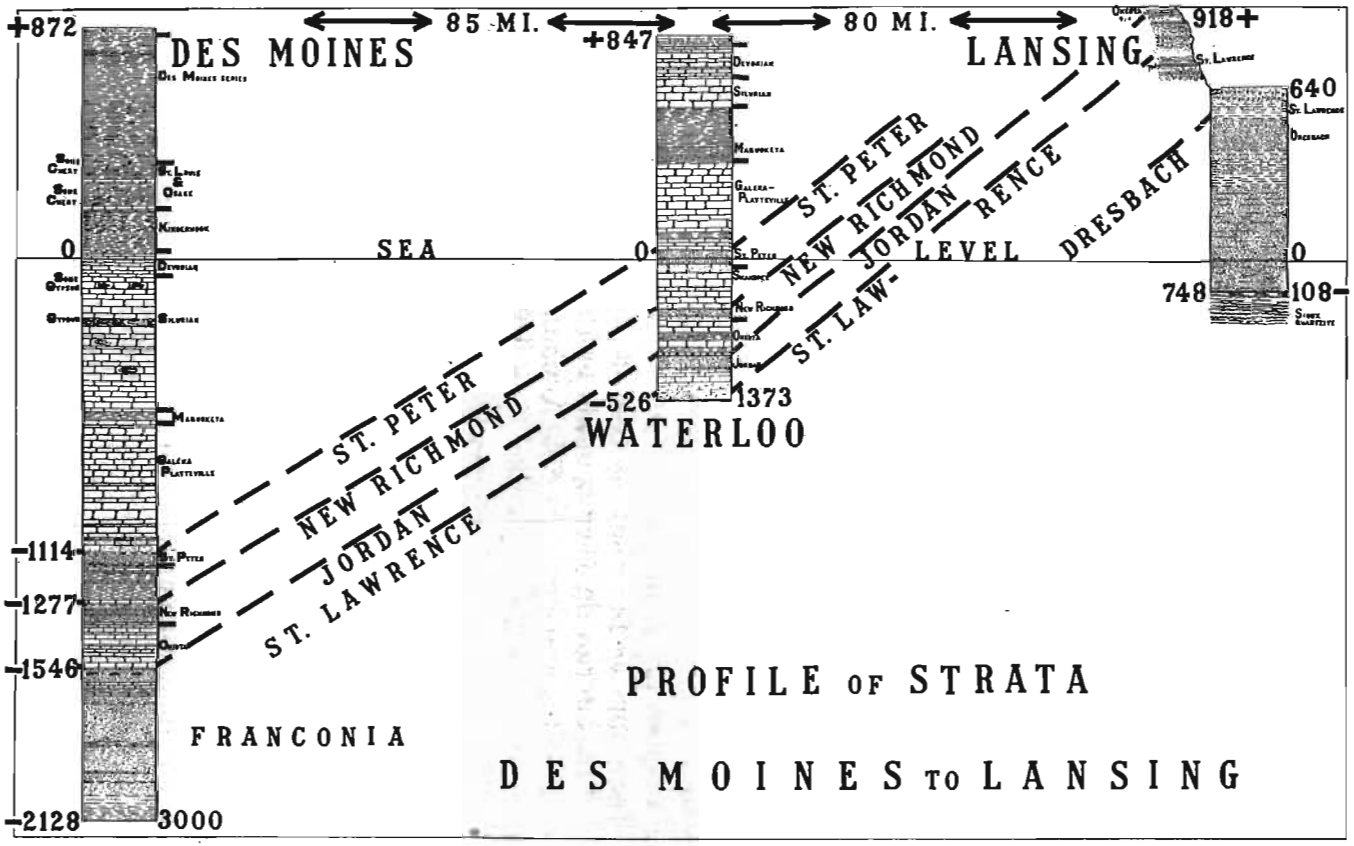

Fig. 4.—Profile showing dip of water-bearing beds from Lansing to Des Moines.

newer strata in the northwest township of the state, is 1600 feet deep or more in the north-central counties and is 750 feet below the Mississippi in the northeast corner of Iowa. Wells in central Iowa do not reach it at 3000 feet.

WATER BEARING BEDS

The limestones, of course, are water-bearing and yield generously when a crevice or a channel is reached by the drill, but the most reliable aquifers are the great sandstones, including the Jordan, Dresbach and Mount Simon sandstones of the Cambrian and the New Richmond and St. Peter of the Ordovician. These beds have a large area of outcrop in the adjoining parts of Iowa, Wisconsin, and Minnesota, they also have a very wide distribution under the younger rocks beyond the area of their outcrop and their physical characters are such as to enable them to carry enormous volumes of water under considerable head and under conditions of exceptional purity. These characteristics give the sandstones such high favor that over probably three-fourths of the state they are sought as the ultimate desiderata where deep-lying supplies are required. Flowing wells are obtained along the Mississippi as far south as Keokuk, but under the higher lands of the interior the head is insufficient in most cases to bring the water to the well curb. At New Albin in the northeast corner of the state the Jordan sandstone rises 966 feet above sea level while at Des Moines it is 1546 feet below sea level and at Stuart, the farthest southwest at which it has been reached, its surface is 1495 feet below sea level. The distance from the Jordan to the New Richmond is about 175 feet while the St. Peter lies about 150 feet above the New Richmond. The Dresbach and underlying sandstones are at least 500 or 600 feet thick. The Jordan averages about 100 feet, the New Richmond 50 and the St. Peter nearly 100 feet in thickness, thus assuring an abundant water-containing volume.

The foregoing summary may serve to give a generalized impression of the ground water situation in Iowa and furnish the background for a study of the depletion of ground water resources. That there has been such a depletion since settlement

began is a matter beyond question—the difficulty lies in determining the causes and the amount, as well as the remedy.

McGEE'S STUDY OF WELLS

An investigation into the relations of wells and subsoil water was made in 1910 by W J McGee, a native of Iowa, who at that time was in charge of Soil Water Investigations for the U. S. Bureau of Soils. This investigation covered all of the United States, but only Iowa will be considered here.[2] Illinois, Indiana and Iowa were classed as having the most dependable records.

The 99 counties of Iowa were represented by 517 reporters, who sent information about 1527 wells, the highest number reported from any state except Missouri, which had the same number. Besides information about the locations and ownership of the wells the reporters were asked for data as to the character of wells, dates of making, and original and present depths of water in the wells. McGee divided the wells upon which reports were made into shallow or dug and deeper or drilled wells, excluding flowing wells and those of great depth. The summarized data for the two classes of wells were tabulated and arranged as in table 1.

Ground water levels.—A number of the reporters remarked that the water level had not changed much in the preceding 20 years, that is since 1890. Some observed that there had been little change in 40 or 50 years, others that some springs and wells gave better supplies than formerly. But most observers reported that the general water level had lowered so much that, whereas the settlers and early residents had obtained sufficient water from dug or bored wells 10 to 30 feet deep, now nearly all the wells within the reporters' knowledge were drilled—to depths of 60 to 100 feet, or some to 200 and 300 feet. In his own summary McGee states: "To one familiar with the state since the settlement of the eastern counties (as he was) the records and remarks jointly indicate a mean lowering of the subsoil water level during an average of 50 years that can hardly be put at less than 20 feet." However, as an average of the wells reported to him McGee estimated 12.5 feet as the lowering during the preceding

2 United States Department of Agriculture, Bureau of Soils Bulletin 92.

half century. For the typical agricultural states McGee states that "the average lowering since settlement would appear to be no less than 9 feet, i.e., from well within to about the limit of capillary reach from the surface."

Table I, McGee Classification of Wells

	SHALLOW		DEEP		AVERAGE
	NUMBER		NUMBER		
Date of making, average	768	1875	535	1895	1887
Depth of well, feet	895	36.1	632	153.0	
Original depth of water	749	15.4	506	77.8	
Present depth of water	852	11.8	551	74.4	
Rise	20	4.17	7	8.93	5.41
Fall	373	6.71	128	14.30	8.65
Depth to water table	895	24.1	607	78.7	46.1

Causes of lowering.—In discussing the causes of the lowering water table McGee dismissed a lessened rainfall as being negligible and unproved. Industrial causes such as tile and open ditch drainage, large wells, mining, etc., are of only local and rather superficial importance, as is consumption by animals and men. The greatest amount of lowering—amounting to 80 or 90 per cent—McGee assigns not so much to consumption of accumulated stocks as to the cutting off of the natural source of supply—the fact that under present conditions of cultivation storm waters do not enter the ground, but run off to the streams and so are unable to replenish the stores of ground water. The remedy, McGee points out, is to make each farm take care of all the water falling on it during the entire year by retaining this water by means of mulch or well-tilled soil or contour furrows and ridges so that it will be forced to pass into the ground.

STUDIES BY UNITED STATES AND IOWA SURVEYS

For a number of years prior to 1910 the Iowa and United States Geological Surveys had coöperated in a special study of underground water conditions in this state and in the prosecution of this study every county in the state had been visited. While the collection of statistical data on the general ground water level was not the main object much information was gathered

and in many of the reports on the various counties statements are made regarding the head of water. A few citations will tell the tale of changing conditions.[3]

The pioneer wells of a flowing field in Bremer county were sunk more than 30 years before and the head of a number has diminished. The static head of some wells on the hill slopes has been so drawn down that they have ceased to flow, but the supply is still ample on the bottom lands. On the open prairie of Buchanan county some of the early settlers obtained water by wells ending in pockets or streaks of gravel in the Kansan drift. Nearly all of these wells were abandoned long ago. In Cedar county the shallow wells, which at an early date found plenty of water at the base of the loess in ashen silts and basal sands, have been generally either abandoned or sunk deeper. Many of the older wells in Iowa county were dug or bored a short distance into the drift, but at present many drilled wells range in depth from 50 to more than 300 feet, ending in sand and gravel interbedded with or immediately below the drift. At Fairfield in Jefferson county shallow wells must now be bored 10 to 15 feet deeper than formerly. Ground water beneath the level prairies of Keokuk county stands high. The basal silts and sands of the loess yield sufficient for house use. Most of the water supply of Lee county is still drawn from the drift, but an increasing number of wells in recent years have been drilled to the water beds of the country rock. The Wisconsin drift of Cerro Gordo county is so imperfectly drained that where it occurs the ground-water table is near the surface. Elsewhere the Iowan drift is too thin and too well drained to be a reliable aquifer. The sandy base of the loess of Marshall county was formerly an important aquifer but drainage and cultivation have reduced the ground-water level far below it. Wells in Adams county have been deepened to the sands at the base of the drift and the same is true of Cass county wells. In general less is said about lowered water levels in the area of the Wisconsin drift than in regions of older drift, more mature topography and better natural drainage, although even here a progressive lowering has been noted.

[3] Iowa Geological Survey, vol. xxi; U. S. Geological Survey, W. S. Paper, 293.

STUDY OF DEEP WELLS

Ever since the inception of its work the Iowa Geological Survey has made the study of underground water resources and conditions a major line of effort. Some of the results of this study of drift wells have been noted. The investigation of the deeper, artesian wells drawing water from the great rock aquifers is attended with less definite and satisfactory results. One can state in many cases that the head has declined, but the reasons are more obscure and one can not always assign changing conditions to stated causes. However, the facts may be stated even though definite conclusions can not be drawn.

Some cases of lowering.—In the northeastern counties, where the Ordovician and Cambrian sandstones lie not far beneath the surface, flowing wells are common in the deeper valleys. Many of these still flow, but the head of the Lansing well has fallen 15 feet and the yield has decreased from 700 to 300 gallons a minute. Many of the wells of this region have been allowed to flow unrestrainedly for years, virtually wasting the stores upon which they were continually drawing. A similar lowering of head was noted at McGregor. Dubuque has a number of deep wells, some of which reach the Jordan, some the underlying Dresbach and some still deeper sandstones. A number of these have suffered diminished flows, from all water-bearing horizons. In some cases the loss is attributed to deterioration of casings, in others to the local effects of nearby wells and in others to general lowering of static head, due to overdraft.

The Davenport artesian field has shown from the beginning a progressive loss of pressure, lowering of static level and diminution of discharge. This has been especially notable in the case of wells drawing chiefly from the St. Peter. The head of the Jordan and lower waters remains higher than that of the St. Peter and it is evident that the latter bed is at least locally overtaxed. The head of the Witt's Bottling Works well has fallen from 81 feet above curb to 6 feet below curb and the yield from 300 to 20 gallons per minute.

Two of Cedar Rapids' city wells have been abandoned owing to the increased cost of pumping caused by the lowered static level and the well of the Burd Creamery Company at Council

Bluffs has had the same history. The head of the Bloomfield city well has dropped from 130 to 172 feet below curb, although the yield remains the same. The head of the West Liberty city well has fallen from 9 feet above curb to 23 feet below, but the yield has increased from 120 to 250 gallons per minute. There have been no repairs. The head of one deep well at Washington has dropped from 44 to 133 feet below curb while the head of another rose from 100 to 70 feet below curb. Waterloo's first deep well (1905) had a static level 20 feet above curb while the fifth one (1922) never flowed and its head has been about 50 feet below curb, or 70 feet below the head of the first well. The static level of the Sioux City wells is reported as falling at the rate of four inches yearly. From 1907 to 1921 the recession was stated to be a foot a year.

These records as well as many others at hand seem to show that a variety of causes has been effective—some of them evidently conflicting. Deterioration of casing, local clogging of the water-bearing beds, interference of nearby wells, filling of the bore hole, leakage into the surrounding strata, these are some local causes which would tend to diminish the supply and lower the head. In some cases the field is really being overtaxed, at least that portion of it near the wells. Whether the entire artesian field is being permanently overdrawn can not be told without intensive study of the relation between the supply and the demand.

RECENT INVESTIGATION OF GROUND WATER

When I was asked to prepare this paper I enlisted the coöperation of the United States Weather Bureau and the Weather and Crop Bureau of the Iowa Department of Agriculture in circularizing crop reporters and well drillers to obtain recent data on wells and ground water. Between 650 and 700 letters were sent out asking for information about the location of wells as to county, township and section; character, whether dug, bored, driven or drilled; whether in valley, hillside or upland; dates of making; depth; original and present depths to water and of water; and owners. The response to this inquiry was not very

complete but some of the best and most dependable of the records submitted are tabulated below.

These records bear out the statements of the drillers to the effect that shallow wells respond quickly to seasons of drought or heavy rains but that deep wells are not so affected. Had this study been made before the rains of 1926 and 1927 undoubtedly many shallow wells would have shown a fall in water level instead of standing equal to the level of early years or rising above that level. Perhaps, also the high level maintained by shallow wells in some localities is due to especially favoring geologic or topographic conditions, as for instance broad level plains underlain by fairly impervious clay or rock, which would tend to retain the ground water. Where a lowering of water level in wells is noticed it is variously attributed to tile and ditch drainage, in so far as shallow changes are concerned, to greater demands from a vastly increased amount of stock, to local causes such as clogging of the aquifer, overdrafts on individual wells or to the exhaustion of sand or gravel beds which had supplied wells.

Table II, showing changes in wells

County	Dug (d), bored (b), driven (drv), drilled (drl)	Valley (v), hillside (h), upland (u)	Date of making	Depth, feet	Original depth to water, feet	Original depth of water, feet	Present depth to water, feet	Present depth of water, feet	Rise +, fall −, same =, feet
Buena Vista	b	u	1895	72	10	62	8	64	+2
Butler	b	u	1880	16	10	6	14	2	−4
	d	u	1898	16	10	6	14	2	−4
Carroll	drl	u		170	40		55		−15
	drl	u		130	40		50		−10
	drl	u		110	35		42		−7
Cass	d	v	1896	29	10	19	15	14	−5
	drl	u	1921	228	198	30	70	158	+128
	b	h	1923	85	30	55	30	55	=
Chickasaw	hydr		1897	63	12	51	20+	43−	−8
Clay	b	u	1897	49	30	19	15	34	+15
	b	u	1895	70	30	40	22	45	+8
Clinton	drl	u	1890	186	90	96	90	96	=
	drv	v	1914	17	15	2	15	2	=

Table II, showing changes in wells (continued)

County	Dug (d), bored (b), driven (drv), drilled (drl)	Valley (v), hillside (h), upland (u)	Date of making	Depth, feet	Original depth to water, feet	Original depth of water, feet	Present depth to water, feet	Present depth of water, feet	Rise +, fall −, same =, feet
Dallas	drl	u	1908	133	60	73	80	53	−20
Decatur	b	u	1892	46	31	15	25	21	+6
Dickinson	drl	u	1926	484	270	214	270	214	=
	drl	u	1925	127	111	16	111	16	=
	drl	h	1923	440	236	204	236	204	=
Emmet	drl	u	1922	302	144	158	144	158	=
	drl	u	1896	160	97	63	100	60	−3
Hamilton	drl	u	1923	80	80	Flow		Flow	=
Harrison			1895	20	10	10	12	8	−2
			1890	18	8	10	8	10	−2
Jasper	drl		1909	107	67	40	67	40	=
Jackson	drl	u	1895	125	90	40	90	40	=
	drl	h	1880	220	80	120	150	70	−50
Keokuk	d		1890	50	33	17	33	17	=
Kossuth	drl	u	1911	100	45	55	45	55	=
Louisa	drl		1890–1927	100	60–80	20–40	Same	Same	=
Lyon	b	v	1914	90	20	70	30	60	−10
	b	v	1920	30	10	20	10	20	=
	b	u	1924	210	54	156	30	180	+24
Mahaska	d		1853	45	29	16	29	16	=
Marshall	drl	u	1912	280	100	180	120	160	−20
	drl	u	1913	2100	300	1800	115	1985	+185
Montgomery	d	v	1894	20	10	10	16	4	−6
O'Brien	b	u	1905	20	12	8	6	14	+6
Plymouth	drl	u	1897	160	100	60	100	60	=
Pottawattamie	b	h	1923	26	20	6	20	6	=
Shelby	drl	u	1922	270	200	70	200	70	=
Sioux	drl	h	1895	140	110	30	110	30	=
	b	u	1917	34	14	20	8	26	+6
Van Buren	d	h	1860	30	15	15	15	15	=
Warren	d	u	1880	28	25	3	12	16	=13
Webster	drl	u	1906	85	26	59	26	59	=

Comments.—The following comments, gleaned from the reports of crop reporters and well drillers over the state, are, perhaps, more illuminating than the records of wells as they reveal

widespread conditions and general impressions gained through years of experience.

Adair county, Orient—Water level rose during April, 1927. Will be normal soon. *Bremer,* Janesville—Water level 75 to 100 feet deep. *Buchanan,* Independence—Depth of wells previous to 25 years ago ranged from 20 to 25 feet. Wells stone walled but of no use now. Drilled wells 75 to 240 feet deep, water level constant. *Buena Vista,* Marathon—Bored wells going dry; have to drill to get water; never less than 140 feet, some as deep as 520 feet. *Butler,* Allison—Many wells drilled deeper. Springs flowing as for past 50 years. *Carroll,* Breda—Surface wells last only in low lands. *Cass,* Atlantic—Some shallow wells 25 feet deep. *Chickasaw,* Ionia—Head of some wells put down 30 years ago has lowered very materially. Shallow wells have changed most. *Clarke,* Murray—There are no springs as there used to be. *Clay,* Spencer—Shallow wells mostly dry before rainy season. Water in deep wells varied but little. *Clayton,* Farmersburg—Formerly used dug wells, up to 90 feet deep; now are drilled, 150 to 400 feet. Ravines dried out. *Clinton,* Grand Mound—Water 40 to 50 feet down. Calamus—driven wells not good in dry season. Drilled wells unvarying. *Crawford,* Denison—Water in wells fell 12 feet in 50 years. *Dallas,* Adel—Draining land causes wells to go dry if they are not over 15 to 35 feet deep. Best dug wells range from 50 to 100 feet, not affected by dry or wet weather. Waukee—Water in drilled wells lowered 20 feet in 20 years. Bored wells 38 to 50 feet deep. Water at about level of tile drains (1927); rarely gets lower than 25 feet. *Decatur*—Many ponds and springs dry and wells low previous to rains of 1926. Now up to normal. *Delaware,* Manchester—Most wells 75 to 100 feet deep, in rock, water within 50 feet of top. Some drive points 20 to 30 feet, plenty water. *Des Moines,* Danville—Haven't heard of a well going dry for 10 years. Wells nearly all bored, 25 to 75 feet deep. *Dickinson,* Milford—Rains in fall of 1926 helped shallow dug and bored wells greatly. Can't notice any change in water level of deep wells. Bored wells not satisfactory in dry years. *Grundy,* Grundy Center—Very few dug wells dependable, all wells drilled, average depth to water 125 to 150 feet. *Guthrie,* Herndon—Many shallow wells, 16 to 30 feet, but not dependable. Stock wells about 125 feet deep. *Hamilton,* Roland—Water level lowered at least 10 feet in 38 years. *Hancock,* Crystal Lake—Water level in drilled wells 150 to 200 feet down. *Harrison,* Modale—Drainage canals have lowered water level on Missouri bottoms. Missouri Valley—In 1900 water reached at 80 feet on high ground, now at 100 feet. Moorhead—Surface water gradually going deeper, dug wells going dry. *Howard,* Cresco—Wells 250 feet deep, plenty water. *Jackson,* Miles—In early day got wells in dirt. Then had to drill short way into limestone. From 1880 to 1895 nearly all wells had to be made deeper. *Jasper,* Sully—Very little change in 18 years. Seasons do not seem to affect drilled wells but dug and bored wells fluctuate very much. *Iowa,* Conroy—Wells 150 to 500 feet, deepest in limestone. *Jones,* Martelle—Wells 80 to 160 feet, average 100. Center Junction—Wells 80 to 300 feet deep. *Kossuth,* Lu Verne—Rain or drought has no affect on drilled wells. Algona—Bored wells playing out. A few springs have stopped running. Head of drilled wells has not changed. *Louisa,* Wapello—Every farm has drilled well. *Lyon,* Inwood—Deep wells not affected by drought. Tile drains not running so much as a few years previously (before fall rains of 1926). Rock Rapids—Wells all drilled, 250 to 350 feet, water not very good. Along Rock river wells 15 to 25 feet, plenty of good water. *Mahaska,* Cedar—Wells go to gravel bed 25 to 60 feet deep and do not vary. *Marshall*—Water level lowered 10 feet in 38 years. *Mills,* Henderson—Water reached on high hills at 50 feet in 1917, at 75 feet in 1926. Drilled wells up to 225 feet deep. *Monona,* Soldier—Water reached in dug wells at 70 feet. Sloan—Wells on Missouri bottoms all drive pipes, 20 to 30 feet deep. *Monroe*—Deep wells and shafts show as much water as 37 years ago. *Montgomery*—No ponds now, wells have to go deeper. Red Oak—Water reached on high ground at 60 feet in 1915; at 75 feet in 1926; on lower ground 25 to 40 feet. Wells mostly bored or drilled, a few dug. *O'Brien,* Paullina—Water plentiful at 25 to 50 feet. Sheldon—Water level raised last three months (spring, 1927). *Page,* Villisca—Water abundant in bottom lands; irregular in hills, many sand beds dry. Wells have to go deeper now. *Plymouth,* Ireton—Deep wells not affected by wet or dry seasons, surface water is opposite. *Pocahontas,* Pomeroy—House wells on hills about 20 feet to water, on low ground about five feet. *Polk,*

Elkhart—no lowering of ground water level seen in 30 years. *Pottawattamie,* Oakland—Has bored 4000 wells in Pottawattamie, Cass, Shelby, Montgomery, Mills; 35 years ago water plentiful anywhere, today on side hills is a thing of the past, plenty on wide uplands, over 100 feet deep at breaks; plenty water at 250 to 350 feet on hills. As much water at 40 feet in valleys as 25 years ago, surface water at 10 feet 85 per cent gone as compared with 15 years ago. Ponds and springs decreased 50 per cent in five years. Hancock—Since Nishnabotna river was dredged water level lowered 15 or 20 feet in wells as far back as two miles from the stream. Ponds and surface moisture disappearing a little each year. Underwood—In 1895 water reached at 50 feet on high ground, now at 70 feet. *Ringgold,* Mount Ayr—Wells 7 feet on flats to 90 feet on upland. One well 40 feet deep in use 40 years, stronger than ever. Benton—Water seems to be same depth as 30 years ago. Shallow water at 10 to 50 feet, deeper vein discovered at 100 to 175 feet. *Scott,* Le Claire—Every farm has drilled well, sunk ten or more years ago, 140 to 300 feet deep, flow in rock, rises within 90 or 100 feet of surface. *Sioux*—More drilled wells made every year, get plenty water, but it is harder. In 1926, very few shallow wells held out but does not know of a drilled well that gave out. Eagle Tp.—Drilled wells 75 to 275 feet, average 175, not affected by drought. Boyden—Water level almost as high as ever has been. *Story,* Roland—Depth of pumping wells in north half is 75 to 300 feet. *Taylor,* Lenox—Water in same clay now as before—on high level land 30 to 40 feet deep, just above a hard clay. *Van Buren,* Bentonsport—Plenty of good wells and springs. Sees no difference in water level since he was a boy. *Warren,* Indianola—Surface water lowered a good deal in 25 years. Top water just above blue clay, bottom water (for bored wells) below blue clay. *Washington*—Can see no change in amount of water. *Webster,* Clare—Wells drilled, 300 to 400 feet. *Wright,* Belmond—Water has lowered 3 to 5 feet, but no drilled well properly made ever goes dry. Bored or dug wells getting very scarce. Water generally found on top of limestone. Eagle Grove—Used to get flowing wells at 50 feet, now at 125 to 150 feet. Where flows are not obtained water rises within 20 to 30 feet of surface. Dows—Still a few bored wells but mostly drilled. Some flowing wells 35 to 80 feet, get weak in dry weather. A few drilled wells over 200 feet, water generally 35 to 45 feet below curb. In last 2 or 3 years water is 5 to 8 feet lower.

It is only fair to the crop reporters and well drillers to say that their replies furnished a great deal of valuable information concerning wells and ground water conditions even though as in some cases they did not include the comparative data which were especially desired for this inquiry. Common knowledge of early water conditions in Iowa coupled with the table and comments given above will enable any one to draw conclusions as to changes in underground water supply.

USES OF RAINFALL AND GROUND WATER

If the ground water supply has been depleted, by exhaustion or by nonreplenishment, it may be worth while to consider the causes of that depletion, such as consumption by a greatly increased population, interception by an enlarged plant cover, tile and open drainage, methods of cultivation and other changes incident to present day civilization.

Consumption of water by human beings, other animals and machinery may be estimated thus:

Table III, Daily Consumption of Water

CLASS	NO. IN IOWA	EST. DAILY CONS. PER UNIT, GAL.*	EST. TOTAL DAILY CONSUMPT., GAL.
Human	2,420,000	100	242,000,000
Horses	1,164,800	10	11,640,000
Cattle	4,122,000	12	49,500,000
Hogs	8,330,000	2	16,660,000
Sheep	696,000	2	1,290,000
Poultry	28,840,000	0.5	14,420,000
		Estimated daily consumption	335,510,000

Estimated annual consumption 122,462,000,000
1,000,000 gallons equals 3.07 acre-feet (3.07 acres one foot deep)
Estimated annual consumption equals 375,960 acre-feet, or 4,511,520 acre-inches
Acres land in Iowa, 35,575,040
Depth of water consumed in Iowa (acres-inches divided by area) equals 0.13 inch

Much of the water used in human affairs goes right back to the streams. It would be difficult to measure accurately the amount used, but the Des Moines waterworks pumps about 80 gallons per capita per day and much is pumped besides for industrial purposes. There are about 1840 locomotives in Iowa and these will use about 4000 gallons per hour for at least four hours daily. There seem to be no statistics available giving the number of steam industrial plants. However, the arbitrary figure of 100 gallons per day is probably sufficiently accurate to cover the entire population. It is evident in any case, from the data given, that consumption by animals and man is practically negligible. What of the amount received and transpired by plants?

Use by plants.—Of each rainfall a small fraction (1) is intercepted by vegetation and evaporated back to the air without ever reaching the ground, a much larger fraction (2) reaches the ground and runs off to the rills and streams and ultimately back to the ocean and the remainder enters the soil. Thence a part (3) is evaporated, another part (4) is absorbed by plants and is transpired from their leaves, a third part (5) is retained in the soil and subsoil by molecular attraction as soil water and the remainder (6) sinks downward to join the ground water. It is this last part which must maintain the—more or less—steady flow of the streams, must sustain wells and other sources of human and other animal water supplies and must, in intervals

* Adapted from Howell Drillers News, vol. VII, no. 11, Nov., 1928, p. 2: How Much Water per Day? Cows giving milk will drink 20 to 30 gallons per day.

between rainy periods, furnish moisture to the soils above—wherever capillarity can bridge the gap—and so assist vegetation to endure the drought that might otherwise be fatal. Now what portion of the annual rainfall of Iowa, which averages nearly 32 inches, can be assigned to each of these divisions?

1. Raphael Zon, in his excellent memoir, Forests and Water in the Light of Scientific Investigation,[4] which is to be much quoted in the discussion that follows, cites European workers as finding that broadleaf forests intercept and return directly to the atmosphere 13 to 8.48 per cent of the precipitation (pp. 25, 26). Figures for this return in nonforested areas are not at hand, but from data on transpiration it would seem that crop and grass lands would intercept nearly as much of the rainfall as would forests.

2. "In the Mississippi basin one-quarter of the total rainfall forms the run-off."[5] "The run-off of most Iowa streams is close to one-fifth of the rainfall."[6] Of course these fractions include some water supplied from the ground water, so that the fraction contributed by surface water would be less than these figures.

3. Zon states (p. 27) that evaporation from soil in a beech forest with leaf litter is 6 per cent of the precipitation, without leaf litter 15 per cent. The evaporation from soil in an open field with some vegetation is said to be not over one-third of the precipitation. From bare soil the evaporation is about 50 per cent of the precipitation.

4. It is common knowledge that plants evaporate, or transpire, a great amount of water into the air. Zon says (p. 3): "For every pound of dry substance produced it has been found that corn evaporates 233 pounds of water and turnips 910 pounds. Under good cultivation an acre may produce about 7 tons of dry substance. If the evaporation of water be only five hundred times more than the amount of dry substance produced, then an acre will evaporate during the vegetative period about 3500 tons of water." This figure seems rather high for ordinary Iowa cultivation, but other figures given perhaps approach nearer the normal. Speaking of forests Zon gives figures for transpiration

4 U. S. Dept. Agri., Reprint, 1927.

5 Pirsson and Schuchert, Geology, pt. I, p. 32, 2d Ed.

6 Nagler, Floyd, State University of Iowa, Personal letter.

as 567 to 1,019 pounds of water per pound of dried leaves of birch and ash, 436 to 914 pounds for beeches and maples, 253 to 692 pounds for oaks. Stating the case in another way he says: "Höhnel estimates that a fully stocked beech stand, 115 years old, consumes from 1,560 to 2,140 tons of water per acre, or 1.15 acre feet per year.....He found that elm transpired 43½ per cent of the precipitation of 1880, beech 25 per cent and birch 40 per cent" (p. 29).

Considering crop land, Doctor Bakke tells me[7] that "a growing crop of corn uses in our climate about one-third of the annual rainfall;" also that "the amount of water given off by an acre of wheat may be as much as 900 tons." This amounts to 0.662 acre-foot, an acre-foot being an acre covered a foot deep. Wheat uses a little more water than oats, as it produces more dry material.[8] "A square foot of long pasture grass gives off nearly 4 2/5 pints or as much as 106 tons of water to the acre" in 24 hours. "A square foot of turf will yield more than 1 1/5 pints of water in 24 hours," or 27.25 tons per acre.

5. The amount of water that is retained in the soil, both that which is available for plant use and that which can not be so withdrawn, depends on the soil texture and composition and so ranges within wide limits. The subject is elaborately treated by Meinzer[9] who states (p. 62) that King determined that "the water content in materials above the water table ranges from about 4 per cent of the dry weight for coarse mixed sands to 32 per cent for clays of finer texture. This range is equivalent to about 6 to 37 per cent by volume." Some of this water is so firmly held that plants and even evaporation can not remove it from the soil.

6. The ground water is the chief ultimate supply for streams and underground aquifers. At the time of settlement of this state, we are told, the water table, the upper level of ground water, was not far below the surface and could easily be reached by shallow holes. Now in most places it lies rather far below the surface and deep drilling is necessary to reach it. It must be re-

7 A. L. Bakke, Iowa State College, Personal letters.

8 Bakke, A. L., and Plagge, H. H., The Extent to Which Weeds Modify the Transpiration of Cereals: Res. Bull. No. 96, I. S. C., June, 1926.

9 Meinzer, O. E., The Occurrence of Ground Water in the United States: U. S. Geol. Survey, W. S. 489.

membered, of course, that a drilled hole, on account of its small size, can not receive so much water as a larger dug hole and therefore would need to be sunk to a greater depth to obtain the same amount of water. However, the verdict seems to be fairly general that the water level has actually lowered, but, as to the reasons there is diversified opinion and rather bitter argument. The tables given seem to indicate that what lowering has occurred can not be charged to increased use by either animals or plants or to increased evaporation and so must be due to some cause or causes that prevent replenishment. These would seem to be various factors attendant on human use of the land. Such would be destruction of the prairie sod and its replacement by crops, some of which at least would consume more soil water, while furnishing the soil less protection from erosion and evaporation; clearing of forest lands, some of which have since suffered from erosion; artificial drainage and straightening of streams; and methods of cultivation which are not adapted for avoiding soil erosion or for holding the rainfall until it can sink into the ground.

Numbers 1, 2, 3 and 4 may be tabulated as follows, on the basis of figures given by the authorities already cited. Zon's figures are based on a rainfall of 31.5 inches, practically the same as Iowa's rainfall.

Table IV, Total Amount of Water Lost to Streams and Soil

CLASS	INTERCEPTED BY VEGETATION	EVAP. FROM SOIL	TRANSPIRED BY LEAVES	TOTAL LOSS	TOTAL LOSS OF ANN. RAINFALL
	Inches	*Inches*	*Inches*	*Inches*	*Per cent*
Beech forest with litter (1)	6.7	1.9	10.8	19.4	61.5
Beech forest, no litter (1)	4.7	4.7	10.8	20.2	64.1
Potato field (1)				13.5	42.9
Grain field (1)				25.3	80.3
Field crops in general (1)				19.4	61.6
Corn (2)			10.5		
Wheat (2)			8.		
Long grass (120 da.) (2)			111.6		
Turf (120 da.) (2)			28.6		
Runoff (3)				7	22

(1) From Zon, p. 30, (2) from Bakke, (3) from Nagler. See also page 400.

It seems probable that interception and evaporation from field crops and grasses and evaporation from soils on which these were growing would be in some degree comparable with those from the forests. If this is true the total loss to the land would equal these items plus transpiration plus runoff, or approximately 27 inches, leaving about five inches for soil water and ground water. Nagler says that evaporation and transpiration account for 24 inches, but this leaves practically none to stay in the ground.

Changes in transpiration.—It is an interesting speculation as to whether evaporation and transpiration have changed materially in Iowa since settlement was an established fact. According to the Iowa Census of 1865 there were 23,310 acres of orchard and 26,285 acres of planted forest. Native forest probably covered 2,400,000 acres, as the 1875 census recorded 2,321,659 acres of native timber and certainly extensive clearing had been done during the decade.[10] This gives a total tree-covered area of 2,450,000 acres. The census of 1925 gives the acreage of timber as 2,132,461 and the Iowa Weather and Crop Service estimates the acreage of orchards in 1928 as 75,000, giving a total acreage of about 2,207,500. So it seems that forest transpiration has been eliminated over 242,500 acres. Eastern and southern Iowa is said by early residents to have been covered with high lush grasses while northwestern Iowa bore shorter prairie grass. According to the figures given in table IV these grasses must have transpired enormous amounts of moisture, especially as they were active from early spring until autumn. Again, then, it would seem that transpiration from the primeval prairie would have been greater than from our present day crop and pasture lands.

The foregoing paragraphs are not intended as a complete discussion of the subject but rather are hoped to give a reasonably accurate summary of the ultimate disposition of our annual rainfall. There are many important questions asking for a solution which can come only with time and experience. For example: If the water level gets below the capillary reach of crops will

10 For a map showing original forest area of Iowa see The Prairies, by B. Shimek, Bull. Lab. Nat. Hist. S. U. I., vol. VI, no. 1, 1911.

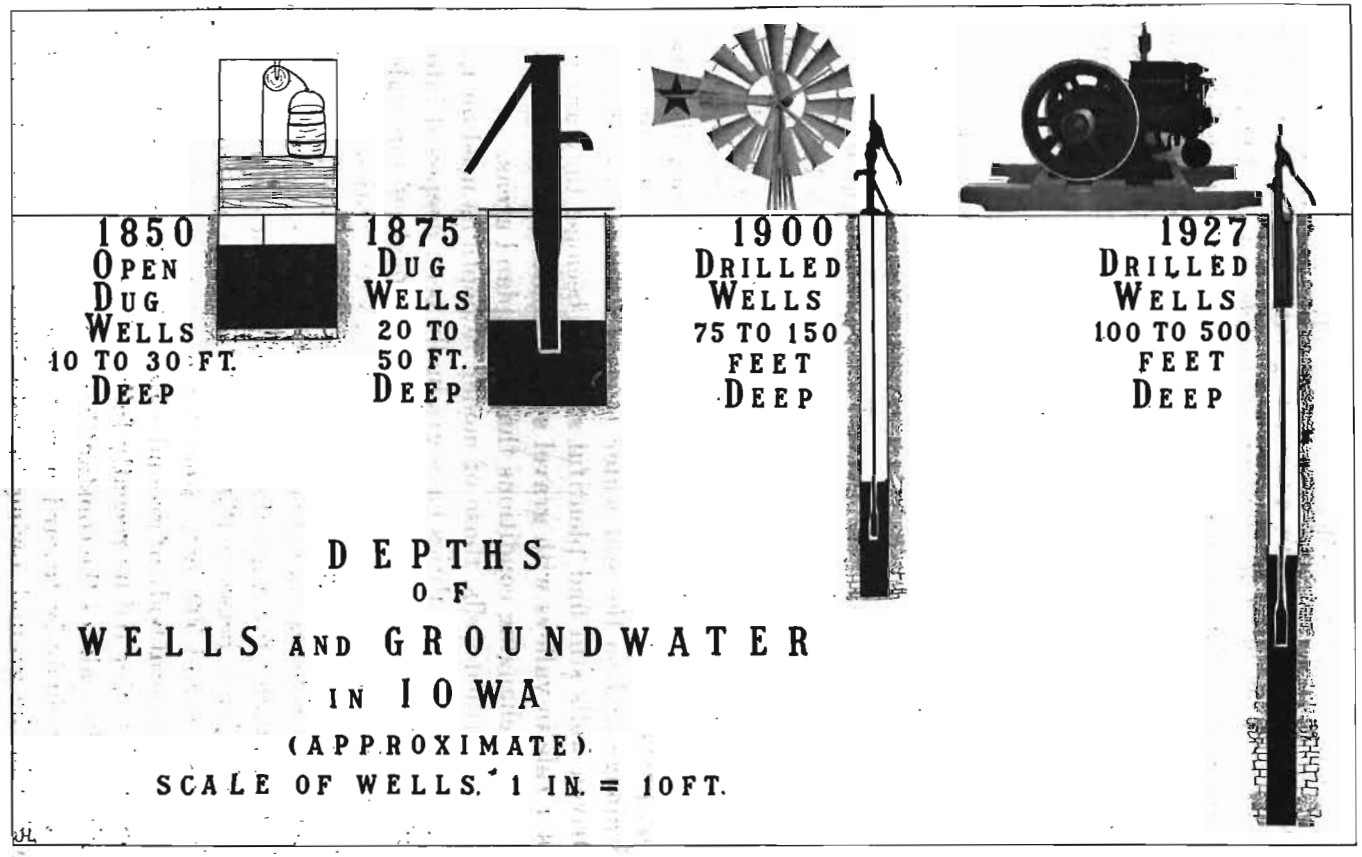

Fig. 5.—Diagram showing gradual change in character and deepening of wells in Iowa owing to improved sanitation and lowering of water table. Reduction not true to scale.

summer rainfall be sufficient indefinitely to keep up growth of crops and other shallow rooted vegetation that can not reach ground water but must depend on vadose water—the moisture in the soil and upper subsoil? Will the zone between the capillary fringe above the ground water and the overlying vadose water become dry or so nearly so that plants can get no moisture from it? In such a case how shall we get the utmost benefit from the ground water resources?

CONCLUSIONS

I believe that we are justified by the evidence at hand in drawing these conclusions: With regard to the shallow types of wells, dug or bored especially, in general these have become scarcer with the passing years because the supplies of water within their reach have gradually been depleted, partly by increased consumption by animals, by increased transpiration by cultivated crops, by open and closed drains, and partly by increased runoff of rainfall from cultivated areas. However, some parts of the state do not seem to have suffered from this lowering, perhaps because conditions are not so favorable for natural drainage and so the soil water is retained to a greater extent. Driven wells still find plentiful supplies because they are made as a rule in valleys with gravel strewn floors, which are less affected by changing conditions than are upland areas.

As to drilled wells, those of moderate depth as used on farms or smaller municipalities have gradually been deepened into the lower strata of the drift—many drillers speak of top water in yellow clay and lower water in blue clay, with another horizon in sand at the base of the drift. In parts of the state having thinner drift drilled wells now enter the stratified rocks, some for a few feet, many for a greater distance. Most wells of this class range in depth between 100 and 200 feet, although some are as deep as 400 and 500 feet. Since these wells draw their supplies from the general body of ground water rather than from the shallower soil water fed by recently fallen rains, their gradual deepening in the wake of the constant lowering of head seems to point rather conclusively toward a real lessening of the amount of water in the ground, owing to both increased demand and de-

creased supply. In some localities this lowering of head amounts to 20 feet or more during the present century, according to the reports of several drillers, and the total lowering from the time of settlement must be much more than this amount. However, other drillers state that they see little or no difference in ground water conditions while they have been drilling and of course those local factors which affect shallow wells would have some, though less, influence on wells of this type. Again, while shallow wells fluctuate with the seasons and respond quickly to periodic variations in rainfall, deeper wells show much less change from season to season and year to year.

Finally, as to the deep artesian wells which seek out the great aquifers of the stratified rock series, the evidence so far obtainable seems to be far from conclusive or even consistent. Some of these wells have suffered diminished yields and lowered heads, some of them headed lower from the start than did earlier wells in the same region. But some have higher heads than would be expected from the known factors and a few report higher heads or greater yields than formerly. Unfortunately for purposes of study these wells are not spaced closely enough for us to say definitely whether or not the general level or the amount of water has receded or remained the same, or, in other words, whether such changes as have occurred are due to local or to widespread causes. Of course, the deeper a well is the greater is the available radius from which it may draw its supply and the greater its chance of surviving drought or draft. Therefore, these deep wells as a class will always have a large assurance of permanence even in the face of the unfavorable factors.

Addendum—Since the above was written the writer has had access to Dr. Meinzer's Plants as Indicators of Ground Water (Water Supply Paper 577) and a mimeographed report by Mr. W. N. White on work in the Escalante Valley of Utah on the discharge method of estimating ground-water supplies. Meinzer (p. 87) cites the studies of other workers, as G.E.P. Smith (Trans. Am. Soc. Civ. Eng., vol. 78, pp. 226-230, 1915) showing that the ratio of transpiration to evaporation seems to be independent of such factors as light, temperature and humidity; also that, climatic factors being equal, transpiration depends on the

ease of obtaining supplies from the ground water and the character of the vegetation. He states that alfalfa has been found to use 831 tons, or 0.637 acre foot, of water for each ton of dry plant produced. In line with data given above in table IV, Smith states that alfalfa grown in Wisconsin transpired 41 inches of water and that evaporation from the soil amounted to 10 inches additional. Transpiration and evaporation from soil in a clover field amounted to 22.3 inches during the growing season.

White's work indicated that beneath an alfalfa field the daily draw down of the water table averaged 1¼ inches and that while there was some recovery during the night it did not quite equal the diurnal loss. The daily draw down under sedges and marsh grasses reached as high as 4¼ inches. The depths of (added) water required to raise the water table one inch ranged in different soils from 0.024 to 0.09 inch. This gives an indication of the effect of rainfall on the water table.

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS*

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Ackley	3 wells	12 in.	127		Ample
		10 in.	150		Ample
		13–9 in.	263		100 g.p.m.
Adair	well	20 ft.	30		Ample in wet seasons
	12 wells	3 ft.	30–60		Used in dry weather
Adel	well	8 ft.	28		3, 3 in. strainers extend into sand (reserve)
	Raccoon R. water is filtered				
Afton	well	12 ft.	35		Ample. Low ground
Ainsworth	well	6 in.	180		Ample
Akron	2 wells	36 in.	43		Ample. Into gravel, 75 ft. apart
Albert City	well	12 in.	182	–30	Unfailing
Albia	Surface reservoir, cap. 300,000,000 gal.				Sufficient all seasons
Alden	well	8 in.	305		Overflows when not in use. Pump lowers head 25 ft. Tests 100 g.p.m. On river bank
Alexander	well	8 in.	117		Ample
Algona	3 wells	12 in.	1000		100 g.p.m.
		6 in.			100 g.p.m.
		12 in. +	1885	–100	200 g.p.m.
Allison	well	6 in.	250 +		Not affected by pumping 40 gal.p.m. 16 hr. per da. for 31 da.
Alta	2 wells	8 ft.	72		46 g.p.m.
		12–4 in.	1465	–320	100 g.p.m.
Alta Vista	well	10 in.	144		Ample and reliable
Alton	2 wells	14 ft.	34		On bank Floyd R. In dry weather pump empties wells in 2 hrs., refill in 5 hours
		10 ft.	34		
Alvord	6 wells	6 in. (1)	39		
		2 in. (5)	37		Ample

* This table was prepared from the pamphlets published by the Iowa Insurance Service Bureau, which give data regarding the water supplies and fire protection of all Iowa cities and towns. The Geological Survey is indebted to the manager of the Service Bureau, Mr. K. L. Walling, for permission to use the information in the files of the Bureau and to the engineers, Messrs. Corcoran and Stokes, for their help in bringing the data in the table down to date.

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Ames	3 wells	12 in.	105		
	1 well	16 in.	180		Ample (4th ward)
	1 well	large	100 +		large, gravel-pack
Anamosa	well	10 in.	1800		300,000 g.p.d., reliable
Anita	well	20 ft.	30		Limited. Low ground
Ankeny	well	8 in.	507		20 g.p.m. without lowering
Anthon	1 well	.....	136	–19	
	1 well	10 in.	144	–30	200 g.p.m. No draw down
Alpington	well	8 in.	134	curb	Ample in all seasons
Arcadia	well	6 ft.	16		67% of normal in dry weather
Arion	well	6 in.	56		Ample in all seasons
Arlington	2 wells	6 in.	190		Ample at all times
	1 well	8–5½ in.	823		-----
Armstrong	2 wells	6 in.	180		Adequate
Arnolds Park	Lake Okoboji	6 in. pipe	350 ft. long		-----
Arthur	2 wells	24 ft.	20		May be pumped dry in 1 hr. 40 min. { Enough for 4 hrs. pumping
		14 ft.	18		May be pumped dry in 35 min.
Ashton	well	30 in.	68	overflows	Ample at all times
Atlantic	7 wells	12 in.	80–85		Sufficient & reliable, gravel-pack, 7th in 1928, pump 150 g.p.m. from each
Auburn	well	10 in.	180		Test 50 g.p.m. 4, 24 hr. da., not lowered Well ends in sand rock
Audubon	well	12 in.	2492	–225	Unfailing—pumped at 275 g.p.m.
Aurelia	2 wells	8 in.	210 & 216		Ample at all times
Avoca	5–3 in. sand points		27		Ample at all times. Low ground
Ayrshire	well	10–6 in.	877	–116	Tested at about 120 g.p.m. No decrease
Bagley	well	6 in.	70	–15	Ample at all times
Baldwin	well	8 in.	167		Ample. Into limestone
Bancroft	1 well	6 in.	500		Ample, diminishing
	1 well	10–8 in.	600	–16	135 g.p.m., drilled 1928

Battle Creek	12, 2 in. sand points driven into sand and gravel bed				
Baxter	well	8 in.	503		Supplies 30 g.p.m. 243 ft. in rock
Bayard	well	10–8 in.	208	–30	Ample at all times
Bedford	Reservoir, dam across 102 River, 70 ft. long, 6 ft. high.				No shortage
Belle Plaine	3 wells	8 in.	36		Yield 450 g.p.m. (No. 4 yields 250 g.p.m. not used acct. sand)
Bellevue	dug well	20 ft.	30	About river level	In bank of Miss. R.
Belmond	well	8 in.	500		Ample continuously
Bennett	2 wells	8 in.	198		Ample
		6 in.	122		Ample
Bettendorf	2 wells	10 in.	1650	flows	40 g.p.m. Cap. 720 g.p.m. with pump
		20–10 in.	2122	flows	200 g.p.m. Cap. 1,000 g.p.m. with pump
Blairstown	well	8 in.	110	–15 at rest –30 pumped	Ample. Drilled 1919
Blanchard	2 wells	8 ft.	22	8 in. sand	point 25 feet lower { supply pump 2 hrs.,
		8 ft.	22	2 in. sand	point 25 feet lower { refilling in 4 hrs.
Bloomfield	well	8 in.	1817	–160	Ample
Bode	well	6 in.	210		Ample and reliable
Bonaparte	well		shallow		Ample, fed by river
Boone	10 wells 2 large dug wells	10 in.	40	slight during high water	Ample. On island in river, level changes with river level
Boyden	well	10 ft.	20		Fed by seepage and by 12 in. tile line 200 ft. long. Limited in dry weather. Ample in wet
Brandon	well	6 in.	196		Ample
Breda	well	10 in.	350	–180	Ample, 6 in. casing
Brighton	2 wells	5 ft.	48		16,000 g.p.d., may be pumped dry in 3 hrs.; supplied by seepage
		12 in. +	1815	–90	.....
Bristow	well	6 in.	170		Ample, not affected by dry weather
Britt	well	10 in.	218		Filled with gravel 40 ft. Supply not affected

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Brooklyn	4 wells	8 in.	31–39		1st well tested 30 g.p.m. for 2 mo., then 50 g.p.m for a da., supply not affected. Other wells can supply 20 g.p.m. Level lowered to –20 ft. while pumping
	2 old wells	6 in. 8 in.	580 210		Used only in emergencies
Buffalo Center	well	5 in.	198		Ample at all times
Burlington	Miss. R.				
Burt	well	8 in.	518	–24	18 hr. test did not affect flow, 95 g.p.m.
Calmar	2 deep wells			–50	75,000 & 120,000 g.p.d. each. Not affected by dry weather
Cambridge	2 wells	4 & 6 in.	70		Ample, est. 300,000 g.p.d. Drilled
Carlisle	1 well	10–8 in.	700		35 g.p.m.
Carroll	4 wells	1–8, 3–12 in.	125–140		3 wells supply demand, no seasonal decrease. 1 supplies 75 g.p.m.
Carson	32 sand points		20		In creek valley. Ample
Cascade	large dug well, walled, fed by springs				Ample
Casey	3 wells	10–20 ft.	20–35		Enough for 5 hrs. pumping during entire year
Castana	2 wells	6 in.	75		Enough for 48 hrs. pumping. Not affected by dry weather
Cedar Falls	3 wells	8 in.	125	–11	Sufficient. In limestone
Cedar Rapids	Cedar R. direct into 2 wells 2 wells	 32 ft. 10 in.	 26, on island 1515		
Center Junction	deep well				Ample
Center Point	26, 2 in. and 2, 4 in. sand points, 30 ft. long				Reliable at all times
Centerville	Storage reservoir, 417,000,000 gal.				
Central City	2 wells	6 in.	100		Ample at all seasons
Chariton	Reservoir 100 acres, 300,000,000 gal., 3 mi. E. of Bus. section				Storage ample
Charles City	3 wells				
Charlotte	well	8 in.	185		Ample, tested 24 hrs., no sign of failure. Cap. 300,000 g.p.d. Pump cap. 288,000 g.p.d.

Charter Oak	well	29 ft.	45		In sand & gravel, 300 ft. from creek. Probably no shortage
Chelsea	2,6 in. sand points 6 ft. long, 36 ft. below surface.				Ample at all seasons. Wells 100 ft. apart
Cherokee	2 wells	8 & 10 in.	210	–70 while pumping	400 g.p.m.
Chester	well	6 in.	250		Test of 2 da. (pump cap. 58,000 g.p.d.) did not lower water
Churdan	2 wells	4 & 6 in.	160		Ample
Clare	well	8 in.	100		Ample
Clarence	2 wells	6 in.	122 & 164		Ample for pumps
Clarinda	Nishnabotna R. 2, 12 in. intake pipes				
Clarion	1 well	10 in.	250	flows	1,000,000 g.p.d.
	1 well	38 in. (16 in. casing)	160		1,000–1,200 g.p.m., 40 ft. draw down, gravel-pack
Clarksville	2 wells	6 in.	70		Ample at all times
Clear Lake	Clear Lake, 1, 12 in. suction line 800 ft. into lake, 1, 8 in. line 160 ft. into lake				
Clermont	2 wells	8 in.	216, 218		Ample. In limestone
Clinton	5 wells	2 each 6, 8, 10 in.	1135–2101		Flow 2,225,000 g.p.d. Test on No. 6 under air, produced 2,340,000 g.p.d. Total capacity 5,020,000 g.p.d.
Clutier	well	4 in.	230	flows	Ample at all times
Coggan	2 wells	8 in.	298		Ample for pump
		6 in.	200		25 g.p.m.
Coin	well	6 in.	42		Ample at all times; low ground
Colfax	6, 6 in. pipes with strainers driven 32 ft. into gravel. Head 17 ft. below pumps.				No data on capacity
Collins	2 wells	6 in.	180		250,000 g.p.d. (abandoned 1928)
		10 in.	384		40 g.p.m.
Colo	well	10 in.	262		Bottom 29 ft. filled with gravel. Original head—33 ft. Tested at 70–75 g.p.m., level constant at –188

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Columbus Junction	5 pipes	6 in.	53–83	flow	Ample when not pumped. Strainers on bottom of pipes, in gravel bed on Iowa R. bottoms
Conrad	well	10–8 in.	606	–160	Ample for pumps; 40,000 g.p.d.
Coon Rapids	2 wells	6 in.	107		Ample & reliable
Corning	Reservoir, dam 500 ft. long, 30 ft. high, cap. 40,000,000 gal.				
Correctionville	well	6 ft.	30		Ample in all seasons
Corwith	well	10 in.	153	–30	Ample, not affected by dry weather. Drilled 1919
Corydon	Reservoir, earth dam 600 ft. long, cap. 85,000,000 gal.				
Council Bluffs	Intake pipes 20 and 24 in. diam. 150 ft. long into Mo. R.				Watershed 320,000 sq. mi.
Coulter	well	8 in.	257		Ample, not affected by dry weather
Crawfordsville	2 wells	8 in.	240 695		15,000 g.p.d., drilled 1921 20,000 g.p.d., drilled 1915
Cresco	2 wells 1 well	8 in. 16 + to 12½ in.	200 & 400 670	 –151	Est. at 200,000 g.p.d. 250 g.pm.
Creston	Summit Lake, artificial reservoir, 150 acres, 25 ft. deep max.				Watershed 35 sq. mi., abundant
Cumberland	2 wells	5 in. 4 in.	150 200		Ample in all seasons Ample in all seasons. Held in reserve
Cushing	10, 1½ in. sand points 25 ft. deep				Ample for the pump
Dakota City	well	6 in.	164		Ample for 70 g.p.m. pump
Danbury	2 wells	5 in. cased 4 in. sand points	50 50		----------
Davenport	Miss. R. Water passed through sedimentation reservoir and pressure filters				
Davis City	well	4 in.	900		Ample in all seasons
Dayton	well	10–6 in.	470	–100	Ample, draws down 50 ft. when pumped
Decorah	well 4, 4 in. sand points into gravel bed bordering river.	20 ft.	36	.....	Ample at all times; in limestone Used for emergency
Dedham	well	6 in.	40		Ample, not affected by dry weather

Deep River	well	4 in.	244		Ample for pumps at all times
Defiance	3 cased wells	8 in. with sand points 46 ft. in gravel			Cap. 110,000 g.p.d. If emptied refill rapidly
Delmar	2 wells	8 in.	220		Ample for pump at 11 g.p.m.
		13–8 in.	1592	–196	100 g.p.m.
Denison	well	14–8 in.	1810	–88	Yield 200 g.p.m. Held in reserve
	dug wells in reserve. Yield 60,000 g.p.d.				One well yields 50 g.p.m.
	well	24 in.	57		600 g.p.m.
Denver	well	6 in.	170		Ample, reliable
Des Moines	Galleries in Raccoon R. bottoms, 11,821 feet.				Yield about 20,000,000 g.p.d.
DeWitt	2 wells	8 in.	524	.....	In limestone
		6 in.	274		In limestone, yields 50 g.p.m.
	well	12½–8 in.	1646	–101	225 + g.p.m.
Dexter	well	12 ft.	28		Ample to supply present pump. By seepage
Diagonal	2 wells	13 in.	44 & 47½		Ample for pump. In sand & gravel in river valley
Dike	well	6 in.	160		Unfailing
Dixon	well	6 in.	130		Good, ample for pump
Dolliver	well	6 in.	250		Ample and reliable
Donnellson	3 wells	8 in.	275		Failing, deepened for new well
		6 in.	150		Yields 35 g.p.m.
		8¼–4½	1095	–80	Yields 80 g.p.m.
Doon	well	12 ft.	30		Ample for pumps. Can be emptied in 2 hrs., in very dry weather. Fills rapidly. In gravel. Brick lined
Dow City	well	6 ft. for 20 ft., 6 in. to base	51		Ample at all times
Dows	2 wells	3 in.	85		Ample in all seasons
		10–4 in.	500		
Dubuque	5 wells	6–16 in.	- 1,300–1,500	flow	700,000 g.p.d. Increased under air lift to 6,500,000 g.p.d.
	Reservoir fed by abandoned mine workings, 400,000 g.p.d.				
Dumont	6 wells	6 in.	25	–5	Adequate
Duncombe	well	8 to 6 in.	500		Ample for pumps at all times

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Dunlap	4, 5 in. sand points driven into gravel				Ample at all times. Installed 1918 (not in use, 1928). New well at this station
	1 well	6 in.	1500		Ample (abandoned, 1928)
Durant	well	10 ft.	60		Drawn down only 7–8 ft. by 12 hrs. pumping
Dyersville	well	20 ft.	30		Concrete lined, supply ample, by infiltration. In rock
Dysart	well	10 in.	1600	–120	Unfailing, 60 g.p.m.
Eagle Grove	dug well	16 ft.	56	–16	When 2 pumps are running water drops 10 ft. further, then stands constant
	old well	25 ft.	25	–6	Failed. 14 inch pipe extends to 60 ft.
Earlham	well	6 in.	510		Ample for pump
Earling	2 wells	6 ft.	30		Limited in dry weather. West sta.
	3 wells	6 ft.	30		Limited in dry weather. East sta.
Earlville	well	8 in.	175		Ample, reliable, unaffected by drought
Early	springs				
Edgewood	wells	8 in.	128, 260		Ample, wells new
Elberon	art. well	4 in.	200	flows	30,000 g.p.d. 200,000 g.p.d could be pumped
Eldon	2 wells	25 ft.	20		Ample for pump. Old sta.
	1 well	25 ft.	23		Cap. 210,000 g.p.d. New Sta. Both Sta. on low ground across D. M. river
Eldora	3 wells	10 in.	300		Cap. 50,000 g.p.d. (10 in. well)
		6 in.	200		
		8 in.	250	–132	Ample, affected little by dry weather
Eldridge	well	10 in.	573		Ample at all times
		8 in.	300		Not used, ample, but muddy
Elgin	2 wells	6 in.	150		Ample, drilled
Elkader	1 well	15–10 in.	659	+20	190 g.p.m.
	2 wells	10 & 8 in.	185	flow	12 g.p.m. each
Elliott	15 sand points, 2, 3 in.; 1, 1¼ in.; 12, 2 in., 30 feet deep				Ample. In use 10 years
Ellsworth	well	6 in.	340		Ample at all times

Elma	well	6 in.	100		Ample
	well	10 in.	160		Ample. Emergency supply; pump will lower water only 6 in. all day
Emerson	well	10 in.	44		Ample. In gravel
Emmetsburg	well	12 ft.	25		Ample in all seasons
Epworth	well	6 in.	120		Ample for pump
Essex	2 wells	12 in.	48		
		7 in.	35		Ample for pump
Estherville	2 wells	16 ft.	32 & 38		1,000 g.p.m., not reduced by dry weather. West bank D. M. river
Everly	well	16 ft.	20		Ample at all times
Exira	2 wells	6 in.	147		Ample and reliable
		6 in.	126		
Fairbanks	well	8 in.	219		Good record. In limestone
Fairfield	2 reservoirs—Cap. 180,000,000 gal.				
Farley	well	6 in.	225		Apparently sufficient
Farmington	Reservoir, 200,000 gal. cap., water pumped from D.M. river untreated, not used for domestic purposes				
Farnhamville	driven well	.....	165		Ample, reliable; in gravel
Farragut	well	10 in.	165		Ample. Gravel bed 60 ft. thick
Fayette	2 wells	8 in.	65	near curb	Ample at all times
Fenton	well	6 in.	228	–54	Ample; drilled 1910
Fonda	well	6 in.	365		Ample at all times. 3–'27, casing reported repaired
Fontanelle	well	12 ft.	40		Ample at all times
Forest City	2 wells	6 in.	127		Flows into reservoir 24 by 19 ft. 380,000 g.p.d. in all seasons
		4 in.	117		
Fort Dodge	8 drilled wells	17 to 6 in.	1436 to 215	flow	1,300,000 g.p.d. Incr. by air lift to 2,793,000 g.p.d. Near Sta.
	3 wells		7–14		Emergency only
Fort Madison	Miss. R. 3 intake pipes 12, 14, 16 in., 150-200 ft. long in river				
Fredericksburg	well	10 & 8 in.	570		Adequate and reliable
Galva	21 driven wells, each with 2 in. sand point and strainer				Cap. est. at 250,000 g.p.d.
Garner	well	8 in.	380	–16	Ample at all times

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Garwin	well	8 in.	180	flows	10 g.p.m. at all times. Est. cap. with pump 100,000 g.p.d.
George	well	16 ft.	22	–14	Ample, when pumped down to 3 ft. runs in as rapidly as pumped out
Gilbert	well	6 in.	145	–33	Ample (''in gravel overlaid with shale'')
Gilman	4, 6 in. sand points 20 ft. deep				Unfailing. 2 mi. N. of town
Gilmore City	well	6 in.	120		Unfailing
Gladbrook	2 wells	8 in.	827 & 268		Ample for pumps, 125 g.p.m.
Glenwood	well	8 in.	2165		Level dropping since well was drilled
Glidden	well	10 in.	165		Ample for pump at all times
Goldfield	well	8 in.	168		200,000 g.p.d. 48 hr. test produced no shortage
Gowrie	1 well	8 to 4 in.	775	–60	Head not much reduced by pumping
	1 well	16–8 in.	1842	–81	300 g.p.m.
Graettinger	well	12 ft.	28		Ample but falls short in hot, dry weather. In gravel
Grand Junction	well	12–10 in.	320	–15	150 g.p.m. for 24 hrs., drilled 1926
	old well	10 in.	76		Ample for 24 hrs. (1920). In sand & gravel
Grand Mound	well	6 in.	90	.....	Good record. In limestone
Granger	well	8 in.	106	.....	Unfailing. 200 g.p.m.
Granville	well	10 ft.	30		Somewhat reduced in dry weather
Gray	well	8 ft.	26		25,000 g.p.d. Low ground
Greene	well, 5 ft. sq. for top 20 ft., 20 ft. diam. for lower 5 ft.				Ample for pumps
Greenfield	old works,	17 ft.	41		Will supply pumps 2½ hrs. or at rate of 130,000 g.p.d. 10 blks S.E. bus. dist.
	2 wells	14 ft.	45		
	new works,	18 ft.	42	–22	150,000 g.p.d. 2 mi. W. town on low ground
	2 wells	6 ft.	35		In reserve
	well	20–8 in.	2505	–505	Not finished, Dec. 31, 1928
Grimes	well	18 in.	30		Adequate, reliable
Grinnell	5 wells	10 to 16 in.	2000	–230–250	Nos. 4 & 5. Cap. 150 g.p.m. each
	1 well	16–10 in.	2500	–258	500 + g.p.m.

Griswold	2 wells	8 in.	60		Not affected by dry seasons
Grundy Center	1 well	10 in.	255	.....	80 g.p.m. Tested 50 g.p.m. for 12 hrs. when drilled
	1 well	8 in.	360		65,000 g.p.d.
Guthrie Center	7 wells	6 in.	60		350 g.p.m. all seasons
Guttenberg	well	24 ft.	25		Drains in 5 hrs., fills quickly. Seepage from bluffs and river 10 ft. away
Halbur	2 wells	10 ft.	25		
		16 ft.	26		Ample at all seasons
Hamburg	14 sand points, 2 in. by 4 ft., 25 ft. deep, head –13 ft. 3 springs on side of bluff, flow into basin.				Ample Ample for pump. ¼ mi. from pumping sta.
Hampton	1 well	10 in.	1709	–153	Ample at all times, 366 g.p.m. ¾ mi. E. bus. dist. Springs furnish some.
	1 well	20–8 in.	1700	–153	1,000 g.p.m.
Harlan	22 wells	6 in.	40		Est. 900,000 g.p.d., not affected by dry weather
Harris	well	3 ft.	70		Ample at all times
Hartley	well	12 in.	1000		Ample for pump
Havelock	well	8 in.	138	–25	Unfailing. Drift to 116 ft., sand to 124. Test, 40 g.p.m. for 6 hr. 7 ft. Cook strainer
Hawarden	well	16 ft.	35	–23	Good
Hawkeye	1 well	6 in.	182	.....	900 g.p.h.
	1 well	8–6 in.	835	–265	100 g.p.m. under air
Hedrick	well	6 in.	55		Ample in all seasons
Hinton	2 wells	8 in.	40		90 g.p.m.
Holstein	old well	8 in.	2,000	–300	Ample
	new well	12–6 in.	2,040	–290	200 g.p.m. Drilled 1924
Hopkinton	well	6 in.	80		Reliable. In limestone
Hospers	well	12 ft.	33		Limited
Hubbard	well	6 in.	400	–20	Ample at all times. Cased 80 ft.
Hudson	well	6 in.	212		Ample at all times
Hull	well	8 in.	1300		Constant, sufficient for pump

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Humboldt and Dakota City	springs	Old—across river from Sta.			100 g.p.m.
		New—½ mi. NW. bus. dist.			300 g.p.m.
Humeston	Reservoir 2 mi. from bus. dist. Cap. 40,000,000 gal.				
Hurstville	well	6 in.	165		Ample at all times
Huxley	well	8–5 in.	892	–125	75 g.p.m. during 24 hr. test, little effect on water level
Ida Grove	old, 3 wells		shallow		Permits 5½ hrs. pumping. Good all seasons
	new, 6 wells	3 ft. cement tile lining		–16	Permits 5 hr. pumping
Independence	4 wells	10 in.	200		Est. Cap. 900–1,000 g.p.m. or 1,300,000 g.p.d. Across R. from bus. dist.
	6 wells	10 in.	50		
	1 well	12 in.	257		
Indianola	2 wells	28 ft.	43		8 hrs. pumping at 280 g.p.m.
		25–15 ft.	43		14 hrs. pumping at 280 g.p.m.
Inwood	2 wells	6 ft. sq.	96		1¾ hr. pumping, 7,000 g.p.d.
		12–10 in.	915	–275	60 g.p.m., 86,000 g.p.d. Drilled 1917
Iowa City	10 art. wells, 2,200 ft. timber galleries, 960 ft. 6 in. tile.				Ample. Wells flow 240,000 g.p.d.
Iowa Falls	4 wells	2–8 in.	270	–40	10 in. well installed 1920. Water could not be lowered more than 40 ft. below curb
		1–10 in.			
Ireton	well	6 in.	160		Ample at all times
Jefferson	2 wells	8 in.	2,100	.....	Good record since 1912. Into sandstone
		6 in.	125		Good record since 1916. Into sand
Jessup	well	6 in.			Ample for pump
Jewell	well	6 in.	1,000	flowed till 1922	Ample for pump of 60,000 g.p.d. cap.
Kamrar	well	6 in.	287	.....	Ample for pump of 40,000 g.p.d. cap.
Kanawha	2 wells	5 in.	135	–18	Ample at all times
		8 in.	165		
Kelly	well	6 in.	222	.....	Drift 40, sand 10, yellow clay 60, blue clay 40, sand 72. Test 50 g.p.m. for 10 hrs. 8 ft. strainer
Kellogg	2 wells	3 in.	21	.....	Ample and reliable. Low ground
Keokuk	Miss. R. Flows to settling basin, through filters to clear wells				
Keosauqua	Des Moines R. 8 in. intake pipe to settling well on bank				

Keota	old well	9 ft.	75 ft. with sand point below		50,000 g.p.d., slightly reduced in dry weather
	new well	22 in.	254		50,000 g.p.d. Slightly reduced in dry weather
Keystone	dug and drilled well 6 ft. for 62 ft., 6 in. for 66=128 ft.				Low in summer, probably discarded for new well
	new well	12 in.			
Kimballton	6 sand points	2½ & 2 in.	41	.....	20,000 g.p.d., slightly affected by dry weather
Kingsley	well	12 ft.	32	.....	Seepage; ½ mi. N.W. town
Kirkman	2 wells	6 ft.	52	.....	Not affected by dry weather; connected at bottom by 2 three in. pipes
Kiron	well	8 ft.	22	–13	Ample, "well to rock" (must be a bowlder)
Klemme	well	8 in.	190		Ample in all seasons
Knoxville	2 wells—concrete pit 25 ft. deep; 2, 10 in. pipes with 10 in. by 10 ft. brass strainers resting on rock 37½ ft. below bottom of pit. Wells on D.M.R. bottoms 6½ mi. N. of town, ¼ mi. from R.			.....	Ample
	1 well	24 in.	35	.....	720 g.p.m. for 12 hr., 1,100 g.p.m. for 1 hr.
Ladora	well	8 in.	70	.....	Ample
Lake City	1 well	16–4 in.	1376	.....	200 g.p.m.
	1 well	.....	350	.....	Ample, reserve
Lake Mills	1 well	6 in.	235	.....	Ample at all times, 80,000 g.p.d.
	1 well	12 in.	374	.....	250,000 g.p.d.
Lake Park	Silver Lake. Pumped into settling basin				
Lake View	2 wells	40 in.	32	.....	Ample
Lakota	well	6 in.	115	–15	Ample
Lamoni	Reservoir, dam 200 ft. long. Watershed 460 A.				Enough for 2 mo. dry weather
	well	16–6 in.	2200	.....	100 g.p.m.
Lamont	well	8 in.	165	–8	Ample at all seasons
La Motte	well	6 in.	144		Ample, 50,000 g.p.d. In limestone
Lansing	well	6 in.	.....	flows	Another well supplies drinking fountains
La Porte	well	10 in.	348	.....	Ample
Latimer	well	6 in.	150	.....	Ample at all seasons

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Laurens	1 well	10 in.	1200	.....	Ample at all seasons
	1 well	4 in.	300	.....	Reserve supply
Lawler	well	6 in.	136	.....	Ample, reliable
Lawton	2 wells	4 in.	80	.....	Ample at all seasons
Ledyard	well	8 in.	193	−15	Ample
Leeds, see Sioux City					
Lehigh	well	12 ft.	25	.....	Ample; max. lift 15 ft. Fluctuates with river level. Near Des Moines river
Le Mars	2 new wells	25 in.	110	.....	700 & 750 g.p.m., moderate lowering, lined with concrete strainer pipe
	29 driven wells	3–8 in.	45	.....	800 g.p.m. ¼ mi. W. bus. district
Lenox	Reservoir, earth dam 1,000 ft. long, 30 ft. high.				Cap. 50,000,000 gal. 1 mi. N. of town
Leon	1 well	7 in.	80		100 g.p.m. for 7 hrs. or more; not affected by seasons
	1 well	8 in.	1100	−350	
Lester	well	3 ft.	32	.....	Ample
Lewis	well No. 1	10 ft.	74	.....	Ample at all times
	well No. 2	10 ft.	44	.....	Good now, failed once, deepened
Lime Springs	well	10 in.	160	.....	Ample all times
Lincoln	well	6 in.	511	−170	Good flow, drilled 1919
Linn Grove	well	10 ft.	30	.....	Ample all seasons
Lisbon	Reservoir, supplied by springs, also small well, size unknown				
Little Rock	well	18 ft.	20	.....	Ample all seasons, 500 ft. from Little Rock R.
Livermore	well	6 in.	145	.....	Ample all seasons, not affected by dry weather
Logan	2 art. wells	6 in.	954	+80	Flows 200 g.p.m. Chief supply
		10–6 in.	840	+30	Flowed 13 g.p.m. in 1912. Would yield 20,000 g.p.d. for emergency
	1 well	9 in.	52	.....	Ample all times
Lohrville	well	8 in.	180	.....	Ample at all times
Lone Rock	well	8 in.	153	.....	Ample. Tested 60 g.p.m. for 8 hrs.
Lone Tree	2 wells	6 in.	86	.....	Reliable; in gravel, 4 in. casing

Lost Nation	well	8½ in.	120	.....	Ample. 8 hr. test, no drop. 30 ft. in soil, rest in rock
Lowden	well, drilled				
Low Moor	well	6 in.	226	.....	Ample in all seasons
Luther	well	18 in.	90	.....	10,000 g.p.d. all seasons, wells connected
	well	5 ft.	55	.....	
Luverne	well	8 in.	154	.....	Ample, reliable
Lytton	drilled well	8 in.	1141	.....	Supply ample for pumping capacity. In sandstone
McGregor	drilled well	8 in.	440	flows	50 g.p.m. Pumping cap. 300,000 g.p.d.
Macedonia	old well	8 ft.	29	.....	70,000 g.p.d.
	new well	3, 4 in. sand pts.	25	.....	Ample all seasons
Madrid	well	16 in.	134	.....	Ample, reliable. Installed 1925
Malcom	2 wells	8 ft.	20	.....	Pumped dry occasionally in dry weather. Not often
		12 ft.	20	.....	Supply ample for pump of 90,000 g.p.d. cap.
Mallard	well	12 ft.	33	.....	Level varies during year, but enough for 7 hr. pumping
Malvern	14, 1¼ in. sand points		20–27	.....	Not affected by dry seasons. At cold storage plant ½ mi. from bus. dist.
	well No. 1	14 ft.	45	.....	100,000 g.p.d., reduced in dry seasons
	well No. 2	16 ft.	30	.....	Ample at all times
	well	8 in.	42	.....	
Manchester	drilled well	10–6 in.	1870	.....	300 g.p.m.
	well	5 in. drilled from base of pit 30 ft. by 20 ft. deep			Flows when deep well is not pumped. 200 g.p.m.
Manilla	well	12 in.	62	.....	Ample at all times
Manly	2 wells	10 in.	300	.....	Ample, reliable
Manning	9 sand pts.		38	–9	240 g.p.m. for short period. In gravel, head 5–6 ft. higher in wet weather
Manson	well	10–4 in.	1320	–60	Ample
Mapleton	6 points	.....	25–32	.....	Good. In gravel; equipped with strainers

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Maquoketa	well	22.5 ft.	30	.....	Ample for pumps all seasons. In gravel. 600 feet 24 in. tile laid in gravel
Marathon	well	10 in.	182	−74	100 g.p.m. for 8 hrs. Last 11 ft. in sand
Marble Rock	well	6 in.	186	.....	Ample all times
Marcus	well	12 in.	300	.....	No shortage. In sandstone
Marengo	1 well	25 ft.	30	.....	Ample. In sand (in reserve)
	2 wells	24 in.	34	−19	Ample. 500 g.p.m. Connected
Marion	Springs 1 mi. west of business district				Ample, unfailing
Marne	well	6 ft.	31	.....	1 hr. pumping lowers water 9 ft. 2 hr. seepage restores level
Marquette	well	6 in.	585	+10 flows	Ample
Marshalltown	9 wells	1, 6 in. 8, 12 in.	74 to 178	−15	10,000,000 g.p.d.
	51 wells	6 in.	37–38	.....	500,000 g.p.d. Reserve. In gravel. Wells 1 mi. from town
Mason City	4 wells	12–24 in.	1,200 & 1,219	−75 to 123	5,500,000 g.p.d.
Massena	well	7 ft.	36	.....	Adequate
Maurice	well	12 ft.	22	.....	Ample all seasons
Maxwell	well	6 in.	380	flows	70,000 g.p.d. "Driven into gravel under soft shale"
Maynard	1 well	10 in.	700	.....	Ample, reliable, 32,000 g.p.d. (abandoned in 1928)
	1 well	.....	70	.....	60,000 g.p.d.
Mechanicsville	well	8 in.	300	.....	Adequate at all times
Mediapolis	1 well	8 in.	54	.....	150 g.p.m.
	1 well	6 in.	54	.....	Ample for pump of 75 g.p.m. cap.
Merrill	well	18 in.	42	.....	Kelly well. In gravel. Ample
Meservey	well	6 in.	160	.....	Ample, reliable
Miles	well	8 in.	50	−6	200,000 g.p.d., draws down 15 ft. when pumping; diminished in summer. In limestone
Milford	Lake Okoboji, pumped through 6 in. main 1½ mi. to town				

Minden	A, tile well	18 in.	40	–20	20,000 g.p.d. Installed 1914
	B, brick well	7 ft.	40		5,000 g.p.d., less in dry weather
Missouri Valley	2 wells	10 in.	77 & 85	–13	Ample. Drilled 1918
Mitchellville	River Sta. 3 wells, 6 in. pipe driven 45 ft. into gravel, strainers at ends				Ample all times. 2 mi. NE. of town
Modale	well	6 in.	90 ft.	.....	12 hr. test 200 g.p.m. showed no shortage. 1,000 ft. from bus. dist.
Monona	well	6 in.	427	.....	Ample, reliable
		8 in.	814	.....	
Monroe	2 wells	4 in.	120	.....	Good. Ample for pumps
		6 in.	180	.....	
Montezuma	well	5 in.	250	.....	Ample for pumps; down to rock (reserve). New well, cylinder at 220 ft.
	Springs, run into basin 9 ft. deep, 60,000 gal. cap. 2½ mi. from town				Overflow basin in wet weather
Monticello	2 wells	8 in.	275	few ft.	
		12 in.	500	below curb	Ample all times (new well drilled 1925, not placed in service). Est. yield 250–300 g.p.m.
Moorhead	shallow well	.....	.....	.....	Ample for pump of 20,000 g.p.d.
Morning Sun	well	12–8 in.	1205	–122	130 g.p.m.
Moulton	Reservoir, dam 560 ft. long, 24 ft. high. Cap. 55,000,000 gal. 2 m. NE. town				
Mount Ayr	Reservoir, dam of earth, cap. 5,000,000 gal. ¼ mi. N. town				
Mount Pleasant	main, well	6 in. at base	1820	.....	250 g.p.m.
	old, 4 wells		50, 2 have 16 ft. sand pts. in bottom of brick lined well		Supply low in dry years
Mount Vernon	2 wells	8 & 12 in.	337 & 327	.....	Over 200 g.p.m., no reduction in dry weather
Moville	21, 2 in. sand points		40 ft. deep		Ample all seasons
Muscatine	13 wells	6 in.	48, with strainers	–2 to 15 ft.	5,500,000 g.p.d.; good quality; 2 mi. SW. bus. dist. In gravel under island
	1	8 in.			
	2	10 in.			
	3	12 in.			
Nashua	well	8 in.	160	–19	Pump lowers water to –29 ft.

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Neola	sand points	1, 10 in. 2, 6 in.	48	.....	Ample all seasons
Nevada	3 wells	16–6 in.	2792	–163	Not affected by dry seasons, 180 g.p.m.
		16–6 in.	2791	–165	250 g.p.m.
		8 in.	1000		Reserve
New Albin	well	10–8 in.	585	flows	150 g.p.m. by pumping does not lower water
Newell	2 wells	8 in.	300	.....	Ample for pumps. No shortage in dry weather
New Hampton	2 wells	10 in.	235 & 262	.....	Ample all times
New Hartford	well	8 in.	237	.....	Ample; top 80 ft. cased, rest in rock. Installed 2–'21
New London	well	6–4 in.	1485	–140	40 g.p.m. Into sandstone. ¼ mi. E. bus. dist.
New Sharon	2 wells	8 in.	165	.....	Ample. Supplied pumps for 86 hrs., no effect. Each pump cap. 33,000 g.p.d.
Newton	8 wells	12 in.	50	.....	1,000,000± g.p.d. in dry weather. On Skunk bottoms 1 mi. from river, 6 mi. SW. town
	3 wells	12 in.	47	.....	1,000 + g.p.m. each
New Vienna	well	4 in.	75	.....	Cap. est. 15 g.p.m.
	well	6 in.	160	.....	For fire. Ample for pump.
Nora Springs	old well	8 in.	280	.....	In reserve, to be enlarged & deepened
	well	8 in.	385	.....	Ample; pump cap. 130 g.p.m.
North English	well	13–6 in.	1678	–70	Ample, reliable, 100 g.p.m.
Northwood	well	10 in.	90	near top	Ample all times
Norway	well	12 in.	120	.....	Ample all times
Oakland	well	16–7 in.	1936	–92	Ample. Test of 150 g.p.m. 36 hrs., no change; drilled 1919
Ocheyedan	old well	16 ft.	30		1000 ft. 8 in. drain tile extending from it. In reserve 7 wells 36 in. by 30 ft. deep
	new well	6 in.	233	.....	50 g.p.m.
Odebolt	No. 1, 5 wells	7–18 ft.	15–28	.....	100,000 g.p.d. max., 50,000 g.p.d. in dry weather
	No. 2, well	15 ft.	22	.....	40,000 g.p.d. max., 20,000 g.p.d. in dry weather
	No. 3, well	20 ft.	21	.....	50,000 g.p.d. max., 30,000 g.p.d. in dry weather

Oelwein	old, 3 wells	10 in.	150	overflows 60 g.p.m	225 g.p.m. into old well pit 20 ft. diam., 40 ft. deep, 5 points in base, yield 40 g.p.m.
	new well	12–8 in.	1316	–30	90 g.p.m. 1¼ mi. S. of bus. dist. Not used
	new well	18–12	122	–3½	Connected by 2½ in. siphons and cross pipes
	new well	12 in.	111	.....	
Ogden	well	10–6 in.	2200	.....	Ample all seasons
	well	16–4½ in.	2852	–163	150 g.p.m.
Olin	well	.....	.....	.....	Ample
Onawa	art. well	4 in.	940	flows	72,000 g.p.d. Intermittent
	2 wells	12 in.	110 & 111	.....	1,000,000 g.p.d.
Onslow	well	6 in.	237	–160	Will supply pump for 15–20 min. Refills rapidly
Orange City	well	8 in.	825	–200	Test, 110 g.p.m. 48 hrs. Ample. Drilled 4–'22
	well	8–6 in.	562	–225	20 g.p.m. Reserved
Osage	2 wells	10 in.	782 & 820	.....	Ample all seasons
Osceola	Reservoir, cap. 25,000,000 gal., drainage area 280 A.				
Oskaloosa	Skunk R. 2 wells, 18 in. gravel-packed Kelly wells. On flat of Skunk R. 4 mi. N. town. One has separate pump 39, 6 in. sand points 30–40 feet deep. Cleaned and connected with one of new wells. Cap. 1,000,000 g.p.d.				
Ossian	well	6 in.	700	–435	Good. Drilled 1916; cased to 500 ft.
Oto	5, 2 in. sand points 47 ft. deep				Ample all seasons
Ottumwa	well	22 ft.	32	–24	On Turkey Is. Extends to rock
Oxford	well	20 ft.	40	.....	Seepage. Will supply pump (cap. 86,000 g.p.d.) for 8 hrs. except dry weather, then only ½ hr.
	2 wells	10 in.+	586	–62	75 g.p.m. each
Oxford Junction	well	14 ft.	16	.....	Ample. Into gravel
Palmer	well	4 in.	165	.....	Ample
Panama	well	6, 1¼ in. sand points 42 ft. deep			Ample, on low ground
Panora	well	6 ft.	48	–24	Ample, on low ground
Parkersburg	well	6 in.	100	.....	Ample all seasons
	well	12 in.	281	.....	
Paton	well	6 in.	225	.....	50 g.p.m. In gravel. Strainer in bottom

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Paullina	well	20 ft.	24	.....	125 g.p.m., slightly less in dry seasons; ½ mi. NE. bus. dist.
Pella	900 ft. 30 in. tile 20 ft. below surface, discharge into well				Adequate exc. very dry weather. Near D. M. river 3½ mi. SW. town
	Several sandpoints ½ mi. W. station				
Perry	4 wells	10 in.	120	.....	760 g.p.m. test 30 min.
Persia	well	8 in.	60	.....	Ample all seasons
Peterson	well	14 in.	80	.....	Ample all seasons
	well	6 in.	80	.....	Ample all seasons. Reserve
Pierson	well	13 ft.	21	–10	Pump cap. 200 g.p.m. Well near creek
Pleasantville	well	10 in.+	1826	–180	70 g.p.m.
Plover	well	8 in.	43	.....	Ample for pump; cap. 60,000 g.p.d.
Plymouth	well	12 in.	268	overflows when idle	Ample for pump; cap. 180,000 g.p.d.
Pocahontas	well	10 to 6 in.	1300	.....	Ample all seasons
Pomeroy	well	6 in.	135	–20	Ample all seasons for pump; cap. 91,000 g.p.d.
Portsmouth	12, 1¼ in. and 2½ in. sand points, 52 ft. deep				Ample all seasons
Postville	well	10 in.	518	–275	Good. In St. Peter sandstone; drilled 1895
Prairieburg	well	8 in.	230	.....	Ample all times
Prairie City	well	5 in.	430	–70	39 g.p.m. by test
Preston	new well	10–5 in.	989	–19	Ample for pump, at 75 g.p.m.
	old well	6 in.	140	.....	Adequate for pump at 35 g.p.m.
Primghar	5 wells	1, 10 ft.	20	.....	In gravel. ½ mi. E. town; low ground. Intermittent
		4, 3 ft.	20	.....	
Protivin	well	4 in.	75	.....	Ample
Quimby	well	8 in.	140	.....	Ample for pumps all periods, cap. 40 g.p.m.
Radcliffe	2 wells	6 in.	135 & 95	–74½	Ample. Into rock
Readlyn	well	8 in.	108	.....	Adeqnate and reliable
Redfield	old well	10 ft.	23	.....	4–9 ft. water, pump can empty in 2–4 hrs. but refills rapidly
	new well	12 in.	215+		
Red Oak	S. Sta. 2 wells	18 ft.	68 & 52		Also 160 ft. tunnel 4½ x 6 ft. 500,000 g.p.d.
	E. Sta. 1 well	18 ft.	50	.....	550,000 g.p.d.

Reinbeck	2 wells	8 in.	380	–75	Ample at all times
Remsen	3 wells	2, 16 ft. 1, 18 ft.	22 & 23 34	....	Ample for pumps, reduced in dry weather
Renwick	well	6 in.	150	.....	Ample all times
Rhodes	well	8 in.	300	.....	Ample, reliable
Riceville	well	12 in.	525	–3	Ample, all seasons
Ricketts	6, 2½ in. sand points	20 ft. deep			Not affected by dry seasons
Ringsted	2 wells	6 in. 8 in.	517 160	–76	Ample. In gravel
Rippey	well	12–6 in.	1770	.....	60,000 g.p.d.
Riverside, Wash. County	1 well 2 wells	10–6 in. 3 in.	565 116	....	40 g.p.m. Ample at all times
Riverside, Woodbury County	see Sioux City				
Rockford	well	10 in.	185	at curb	Ample at all times
Rock Rapids	2 wells	18 ft.	35 and 32.5	....	Supply near that of pump; cap. 530,000 g.p.d.
Rock Valley	well	8 ft.	29	–21	Ample exc. extreme dry weather; refills rapidly
Rockwell	2 wells	6 in.	200 & 250	.....	160,000 g.p.d. In limestone and shale
Rockwell City	2 wells	10 to 6 in.	952+		120,000 g.p.d. In service 20 yrs. Deepened since 7-'22
		12 to 6 in.	1542	–165	225,000 g.p.d. In service 10 yrs.
Roland	5 wells	1, 8; 1, 3; 3, 6 in.	70	–15	Ample ordinarily, fail during canning season. Refill rapidly. Canning plant well, 8 in. 305 feet deep, in reserve
Rolfe	old well new well	8 in. 10 in.	230 634	....	40 g.p.m. 100 g.p.m. Drilled 1924
Rudd	well	8 in.	196	.....	Unaffected when well is pumped all day
Ruthven	well	5 in.	167	–50	Ample, not lowered by 24 hr. pumping
Ryan	2 wells	5 in.	400	.....	Ample all times
St. Ansgar	well	10 in.	230	–40	Ample for pump all times
St. Olaf	well	8 ft.	.....	.....	Seepage. Lined with stone
Sabula	2 wells		300 & 900	flow with	12 lb. pressure, failing

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Sac City	Springs in valley Raccoon R., 1 mi. N. city				200,000 g.p.d. flow into reservoir, cap. 100,000 g.p.d.
Salix	2 wells	6 in.	120 & 273	.....	Ample, but lowered to maximum possible lift by pumping
Sanborn	well	18 ft.	62	.....	Decreased till it scarcely supplies needs
Schaller	9 wells	40 in.	20	–8 to 10	Tile lined. Ample, decrease during dry weather
Schleswig	2 wells	10 & 12 ft.	25	.....	Brick lined { SE. pt. town ½ mi. from bus. district. In reserve
	10 wells lined with 10 in. tile, shallow				Installed in 1921
	New well	24 ft.	29	.....	West of town. Ample, 300 g.p.m. for 72 hrs.
Scranton	well	6 in.	212	–150	Ample for pump all times
Sergeant Bluff	well	8 in.	350	.....	Ample for pump all times
Seymour	Reservoir, cap. 40,000,000 gal.				Not affected by dry weather. ¾ mi. S. bus. district. Dam 500 by 15 ft.
Sheffield	dug well	16 ft.	25	.....	Limited to pump capacity. One pump has 400 g.p.m., other 250 g.p.m. cap.
Shelby	well	14 in.	60	.....	Ample all seasons
	reserve well	8 in.	170	.....	20,000 g.p.d.
Sheldon	10 wells	6 & 8 in.	28	.....	Ample for pumps
	3 dug wells with radiating tile drains				Act as storage, 150,000 gal.
Shell Rock	well	10 in.	169	.....	Ample at all times
	new well	.....	.....	.....	100 g.p.m. pump
Shellsburg	well	12 ft.	23	.....	Normally good, reduced in dry weather, sufficient for 3 hr. pumping
Shenandoah	Sta. 6 and 2	18 in.	50	.....	200,000 g.p.d. each
	Sta. 3	12 in.	51	.....	125,000 g.p.d. } only slightly affected by drought
	Sta. 5—1 well	10 in.	42	.....	400,000 g.p.d., new
Sibley	2 deep wells, No. 1,	10 in.	314	–112	Ample for pumps, alternately (cap. 100,000
	No. 2,	8 in.	325	–112	and 64,000 g.p.d.)
	1 shallow well	10 ft.	30		82,000 g.p.d.
Sidney	Springs, not affected by dry weather				200,000 g.p.d. Low ground 3 mi. E. town. Reservoir cap. 42,000 gal.

Sigourney	well	16–8 in.	1978	–83	500 g.p.m. Air lift
Sioux Center	well	6 in.	430	.....	88,000 g.p.d.
Sioux City	17 wells	16–26 in.	222–415	–40	Cap. 2,250,000 to 3,000,000 g.p.d. each
Leeds	2 wells	8 in.	267	.....	400,000 in 12 hrs., 1920 summer
Riverside	2 wells	12 in.	325	.....	East well tested 670,000 g.p.d.
Sioux Rapids	well	10 ft.	30	.....	Ample all seasons. In gravel
Slater	well	16 in. to 190, 4 in. to base	325	.....	Ample all seasons
Sloan	4 sand points				Ample all seasons
Smithland	5 sand points	2 in.	52	.....	Ample, reliable. One additional well in reserve
Soldier	well	6 in.	110	.....	Ample, reliable
Solon	well	6 in.	145	.....	Ample, decreased in dry weather
Spencer	2 wells	20 ft.	24	.....	2,200,000 g.p.d.
Spillville	well	6 in.	75	.....	Good, ample
Spirit Lake	5 sand points	5 in.	14	.....	Ample in all seasons. Shore Spirit Lake, in
	1 well	18 ft.	19		gravel, 1¼ mi. N. of town
Springville	well	6 in.	150	flows when not pumped	Max. cap. 400,000 g.p.d. In limestone
Stacyville	well	10 in.	100	flows when not in use	Pump cap. 130,000 g.p.d.
Stanhope	2 wells	8 in.	1,200 & 1,800		Ample
Stanton	well	14 ft.	58	–35	90,000 g.p.d.
Stanwood	well	6 in.	237	.....	50 g.p.m.
State Center	well	13 ft.	19½	–11 to 6	Ample, pump 220,000 g.p.d. Located ½ mi. N. town along creek
Storm Lake	Storm Lake, 12 in. intake pipe 800 ft. into lake.				Settling basin, sand filters, clear well
Story City	3 wells	8 in.	62	flow	Est. cap. 180,000 g.p.d. Reservoir, low ground
	1 well	8 in.	65	.....	Pump cap. 80,000 g.p.d.
Stratford	well	8 in.	500	–119	Ample
Strawberry Point	3 wells	7 in.	165	.....	Ample, reliable
Stuart	well	8 in.	3021	–345	212 g.p.m. during 24 hr. test

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Sully	well	6 in.	325	.....	Pump can empty well in 3 hrs. Refills rapidly; pump cap. 23,000 g.p.d.
Sumner	well	12–6 in.	1785	–100	Pumped to capacity. Air lift, cap. 108,000 g.p.d.
Sutherland	well	8 in.	200	.....	Ample for pump (cap. 120,000 g.p.d.) all seasons
Swea City	well	8 & 6 in. casing	125	.....	Ample
Tabor	Reservoir, 20,000,000 gal. cap. fed by stream at rate of 3,000 g.p.h.				
Tama	well	20 in.	55	.....	1,000,000 g.p.d. In gravel
Templeton	well	8 ft.	28	.....	Seepage. 5 in. tile ¼ mi. long. Installed 1922. Low ground. Reserve well 8 ft. by 26 ft.
Terrill	well	8 in.	98	.....	Ample all seasons. In gravel
Thompson	1 well	4 in.	200	.....	Good
	1 well	8 in.	259	–70	Ample. Estimated 125 g.p.m.
Thurman	well	6 in.	94	.....	Cylinder 82 ft. Tests 40 g.p.m. 10 hrs.
Tipton	old well	10 in. at top	2,750	.....	150 g.p.m. } Air lift
	new well	16 in.	1,650	.....	150 g.p.m. }
Toledo	old well	6 in.	425	.....	Practically abandoned
	new wells (4)	6 in.	40	.....	3,000,000 g.p.d. Also may get water from Indian school
Traer	well	8 in.	260	.....	Ample for pump (cap. 65,000 g.p.d.)
Tripoli	well	6 in.	102	.....	Ample for pump (cap. 144,000 g.p.d.)
Underwood	well	6 in.	52	.....	Ample for pump (cap. 14,000 g.p.d.)
Union	4 wells	6 in.	28	near curb	Ample for pump (cap. 62,000 g.p.d.) Lowers 6 to 8 ft. by pumping
Urbana	well	8–6 in.	1154	–125	35 g.p.m.
Ute	8 strainers	2 in.	60	.....	Ample all seasons
Vail	1 well	14 ft.	25	.....	Can supply pump (cap. 170,000 g.p.d.) 5 hrs. Est. cap. 40,000 g.p.d.

Valley Junction	well	16 ft.	25	.....	Seepage. Est. cap. 500,000 g.p.d. (in reserve)
	3 wells	16, 10 in.	37	–17	Pump can run 8–10 hrs. p.d. max. 720,000 g.p.d. New Sta. ¼ mi. SW. old Sta.
Van Horne	well	10 to 6 in.	2300	.....	Ample, uniform through year; pump cap. 90 g.p.m.
Victor	well	14 ft.	30	.....	Cap. 150,000 g.p.d.
Villisca	west well	10 in.	67	.....	Ample
	south wells (2)	shallow		.....	Ample, but condemned
Vinton	2 wells	5 in.	1,290 & 1,350	.....	Adequate all times, 400 g.p.m. Air lift
Walcott	well	6 in.	140	.....	Adequate, reliable; pump cap. 100 g.p.m.
Walker	well	6 in.	220	.....	Ample, reliable; pump cap. 40,000 g.p.d.
Wall Lake	4 sand points	6 & 4 in.	28	.....	Ample, reliable. In gravel, low ground
Walnut	well	13–5⅜ in.	2,510	–263	Ample, air lift, cap. 400 g.p.m.
Wapello	10, 3 in. sand points		26	.....	Ample 400,000 g.p.d.
Washington	4 wells	15½ to 10 in.	1,217 to 1,817	–58 to 120	1,000 g.p.m.
Washta	dug well	3 ft.	27	.....	Est. cap. 175,000 g.p.d. In use 10 years
Waterloo	4 wells in use 1 well in reserve	20 to 12 & 7 in.	1,365–1,409	–40 drawn to 130 or 167	Perforated at 870 ft. opp. St. Peter. Main supply from Jordan, 1200-1400 ft. Av. consump. 1922, 1,495,549 g.p.d. Max. 2,887,435 g.p.d.
Waukon	3 wells	2, 10 in.	577	.....	Used 15 yrs. no diminution. In sandstone
		1, 16–10 in.	910	–308	Test 350 g.p.m. Used few hrs. daily. In sandstone. 3d well failing
Waverly	well	10–6 in.	1,720	Originally flowed 300 g.p.m.	Present cap. 700 g.p.m. Air lift raises 350 g.p.m.
Webster City	1 well	6 in.	100	flow	800,000 g.p.d.
	1 well	10 in.	657		
	1 well	16–8 in.	1,805	–6	2,500,000 g.p.d.
Wellman	7 points	3 in.	55	.....	Ample all times. In valley. Pump cap. 250,000 g.p.d.
	1 well	20 in.	138	.....	
Wellsburg	2 wells	10 & 6 in.	180	.....	10 in. well, supply ample for pump. 6 in. new, will not supply pump full cap.

MUNICIPAL WATER SUPPLIES OF IOWA CITIES AND TOWNS (Continued)

Town	Source	Diameter	Depth, feet	Head, feet	Supply
Wesley	well	6 in.	185		Unfailing
	well	8–5.3 in.	1,100	–215	35 g.p.m.
West Bend	well	8 in.	107	.....	Ample all seasons
West Branch	well	8 in.	60	.....	Reduced 12% dry weather. Pump cap. 115,000 g.p.d.
West Burlington	well	8 in.	190	.....	Ample for pump (cap. 60 g.p.m.)
Westgate	well, drilled	6 in.	98	.....	Ample. In limestone
West Liberty	2 wells	12 in. old	1,018	–25 drawn	Not affected by dry weather. Old well 1,650 ft., filled to 1,018 in 25 years
		12 in new	1,705	down to –90 at 230 g.p.m.	
West Point	well	6 in.	186	.....	24 hr. test prod. no shortage. Pump cap. 35 g.p.m.
West Side	well	15 ft.	22	.....	Ample. No test. In quicksand, brick lined
West Union	4 wells	10 in.	av. 100	overflow soon after pumps stop	1,000,000 g.p.d., dry weather has little effect. When both pumps stop water falls to –10 ft.
What Cheer	Reservoir, cap. 3,000,000 gal. dam, earth, 300 ft. by 6.				Fed by small streams, drainage area 3 sq. mi.
Wheatland	2 wells	4 in.	185	.....	25 g.p.m.; air lift
		8 in.	185	.....	Pump. cap. 70 g.p.m.
Whittemore	2 wells	6 in.	160	.....	Decreasing, filling with fine sand
		8 in.	160	.....	Adequate and reliable
Williams	2 wells	6 in.	350	.....	Ample all times. Pump cap. 50,000 and 90,000 g.p.d.
Williamsburg	3 wells	6 in.	140	–90	Supply pumps at cap. (48,000 + 72,000 + 50,000 g.p.d.) Screens replaced every 2 yrs.
Wilton Junction	well	12 in.	1570	.....	Ample and reliable
Winfield	2 wells	old, 6 in.	185		20,000 g.p.d.
		new, 12 in.	1,268	–73	225,000 g.p.d. at test, only slight drop in water level
Winterset	4 cased wells	8 in.	30; sand points in bottom		Ample, 40 g.p.m., not affected by dry weather. 2 mi. S. town
Winthrop	2 wells	8 in.	173	.....	
		10 in.	177	.....	Ample from both wells

Woodbine	3 sand points		40	.....	Test 48 hr. at 200 g.p.m., supply did not decrease, no shortage
Woodward	.....	.....	.....	.....	Supplied by State Institution, from reservoir at edge of town
Wyoming	well	6 in.	85	–30	Ample for pump (cap. 80,000 g.p.d.)
Yale	well	8 in.	92	–6	Cap. 90,000 g.p.d.
Zearing	well	8 in.	99	flows	Tested 100 g.p.m. 6 hrs. water lowered only 11 ft. Ample

Appendix

NOTE ON ELEVATIONS

The elevation above sea level of the well curbs is assumed to be that of the tracks at the railway stations as given by Gannett,[76] except where the difference between the curb and the tracks is considerable and was ascertained by leveling. The elevations of the towns, as added by Lees, are those of Lees[77] and were published too late to use in the records of strata of the wells. Thus in several cases a slight discrepancy may be noted between the elevation of a town and that of the curb of the town wells.

BAYARD, GUTHRIE COUNTY

CENTRAL OIL & GAS CO. PROSPECT, CONTINUED

Devonian and Silurian—continued:	
"Shale and limestone, about 50 per cent of each; shale blue and green." 1320 to	1449
"Shale, gray"	1463
"Limestone, gray, cuttings coarse. Small show of oil"	1477
Dolomite, light gray, in fine crystalline granules, which dissolve slowly in cold acid, briskly in hot acid; a little residue, some chert	1472–1475
"Limestone and shale, bluish green"	1490
"Cap rock, gray, very hard"	1492
Dolomite, light tan, otherwise very simlar to sample at 1472; very small residue, mostly chert	1494
"Lime, sandy (dolomite), brown to buff"	1500
"Contained oil from 1492 to 1498."	

Probably the traces of oil occurred in the lower beds of the Silurian. The suggestion has been made that the lower beds penetrated belonged to the Galena-Platteville, but no shales were penetrated which seem to correspond to the Maquoketa of the upper Ordovician. Moreover the thickness here assigned to the Devonian and Silurian—665 feet— is not enough to include the Galena-Platteville also, which should have a thickness of at least 300 to 400 feet.

CLARINDA

WILSON NO. 1 OIL PROSPECT—CONTINUED

Des Moines series (895 feet thick; top 297 feet above sea level):	
Shale, very dark gray, fine textured, smooth feel, no lime; sand in fine	

[76] Gannett, Henry, Dictionary of Altitudes in the United States: 4th Ed.: U. S. Geol. Survey, Bull. 274, 1906.

[77] Lees, James H., Altitudes in Iowa: Iowa Geol. Survey, vol. XXXII.

frosted grains of irregular sizes; some concreted fragments of whitish powder which effervesces freely in acid but leaves a large residue of very fine material, probably "gypsum" of driller. Mostly shale at 1540 and 1563-1568; mostly sand at 1540-1545 and 1568-1575; about equal, 1545-1563; some fragments of shale show small pockets of fine sand and lime. Six samples 1540–1575

Shale and limestone; dark gray, shale finely gritty, some fragments black 1575–1580

Mississippian system (penetrated 420 feet; top 598 feet below sea level):

Meramec and Osage (315 feet thick)—

Limestone, light gray, finely crystalline; some dark gray shale in small fragments; some sand like that above (Driller's log shows that limestone begins at 1610 feet) 1614

Limestone, gray, very finely crystalline, in powder to small chips, response to acid prompt and long continued, 1614-1624; in powder and fine grains, with much sand in fine rounded frosted grains, 1624-1642; somewhat coarser granular chips below 1642 feet; darker gray, some chert, not much sand, 1647-1657; 9 samples 1614–1657

Limestone, dark gray, very finely granular, some pyrite, ready response to acid; 2 samples 1657–1667

Limestone, bluish gray, in rounded chips and granules, a good deal of powder of gray shale 1667–1674

Limestone, similar to above except for absence of shale, in small angular subcrystalline fragments 1674–1680

Limestone, pepper and salt gray, in fine angular crystalline fragments, effervescence fairly rapid, fine white siliceous residue, 1680-1689; finer, rather slow reaction in acid, 1689-1697; somewhat darker gray, some clayey material, 1697-1702; prompt reaction, 1702-1712; brownish cast, 1702-1725; a large amount of white chert, 1721-1734; somewhat lighter gray and coarser, 1725-1729; some clay, less flint, 1729-1740; pepper and salt gray, clean, with much flint, sand grains and crystalline silica, 1740-1749; finer and more uniform, sample nearly all silica, 1749-1754; 16 samples 1680–1754

Limestone, similar to above, rather dark gray, with much light gray chert and some darker insoluble fragments; a little pyrite; limestone finely sugary texture; a little finer, lighter and more uniform of grain, 1765-1769, 1778-1792; larger chips of light chert, 1773-1778, 1792-1796; some chips of greenish shale, 1773-1787; chert same dark gray color as limestone, 1805-1810; nearly all chert and crystalline silica, 1810-1827; 15 samples 1754–1827

Shale and limestone, shale dark greenish, gritty, noncalcareous, in chips and powder; limestone gray, in powder and small chips, briskly effervescent; 3 samples 1827–1842

Limestone and shale, similar to above, except that limestone is predominant; chert abundant 1842–1845

Limestone, rather light gray, briskly effervescent, very finely granular, much chert, a few small chips of green shale; in fine grains, 1845-1853; somewhat more irregular sizes, pepper and salt gray with light chert and darker gray limestone, 1853-1862; finer, more uniform grains, 1862-1875; somewhat clayey, 1871-1879; chert in irregular chips, 1879-1885, 1890-1896; all fine and uniform, 1885-1890; brownish cast, much insoluble residue, partly silica, partly clay, 1896-1904; 13 samples 1845–1904

Shale, in green chips; limestone, in gray powder that effervesces rapidly; probably about equal parts 1904–1908

Limestone, light gray chips and dark gray grains and powder; shale, in green chips, subordinate in quantity 1908–1912

Limestone, light gray, in small grains, brisk effervescence, some siliceous residue; a few chips of green shale, possibly from above 1912–1916

Limestone, dark gray chips and powder, some flint; shale in gray chips and powder; 2 samples 1916–1925

Mississippian-Kinderhook (penetrated 105 feet; top 913 feet below sea level)—

Shale, light bluish gray, very fine textured, strongly calcareous; less calcareous below 1943; dark gray, 1950-1955; same as at 1925 but not so highly calcareous, 1959-1968; 10 samples 1925–1968

Shale, mostly light brick red, very fine textured, strongly calcareous; dark brick red, 1976-1979; powder of all shale samples is more calcareous than lumps; 3 samples 1968–1979

Shale, gray to blue-gray, fine textured, noncalcareous; limestone, light gray, briskly effervescent, crystalline; apparently about equal, 1979-1988; mostly shale, 1988-1996; practically all shale, light blue, calcareous, 1996-2000; 5 samples 1979–2000

Shale, blue-gray, hard, fine textured; at 2000-2004 feet chips show no reaction with dilute HCl, but when powdered they respond fairly briskly, also the powder of all samples reacts quickly; at 2004-2010 chips show no reaction, even when powdered and heated; somewhat calcareous, 2010-2016; powder strongly calcareous, 2016-2021; much crystalline, light gray limestone in chips and powder, also some blue flint, 2021-2030; 7 samples 2000–2030

Driller's log of Wilson No. 1—continued

Character	Thickness, Feet	Depth, Feet
Water sand	5	1530–1535
Lime, gypsum, sand and dark shale	30	1535–1565
Shale and pyrites	10	1565–1575
Black shale	15	1575–1590
Pyrites of iron	5	1590–1595
Dark shale	15	1595–1610
Sandy lime	64	1610–1674
Light shale	4	1674–1678
Lime	2	1678–1680
Water sand (fresh)	20	1680–1700
Brown lime flint (salt water)	32	1700–1732
Shale, sand, broken lime	1	1732–1733
Lime	2	1733–1735
Lime streaked with sandy shale	3	1735–1738
Brown lime	12	1738–1750
Lime, gray, very fine, drills like sand	40	1750–1790
Lime, coarse	11	1790–1801
Lime, hard	4	1801–1805
Lime, coarse	26	1805–1831
Hard gray shale	4	1831–1835
Lime, hard	2	1835–1837
Shale mixed with streaks of lime	8	1837–1845
Lime, fine and very hard	53	1845–1898
Brown shale	2	1898–1900
Lime, very fine	14	1900–1914
Lime, coarse	5	1914–1919
Lime, streaks of shale	2	1919–1921
Lime, hard	13	1921–1934
Shale, black, mixed with lime shells	36	1934–1970
Shale, red	1	1970–1971
Lime	2	1971–1973
Shale, a trifle more red than above	6	1973–1979
Lime, gray, hard	17	1979–1996
Shale, hard, grayish blue	4	1996–2000
Blue shale	3	2000–2003
Lime, gray, hard, very fine	18	2003–2021
Lime, blue, hard, coarse, mixed with gray and brown	9	2021–2030

1609 feet of 6⅛ inch casing set at 1610 feet.

GREENFIELD

CITY WELL NO. 1—CONTINUED

Since the account of the Greenfield well was written (pages 211 to 215) drilling has been resumed and has now reached the depth of 3280 feet (June 24, 1929). It will be noted that at 2420 feet the drill passed out of the dolomites and limestones of the Silurian in which it had been working into a reddish shale, which may be compared with the red arenaceous shale at Stuart at 1865 feet which was referred to the summit of the Maquoketa shale. The drill then entered a bed of chert, dolomite and quartz sand which continued to 2455 feet, the last of the samples described. Much trouble was encountered here from caving and two drills were lost.

When the drilling was resumed and the well was cleared out, better samples of the caving stratum were obtained which proved it a chert conglomerate.

Record of strata—Continued.

Hoing formation, Maquoketa (?)

Conglomerate; chert, pebbles up to 2.8 cm., surfaces worn and softer than iron; shale, buff; a pebble 1.5 cm. of limestone, white, gray and greenish, inclosing bits of white flint, quartz sand and a little greenish clay. Sample said to have come probably from 2429–2475

Chert, white, some gray, some with finely pitted surfaces as from the removal of fine grains of quartz sand; crystalline quartz; limestone, whitish, rapid effervescence; much fine well rounded quartz sand; a little shale in fine chips, green, drab and bright buff. Drillers could not be sure that the drill had yet passed through the fill and had reached rock 2475–2482

As above 2482–2487

As above 2487–2492

Sandstone, gray in mass, grains well rounded and frosted, largest about 0.75 mm.; much white and gray chert; limestone, white, rapid effervescence; considerable shale as above 2492–2497

Shale, blue-green and drab, noncalcareous, in flakes; chert, sandstone and limestone as above; 2 samples 2497–2517

Sandstone, as above; some blue-green shale and whitish limestone of rapid effervescence, fossiliferous (fragments of brachiopod and crinoid stem) 2517–2518

Sandstone as above; much chert in chips; chips of green and red shale.. 2522–2537

Chert and siliceous dolomite, light gray, in chips, with quartz sand as above 2540–2554

Sandstone as at 2492; much light gray chert with disseminated minute pyrite crystals 2554–2560

Sandstone as above; buff in mass; some chert 2560–2570

Sandstone as above; some chert and light gray limestone, earthy, argillaceous, rather slow effervescence 2570–2575

Sandstone as above, a little limestone and chert 2575–2580

Sandstone, as above; dolomite without inclusions of quartz grains; some chert; shale, gray, in flakes and powder 2580–2615

Shale, gray, in friable masses concreting many chips of gray chert, fine quartz sand of rounded grains, and some dolomite 2615–2622
Sandstone, grains well rounded and frosted, larger, grains about 0.4 mm.; shale gray, medium dark and light, calcareous, in chips; considerable chert; some dolomite and pyrite; 2 samples 2622–2650
Sandstone, buff in mass, grains rounded, larger grains about 0.5 mm.; considerable dark gray and brownish shale in chips 2650–2660
Shale, light gray-brown, calcareous reaction with dilute HCl; considerable quartz sand as above 2660–2670
Galena-Platteville (280 feet thick; top 1300 feet below sea level)—
Dolomite, gray and light gray; 2 samples 2670–2690
Dolomite, light gray, much white chert; 3 samples 2690–2720
Chert, white, crushed to fine sand; some dolomite; 7 samples 2720–2780
Dolomite, buff, light buff and gray; considerable chert; all in sand; some spherules of pyrite 2790–2800
Dolomite, buff, in clean sparkling crystalline sand 2803–2815
Dolomite, buff, brown and gray, with some chert; 8 samples 2815–2910
Dolomite, buff, light brown, in clean crystalline sand; a very little white chert; 2 samples 2910–2930
Dolomite, blue-gray, in small chips 2930–2940
Dolomite, gray-buff; imbedded grains of fine quartz sand and some pyrite 2940–2950
Glenwood shale (33 feet thick; top 1580 feet below sea level)—
Shale, dark green, hard, in flakes, very slightly calcareous, pyrite 2950–2960
Shale, light blue-green, in flakes and concreted masses 2960–2970
Dolomite, buff, in fine sand, much dark green shale in flakes, some fine quartz sand poorly rounded, some grains seen imbedded in flakes of shale 2970–2983
Saint Peter sandstone (17 feet thick ?; top 1613 feet below sea level)—
Sandstone, white grains well rounded, frosted, larger grains 0.6 to 0.7 mm.; 2 samples 2983–3000
Prairie du Chien—
Dolomite, light buff and gray 3000–3010
Dolomite, light buff in mass, much fine rounded quartz sand, much hard dark green shale 3010–3020
Dolomite, buff, rusted, much quartz sand as above; 3 samples 3020–3050
Dolomite, gray, some very fine quartz sand 3050–3060
Dolomite, gray and white; white chert; quartz sand, some grains imbedded in dolomite 3060–3070
Dolomite, light gray and gray, some very fine quartz sand; 3 samples .. 3070–3100
Marl, light gray, in friable masses of cemented powder, argillaceous, calcareous, with microscopic quartzose particles 3100–3110
Dolomite, light gray and buff (rusted) in mass; very fine quartz sand, some fine rounded; 2 samples 3110–3130
Marl, light gray, as at 3100 3130–3145
Sandstone (New Richmond), gray to reddish brown (rusted), very fine to medium, many grains not well rounded, some secondary enlargements, dolomitic, some imbedded grains, some öolite at 3160; 4 samples 3145–3185
Dolomite, gray, much quartz sand, grains fine to medium, not well rounded; 4 samples 3185–3220
Dolomite, gray, in fine meal; 4 samples 3220–3280

Notes.—Comparing the geological section at Greenfield with that disclosed by the deep well at Stuart it will be seen that the Pennsylvanian has thickened to the south-southwest and that its base has declined from 390 feet above sea level at Stuart to 40 feet above sea level at Greenfield.

The Mississippian is also somewhat thicker at Greenfield and the base of the shale referred to the Kinderhook is 395 feet lower than at Stuart.

The base of the Silurian dolomites is placed at Stuart at 660 feet below sea level, while at Greenfield it is placed at 1055 feet below sea level. This marked south-southwestern dip together with the downthrow of the Thurman-Wilson fault is taken into consideration in determining both the Galena-Platteville, the Glenwood and the Saint Peter of the Greenfield section.

The forecasts of the depth to the Saint Peter at Greenfield (page 214) were based especially on the wells at Stuart and Nebraska City. On the scale of the Stuart well, allowing 1561 feet from the top of the Mississippian to the Saint Peter, the Saint Peter would be struck at Greenfield at 2891 feet from the surface. On the scale of the Nebraska City well, allowing 1763 feet for the same distance, the Saint Peter would be encountered at 3093 feet. In fact the Saint Peter was found about half way between these estimates—at 2983 feet.

The Silurian is distinguished, as often, by its gypsum, although no marked beds of the mineral were encountered. Near the base the dolomite becomes arenaceous.

Both at Stuart and at Greenfield the beds underlying the Silurian dolomites are distinctly different from the Maquoketa shale of eastern Iowa, although the beds contain much shale. The Greenfield section in particular recalls the Hoing sandstone and still more the conglomerate found in places below the Saint Peter sandstone. The caving stratum above 2475 feet is clearly a conglomerate of chert pebbles, limestone, shale and quartz sand. The inferior beds with their mixture of these materials may be also of the same nature, but allowance must be made for caving of the upper stratum. Apparently we have here for the most part a continental formation or a basal conglomerate, later in age than Maquoketa time. The same mingling of chert, limestone and rounded quartz sand was found at this horizon at Des Moines, Centerville and Sigourney. At Des Moines, Centerville and Shellsburg, though not at Washington, the sand of this terrane is of well rounded grains, in this respect similar to the Saint Peter sand and that of the New Richmond and Jordan.

The Greenfield well was successfully finished by the Layne-Bowler Chicago Co., July 6, 1929, at a depth of 3435 feet (3437 by newspaper reports). Probably it will hold for many years the record of being the deepest well in Iowa. It was begun March 31, 1927, and is reported to have cost the contractors $64,000, although the original contract price was $36,000.

Record of strata, continued from page 433

Prairie du Chien—continued—	Depth in Feet
Cuttings washed away	3290–3345
Dolomite, light gray in mass, arenaceous, grains fine, mostly broken; pyritiferous; 2 samples	3345–3360
Dolomite, whitish, in fine meal; quartz in minute grains; 3 samples	3360–3390
Jordan sandstone (penetrated 45 feet, top 2020 feet below sea level)—	
Sandstone, light yellow-gray, dolomitic cement, in fine chips and detached grains, larger grains 0.5 to 0.75 mm. in diameter, imperfectly rounded; 2 samples	3390–3410
Sandstone, light buff in mass, dolomitic, "hard, wears bit fast", larger grains less than 0.5 mm. in diameter, imperfectly rounded; 2 samples	3410–3425
Dolomite, light gray, in chips, argillaceous, minute quartz particles in residue; shale hard, drab, in flakes	3425–3430
Sandstone, gray, fine, highly dolomitic, grains imperfectly rounded, "hard, wears bit fast"	3430–3435

It will be noted that the thickness assigned to the Prairie du Chien is 390 feet, a normal thickness for this formation. The sandstone at 3390 feet thus falls in with the Jordan stratigraphically, although in its fineness and poorly rounded grains it differs lithologically from the Jordan in its northeastern sections.

While the Greenfield well is 414 feet deeper than that at Stuart it reaches only 435 feet below the base of the Saint Peter sandstone, while the Stuart well reaches 607 feet below that level and penetrates the Franconia, represented by a typical sandstone of minute angular particles not found in any of the samples of the Greenfield well. Glauconitic shales, characteristic of some beds of the Franconia, were not found at either locality.

The static level had stood at 505 feet below the surface of the ground, 865 feet above sea level, before the drill struck the Saint Peter sandstone. On reaching that formation the static level fell to 592 feet from the surface, 778 feet above sea level, and so remained until the completion of the well. It will be noted that the static level of the well at Stuart stands at 860 feet above sea level, approximately the head of the upper waters at Greenfield, a fact most easily explained on the supposition that the upper waters at Stuart are not effectively cased out.

On the final test the pump discharging 60 g.p.m., with the cylinder set six feet nine inches below the water surface, "failed to lower the level sufficiently to suck air". A newspaper item reports that the city council accepted the well "providing the company installs a Sullivan air lift pump of 200 g.p.m. A 150 h.p. motor will be required to operate the pump".

A similar item reports the popular opinion as to the potability of the water: "The first water out of the well was clear as crystal. It had a slight mineral taste which was not objectionable. In fact it was better tasting water than that now being used by the city."

Chemical analyses of the water of the Greenfield well.

Analysis no. 1, by the Dearborn Chemical Co. of Chicago, depth of well 2500 feet, water believed to enter the well at 1600 feet. For the detailed analysis see page 212.

KEOKUK WELL

	Grains per Gallon
Total mineral solids	120.888
Organic matter	Tr.
Total incrusting solids	31.888
Total non-incrusting solids	89.000
Pounds incrusting solids per 1000 U. S. gallons	4.55
Pounds non-incrusting solids per 1000 U. S. gallons	12.71

Analysis no. 2, by Dr. J. B. Culbertson of Cornell College, Iowa. Sample received June 24, 1929. Depth of well 3280 feet, water of sample said to have been taken from level of 3160 feet. All waters above the Saint Peter sandstone cased out.

Analysis no. 3, made by Dr. J. B. Culbertson, Cornell College, Iowa. Sample received at laboratory July 3, 1929. Depth of well 3435 feet, water of sample said to have been taken from the level where the cuttings washed away, at about 3300 feet.

	Anal. no. 2		Anal. no. 3	
	P.P.M	Gr. per Gal.	P.P.M.	Gr. per Gal.
Silicon	13	0.76	12.5	0.73
Iron and aluminum oxides (mere trace of iron)	2	0.12	5	0.29
Calcium	142	8.29	144	8.41
Magnesium	69	4.03	72	4.21
Sodium	316	18.45	394	23.01
Potassium	27	1.56	28.5	1.66
Sulfate	769	44.91	774	45.20
Chloride	309	18.05	411	24.00
Bicarbonate (determined by acid titration)	206	12.04	222	12.97
Total solids	1750	108.23	1952	120.48
Temporary hardness	169	9.88	182	10.63
Permanent hardness	470	27.44	474	27.68
Total hardness	639	37.32	656	38.31

(Hardness calculated as calcium carbonate)

KEOKUK PURE ICE CO. WELL NO. 2

This well, 1799 feet deep, was drilled by C. W. Varner of Dubuque and completed in 1929. The diameters are 12 inches for 180 feet, 10 inches to 806 feet, and 8 inches to bottom. The main supply was found from 1749 to 1799 feet. A small amount, readily bailed down, came in at 632 feet. The Saint Peter sandstone was dry. On completion the natural flow measured 210 g.p.m., and with the air lift placed at 110 feet a discharge of 480 g.p.m. was obtained. The static level was 12 feet below the curb until the casing was inserted to 180 feet, the only casing in the well. From this level to 632 feet it was necessary to put in water for drilling. From 1232 to 1749 feet water stood 40 feet below the curb and could be bailed down. The static level of the main flow was not determined. The temperature is 67° Fahr.

Driller's log

Fill	0-11	Shale	198-203	Hard brown lime	708-773
Gray shale	11-16	Hard lime	203-213	Sandy lime	773-804
Soft white lime	16-89	Shale	213-226	Lime and brown sand	804-845
Hard lime	89-139	Hard lime	226-303	Saint Peter sandstone	845-935
Shelly lime	139-149	Shale	303-516	Hard lime	935-981
Hard lime	149-177	Hard lime	516-673	Shale	981-983
Gray hard lime	177-198	Sandy lime	673-708	Hard and soft lime	983-1749

Record of strata, well no. 2, Keokuk Pure Ice Co., 1929
(Elevation of curb, 580 feet above sea level)

	Depth in Feet
No samples	0–80
Mississippian (440 feet thick; top 500 feet above sea level):	
Keokuk formation, Montrose cherts (100 feet thick)—	
Limestone, gray, mottled, macrocrystalline, fossiliferous, rapid effervescence in cold dilute HCl, in flakes; chert, blue speckled darker; shale, drab, calcareous	80
Limestone, light yellow-gray, granular; chert, white and blue	90

Chert, white, intermingled with limestone, large chips 100, 110
Limestone, whitish, macrocrystalline, rapid effervescence 120
Limestone, very light yellow-gray; some chert 130
Chert, whitish, large flakes, 140, 160; in small chips, some light yellow-gray limestone, 150; 3 samples 140–160
No sample 170
Burlington and Kinderhook limestones (120 feet thick; top 400 feet above sea level)—
Limestone, very light yellow-gray, macrocrystalline-earthy, in small chips, rapid effervescence 180
Limestone, light buff, granular, in large chips, fossiliferous, rapid effervescence 190
Shale, blue and olive-green, calcareous 200
Shale, drab, in flakes 210
Sandstone, blue, argillaceous, calcareous, grains minute, in chips; some light yellow-gray limestone 220
No sample 230
Dolomite, buff and brown, granular, in small chips; limestone, light yellow-gray, fine granular, soft, rapid effervescence; 4 samples 240–270
Limestone, brown, calcilutite, rapid effervescence, in flakes 280
Limestone, brown, soft, granular, moderately rapid effervescence 290
Kinderhook shale (220 feet thick; top 280 feet above sea level)—
Shale, dark blue-gray, highly calcareous, in large flakes 300
Shale, in concreted masses, blue gray; 6 samples 310–360
Shale, in concreted masses, drab, olive, some blue; at 380 includes brown inflammable chips; 12 samples 370–500
No sample 510
Devonian (120 feet thick; top 60 feet above sea level):
Limestone, dark gray in mass, some buff and gray, rapid effervescence, fossiliferous 520, 530
Limestone, medium dark slate color, fine-grained, pyritic, rapid effervescence, fossiliferous 540, 550
Limestone, dark gray, laminated, very fine-grained, rapid effervescence, in flaky chips 560, 570
Limestone, light yellow-gray and brown, rapid effervescence, in fine chips; 3 samples 580–600
Limestone, light brownish gray and brown, calcilutite, laminated, in flakes and sand; 3 samples 610–630
Ordovician:
Galena-Platteville limestone (210 feet thick; top 60 feet below sea level)—
Dolomite, buff, brown and yellow-gray, granular-crystalline, notably cherty at 680, at 810 sample includes dark chocolate-brown inflammable shale; 20 samples 640–840
Saint Peter sandstone (140 feet thick; top 270 feet below sea level)—
Sandstone, white (light yellow-gray in mass), fine, grains poorly rounded, many secondary enlargements, some of largest grains reach 0.75 mm.; some light yellow-gray dolomite 850, 860
Sandstone, white or light yellow-gray in mass, fine irregular grains; 7 samples 870–930
Sandstone, yellow-gray in mass, coarser, larger grains up to 1 mm., many grains frosted and well rounded 940
Sandstone, white, fine irregular grains 950
Sandstone, white, fine, but including well rounded grains up to 1 mm. diameter; 3 samples 960–980
Prairie du Chien (760 feet thick; top 410 feet below sea level)—
Dolomite, light buff, some dark green shale in chips (see log); considerable quartz sand in cuttings as in all to 1370 990
Dolomite, light grayish brown, in mass considerable white chert; 3 samples 1000–1020
Dolomite, yellow-gray 1030
Dolomite, gray, arenaceous, imbedded grains, some chert 1040
Sandstone, light yellow-gray in mass, fine, ill-rounded grains, many secondary enlargements; a second sample from this depth contains dolomite 1050
Dolomite, gray, cherty; 4 samples 1060–1100

Dolomite, gray and light buff-gray; 3 samples	1120–1140
No samples	1150–1200
Dolomite, grayish brown, very cherty	1210
No samples	1220–1320
Dolomite, gray and grayish brown, cherty, 1330, 1340; gray and whitish, 1350; silicious oölite, 1360; 4 samples	1330–1360
No samples	1370–1470
Dolomite, light gray, crystalline; white chert, some sporadic among dolomite crystals	1470, 1480
Dolomite, gray, brownish gray and yellow-gray, more or less cherty; 14 samples	1490–1630
Dolomite, light gray, a few grains of quartz sand in cuttings	1640
Dolomite, very light gray, arenaceous, grains fine, rounded, some with surrounding concentric rings in matrix as in oölite; cherty	1650, 1660
Sandstone, warm yellow-gray, dolomitic, larger grains of 1 mm. diameter, rounded, in chips and detached grains	1670
Dolomite, very light gray, sporadic fine grains of quartz	1690
Dolomite, yellow-gray, highly arenaceous, grains fine	1700
Dolomite, whitish, in flour	1730, 1740
Cambrian:	
Jordan sandstone (?) (penetrated 49 feet; top 1170 feet below sea level)—	
Sandstone, light buff, dolomitic, fine to medium; some chert	1750
Sandstone, light yellow-gray, dolomitic cement, grains rounded, some with secondary enlargements, larger grains about 0.8 mm. in diameter, in chips	1760
Sandstone, yellow-gray, dolomitic cement, grains fine, rounded	1770, 1780
Sandstone, light yellow-gray, grains minute, poorly rounded	1790

Notes.—The samples of the cuttings of this well confirm the conclusions drawn from those of other recent wells of Keokuk (pp. 234-8) and help to clear up a dubious geological section. They establish, in the log of the famous early Hubinger well, the reference by Gordon, Keyes and Norton of the heavy sandstone at 303 feet below sea level to the Saint Peter, and hence of the underlying dolomites to the Prairie du Chien. The "Oriskany sandstone" and the "Niagara sandstone" of Gordon,* however, are left entirely unsupported. Nor does the reference of these supposed "sandstones" and the "sandstones" of similar horizons of other well logs at Keokuk to an upper member of a bipartite Saint Peter sandstone fare any better. None of the four wells at Keokuk whose cuttings have been examined by the writer shows any trace of sandstone between the base of the Kinderhook and the summit of the Saint Peter, or, it may be added, of a Maquoketa shale. If any of the logs reporting "sandstone" and "shale" at these horizons are correct, there must be in this area an interesting unconformity which leaves in certain places the Maquoketa shale and Hoing sandstone more than 100 feet thick, while elsewhere within the city limits both have been entirely cut away.

It will be noted that in the absence of the Silurian and the Maquoketa the characteristic calcilutites of the Wapsipinicon stage of the Devonian rest directly on the rough dolomites of the Galena. As at Donnellson the Galena-Platteville is wholly dolomitized and embraces no shaly beds. The Glenwood shale, as at Donnellson, is absent, or represented by a thin dolomitic sandstone here placed with the Saint Peter.

Throughout the Keokuk area the Saint Peter sandstone is noteworthy for its thickness and in this well section for its fineness of grain, with secondary enlargements common, and especially for the exceptional and unpredictable fact that it was found dry. In the well of the Electro-Metals Co., for example, the Saint Peter's natural flow is 294 g.p.m. (p. 234). Thus it became unexpectedly necessary to drill to the water beds which supplied the once-famous wells of J. C. Hubinger & Co., wells whose natural flow at one time furnished power for a hydro-electric plant for city lighting.

The interpretation of the beds below the Saint Peter sandstone is made more difficult by two gaps in the sample cuttings aggregating 150 feet. As the Prairie du Chien thickens southward and at Burlington reaches a thickness of 565 feet, it may perhaps safely be assigned at Keokuk a thickness of 760 feet. The water-bearing sandstones from 1750 feet would thus fall in with the Jordan. Certainly the glauconitic beds of the Franconia, struck at Burlington 935 feet below the base of the Saint Peter, were not reached at Keokuk when the drill stopped 809 feet below the same datum.

* Gordon, C. H., Notes on the Geology of Southeastern Iowa: Am. Geol., vol. 4, pp. 237-9.

OGDEN, BOONE COUNTY

CITY WELL NO. 2—CONTINUED

Cambrian, continued:
- Saint Lawrence, Franconia beds, continued—
  - Shale, gray and olive-green, hard, finely laminated; and sandstone, gray, glauconitic, grains minute, calcareous, of rapid effervescence, some finely laminated 2610–2620
  - Sandstone, gray, grains minute, glauconitic, calcareous; some shale; 3 samples 2620–2650
  - Sandstone, as above, grayish buff in mass 2650–2660
  - Sandstone, as above, greenish in mass 2660–2670
  - Sandstone, gray and light buff, grains minute, highly dolomitic; 2 samples 2670–2690
  - Sandstone, brown in mass, grains fine, rounded, highly dolomitic 2690–2700
  - Sandstone, light buff, gray in mass, grains fine, dolomitic 2700–2710
  - Sandstone, light gray, highly argillaceous, dolomitic, grains minute to fine; some dark fissile shale 2710–2720
- Dresbach sandstone (90 feet thick, top 1626 feet below sea level)—
  - Sandstone, very light gray, clean quartz grains, fine, not well rounded; 2 samples 2720–2740
  - Sandstone, yellow-gray, clean, larger grains up to 1 mm.; many well rounded 2740–2750
  - Sandstone, as above, coarse, grains up to 3 and 4 mm. 2750–2760
  - Sandstone, as above, grains up to 1.5 mm.; some concreted friable masses of brown sandy shale at 2780; 5 samples 2760–2810
- Eau Claire, or inferior Cambrian formation (42 feet penetrated, top 1716 feet below sea level)—
  - Shale, or argillaceous sandstone, reddish buff, in friable masses, non-calcareous 2810–2820
  - No sample 2820–2830
  - Sandstone, buff speckled dark, fine to medium, mostly of broken quartz grains, some rounded, much ochreous material, some as spherical crusts inclosing sand grains, glauconitic, magnetic 2830–2835
  - Sandstone, as above, but darker, with a larger proportion of non-quartzose material ..... 2830–2840 and 2845
  - No samples 2845–2852

The sample at 2845 was submitted to Professor A. C. Tester of the State University of Iowa, who writes under date of April 7, 1929:

"I believe you are right in calling this formation the Eau Claire.

I am satisfied that the material is from a sedimentary formation, that is a sandstone, which has been transported and deposited in this place with considerable sorting and reworking from its source. However, certain minerals indicate a contributing source of a rather basic igneous rock, possibly a gabbro intrusive type. I find some olivine, a very few grains of plagioclase feldspar (highly weathered), considerable serpentine and much well rounded or worn magnetite. Some of the grains of magnetite show weathering to hematite. Other minerals present in small quantities are, muscovite, garnet, zircon, titanite, ilmenite and leucoxene (?).

The quartz is both well rounded and pitted and fresh angular. Much of the latter is due to breaking of rounded grains. The large amount of rounded quartz I do not believe came entirely from overlying horizons, though there was undoubtedly some contamination of this horizon from above.

In addition to the minerals given above, I find good fresh glauconite in considerable abundance. I believe this is significant and indicates the accumulation of the materials in marine waters of moderate to shallow depth. The black clay also contains grains of glauconite. The sample also contains 15 to 20 per cent of magnetic iron and iron minerals. Some of this is readily recognized as fragments from the drilling tools or casing, but about 5 per cent is magnetite and considerable is a magnetic iron oxide scalelike concentration which I believe is a cementation or concretionary phenomenon. I have noted this condition in the field in sandstones of various ages.

I do not believe this horizon is closely associated with the pre-Cambrian rocks, but instead is a regularly deposited sandstone of characteristics slightly different from the normal type as already indicated. At the same time I would not be surprised if the pre-Cambrian rocks were encountered within a relatively short distance below this horizon, as igneous rocks were at hand not far distant when this bed accumulated."

WAUKEE, DALLAS COUNTY

Altitude of curb about 1020 feet.

In 1922 Thorpe Bros. Well Co. began drilling an oil prospect on the Forette farm, three miles south and one mile east of Waukee. Rose and Son were subcontractors for part of the work. The bore was sunk to a final depth of 2006 feet, this depth being reached on January 30, 1923. Six and five-eighths inch casing was set at a depth of 1786 feet. Drilling was carried on through a hole full of water from a depth of 1792 feet. These beds carried salt water.

Driller's log of Seibel oil well

	Thickness, Feet	Depth, Feet
Surface soil	3	0–3
Yellow clay	20	3–23
Sand and gravel—small amount of water	2	23–25
Yellow clay	15	25–40
Sea mud	20	40–60
Blue clay	1	60–61
Sea mud	11	61–72
Blue clay	8	72–80
Sand	20	80–100
Blue shale	20	100–120
Red shale	27	120–147

Blue shale	13	147–160
Red shale	27	160–187
Blue shale	15	187–202
Dark shale	28	202–230
Red shale	21	230–251
Blue shale	22	251–273
Light shale	32	273–305
Blue shale	19	305–324
Lime	61	324–384
Coal	1	384–385
Fire clay	1	385–386
Dark shale	19	386–405
Coal	2	405–407
Fire clay	2	407–409
Shale	20	409–429
Lime rock	11	429–440
Blue shale	10	440–450
Sandy shale	80	450–530
Blue shale	40	530–570
Dark sandstone—lots of water	26	570–596
Blue shale	9	596–605
Lime rock	65	605–670
Blue shale	8	670–678
Lime rock	8	678–685
Blue shale	4	685–690
Lime rock	8	690–698
Blue shale	10	698–708
Lime rock	50	708–758
White sandstone—top Kinderhook shale lots of water	40	758 798
Blue shale	4	798–802
Lime rock	72	802–874
Blue shale	20	874–894
Lime rock	140	894–1034
Blue shale	32	1034–1066
Lime rock—lots of water	138	1066–1204
Lime	103	1204–1307
Sand, carried a slight showing of gas	3	1307–1310
Lime, coarse to fine-grained	361	1310–1671
Sand, carried traces of oil, however slight were very good	6	1671–1677
Lime, white, somewhat chalky	15	1677–1692
Shale, red	35	1692–1727
Lime, white	10	1727–1737
Lime, reddish	10	1737–1747
Shale, red	41	1747–1788
Lime, white	4	1788–1792
Shale, blue	30	1792–1822
Lime, white, fine and hard	10	1822–1832
Shale, gray	8	1832–1840
Lime, blue, coarse-grained	65	1840–1905
Lime, white	17	1905–1922
Sand, white, very fine-grained	84	1922–2006

Notes.—The beds to 100 feet belong to the Pleistocene, those to 596 feet at least to the Des Moines, and those to 894 to the Mississippian. The lower beds are difficult of location, although the shales at 1692 feet may be Maquoketa. In that case the strata

below are Galena-Platteville, leaving the eighty-four feet of "sand" at the base for the Saint Peter, assuming that it actually is siliceous material. Of course if it is crushed crystalline dolomite or limestone it may still belong to the Galena-Platteville. In that case the Saint Peter was not reached.