DEPARTMENT OF THE INTERIOR—U. S. GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE

WATER RESOURCES OF ILLINOIS

BY

FRANK LEVERETT

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Mr F. H. Newell
Compliments of the author

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GENERAL STATEMENT.

The paper here presented embraces material gathered chiefly in connection with a detailed study of the glacial drift which the writer began some ten years since. It should therefore be understood that it does not represent a special investigation of the water resources. In the study of glacial deposits natural exposures were found to be so limited that it was necessary to collect well records, and of these about 3,000 were collected in the State of Illinois. They are so distributed as to embrace nearly every county of the State which was encroached upon by the ice sheet. No records have been obtained in the unglaciated counties of southern Illinois aside from a few in the city of Cairo.

The glacial deposits yield such an abundance of good water that over a large part of the State but few wells have gone below these deposits. Where the drift is thin, wells have entered the rock. In northern and western Illinois much prospecting for artesian water has been done.

The "logs" of wells are seldom sufficiently full or reliable to warrant publication, and the writer has had very little opportunity to examine well drillings. From many of the wells, however, information of more or less value has been obtained which throws light upon the character and availability of such water.

No investigation of the water power of the streams has been undertaken further than the collocation of results obtained by others; but the use of streams as sources for city water supply has been investigated, and analyses of waters from this source, as well as from other sources, have been obtained.

A special circular letter pertaining to city water supply was mailed to town officials, or others qualified to give information, in all the towns of the State having a population of 1,000 or more. The generous response to that letter makes it possible to present a somewhat full report upon this subject.

The data on rainfall were obtained from the United States Weather Bureau, and data for the discussion of rainfall for 1895—a year of exceptional drought—were obtained through the assistance of the directors of the State Weather Service in Illinois and adjoining States.

The writer is thus under obligations to many who have supplied information. He is especially indebted to Mr. Daniel W. Mead, C. E., of Rockford, Ill., who, by correspondence as well as by published material, has aided greatly in the preparation of this paper. Mr. Mead has issued several pamphlets dealing with water resources of small areas in Illinois and Wisconsin, and also a pamphlet on the Hydrogeology of the Mississippi River Basin, which presents, largely in tabular form, the material scattered through various State documents of Wisconsin, Minnesota, Iowa, and Illinois, as well as Government publications, and covers a range of topics as wide as those embodied in the present paper, though somewhat different from them.[1]

Thanks are also due to Mr. L. E. Cooley, C. E., of the Chicago Drainage Commission, for assistance in supplying data on the work of that commission in connection with the proposed lake and gulf waterway across Illinois.

Through the kindness of Prof. C. W. Rolfe, of the University of Illinois, the writer was permitted to make a tracing of 50-foot contours from the unpublished map sheets in his office, as explained further on. These contours appear on the base map used in several of the illustrations.

Prof. J. A. Udden, of Rock Island, has made a special examination of the artesian wells in the vicinity of that city, and has submitted a report (published herewith) on the character of the rock formations, based upon his examination of well drillings.

The writer should also acknowledge his indebtedness to Mr. F. H. Newell for numerous valuable aids furnished during the preparation of this paper, and to Prof. T. C. Chamberlin for guidance in field study.

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[1] Hydrogeology of the Upper Mississippi Valley and some of the adjoining territory, by Daniel W. Mead, C. E.: Jour. Assoc. Eng. Soc., vol. 13, No. 7, July, 1894. 68 pages, with 6 maps.

CHAPTER I.

PHYSICAL FEATURES.

ALTITUDE.

Illinois has the distinction of being the lowest of the North Central States. It lies in the midst of the great interior basin, which on the east rises to the Appalachian Mountains and on the west to the Rocky Mountains. The mean elevation of the State is about 600 feet, while that of the bordering States is as follows: Indiana, 700 feet; Michigan, 900 feet; Wisconsin, 1,050 feet; Iowa, 1,100 feet; Missouri, 800 feet.[1]

The State has been covered by a careful barometric survey, conducted by Prof. C. W. Rolfe, of the University of Illinois, a survey which had for its object the preparation of a topographic model of the State for the Columbian Exposition. Professor Rolfe used as datum points the altitudes of railway stations which had been determined by surveyor's level. These are found in nearly every county of the State, at intervals so frequent that there is but little room for error in his maps. He has exercised great care in reducing to a minimum errors arising from barometric fluctuations. From Professor Rolfe's map sheets, which are as yet unpublished, the accompanying map has been prepared, showing the altitude of the greater part of the State by contours with 50-foot interval. In the hilly, driftless tracts in the northwest corner and in the southern end of the State the surface is so uneven that only 100-foot contours are introduced, and for very small areas these are necessarily omitted.[2]

The writer has made an estimate, from Professor Rolfe's map sheets, of the area included between 100-foot contours, the results being as shown in the table on the next page. The highest points are situated in the northern counties, there being four counties (Jo Daviess, Stephenson, Boone, and McHenry) in which points rise above 1,000 feet above tide. In a general way the altitude decreases from north to south. The decrease is, however, far from regular, and a prominent ridge in the southern part of the State rises nearly to the altitude of the northern portion, its crest reaching at one point an altitude of 1,047 feet (Rolfe).

[1] The average elevation of the United States, by Henry Gannett: Thirteenth Ann. Rept. U. S. Geol. Survey, 1892, p. 289.

[2] In the portion of Indiana embraced in the map, 100-foot contours have been introduced, based principally upon a combination of railway-survey altitudes of towns with aneroid readings taken by the writer and on a general acquaintance with the relief and other features.

A reference to the accompanying map (Pl. CVIII) will serve to make clear the altitudes and slopes of the State.

The highest point in the State (1,257 feet) is Charles Mound, on the Illinois-Wisconsin line, in the northwest county. None of the State is below 300 feet at high-water stages of the Mississippi and Ohio; hence, no account is taken of such portions of their valleys as may fall below 300 feet at low water. It appears from the table below that only 125 square miles, or less than four townships, rise above the 1,000-foot contour, and that only 10,747 square miles, or less than one-fifth of the State, falls below the 500-foot contour. A computation of the average altitude of the State was made by assuming for the area between two consecutive contours an average elevation halfway between these contours. This assumption is not absolutely correct, but, as indicated by Mr. John Murray, in a paper in the Scottish Geographic Magazine,[1] it involves no serious error. The areas between consecutive contours were then multiplied by their assumed average elevations, the several products added together, and the sum divided by the total area of the State. By this method the average elevation of the State is found to be 632 feet, or but little different from the estimate made by Mr. Gannett prior to Mr. Rolfe's survey. It appears from the table that 20,000 square miles, or more than one-third of the State, stands between 600 and 700 feet above tide, or at about the average elevation of the State.

Areas of Illinois between 100-foot contours.

	Square miles.
Above 1,200 feet	1
Between 1,100 and 1,200 feet	6
Between 1,000 and 1,100 feet	118
Between 900 and 1,000 feet	1,009
Between 800 and 900 feet	3,981
Between 700 and 800 feet	11,127
Between 600 and 700 feet	20,058
Between 500 and 600 feet	9,603
Between 400 and 500 feet	8,822
Between 300 and 400 feet	1,925
Total area of Illinois	56,650

RELIEF.

The relief of this district is so inconspicuous as to merit but brief attention in a discussion of the water resources. The greater part of the State is so nearly plane that it is difficult to discern the slope

[1] On the height of the land and the depth of the ocean: Scottish Geog. Mag., vol. 4, No. 1, January, 1888.


TOPOGRAPHIC MAP
OF
ILLINOIS AND WESTERN INDIANA
COMPILED BY
FRANK LEVERETT
1896
91°
90°
89°
88°
87°
42°
41°
40°
LAKE
MICHIGAN
MISSISSIPPI RIVER
Racine
Kenosha
Waukegan
Lake Forest
Highland Park
Evanston
CHICAGO
Michigan City
South Haven
St. Joseph
Berrien Springs
Niles
South Bend
La Porte
Valparaiso
Hammond
Calumet
Crown Point
Knox
Winamac
Rensselaer
Tippecanoe
Monticello
Logansport
Delphi
Kentland
Fowler
Wabash Riv.
La Fayette
Williamsport
Frankfort
Covington
Crawfordsville
Lebanon
Newport
Sugar
Galena
Freeport
Rockford
Harvard Jc.
Woodstock
Belvidere
Algonquin
Elgin
Savannah
Mt. Carroll
Oregon
Polo
Sycamore
DeKalb
Geneva
Wheaton
Clinton
Fulton
Morrison
Dixon
Sterling
Amboy
Rock Riv.
Aurora
Yorkville
Rock Island
Muscatine
Geneseo
Mendota
Princeton
Fox Riv.
Joliet
Des Pl. R.
Cambridge
Lasalle
Utica
Ottawa
Morris
Kewanee
Hennepin
Braidwood
Kankakee
Aledo
Toulon
Streator
Dwight
Kankakee River
Oquawka
Galesburg
Lacon
Wenona
Vermilion
Pontiac
Iroquois Riv.
Burlington
Monmouth
Minonk
Metamora
Watseka
Peoria
Fairbury
Ft. Madison
Canton
Pekin
Bloomington
Hoopeston
Keokuk
Carthage
Warsaw
Macomb
Lewiston
Illinois
Gibson
Paxton
Havana
Rushville
Lincoln
Clinton
Farmer City
Champaign
Danville
Big Vermilion
Beardstown
Petersburg
Urbana
Quincy
Mt. Sterling
Virginia
Monticello
Decatur


NOTE.
Data from Illinois obtained from unpublished contour maps showing 10-feet intervals. Prepared by C. W. Rolfe in 1893.
Scale
0 5 10 20 30 40 50 60 70 MILES
LIST OF COUNTIES
No. 1 Jo Daviess.
" 2 Stephenson.
" 3 Winnebago.
" 4 Boone.
" 5 McHenry.
" 6 Lake.
" 7 Cook.
" 8 Du Page.
" 9 Kane.
" 10 Dekalb.
" 11 Ogle.
" 12 Lee.
" 13 Carroll.
" 14 Whiteside.
" 15 Rock Island.
" 16 Mercer.
" 17 Henry.
" 18 Bureau.
" 19 Putnam.
" 20 Lasalle.
" 21 Kendall.
" 22 Grundy.
" 23 Will.
" 24 Kankakee.
" 25 Iroquois.
" 26 Ford.
" 27 Livingston.
" 28 Marshall.
" 29 Woodford.
" 30 Stark.
" 31 Peoria.
" 32 Knox.
" 33 Warren.
" 34 Henderson.
" 35 Hancock.
" 36 McDonough.
" 37 Fulton.
" 38 Mason.
" 39 Tazewell.
" 40 McLean.
" 41 Vermilion.
" 42 Champaign.
" 43 Piatt.
" 44 Dewitt.
" 45 Logan.
" 46 Menard.
" 47 Cass.
" 48 Schoyler.
" 49 Brown.
" 50 Adams.
" 51 Pike.
No. 52 Scott.
" 53 Morgan.
" 54 Sangamon.
" 55 Christian.
" 56 Macon.
" 57 Moultrie.
" 58 Douglas.
" 59 Edgar.
" 60 Clark.
" 61 Coles.
" 62 Cumberland
" 63 Shelby.
" 64 Montgomery.
" 65 Macoupin.
" 66 Greene.
" 67 Calhoun.
" 68 Jersey.
" 69 Madison.
" 70 Bond.
" 71 Fayette.
" 72 Effingham.
" 73 Jasper.
" 74 Crawford.
" 75 Lawrence.
" 76 Richland.
" 77 Clay.
" 78 Marion.
" 79 Clinton.
" 80 St. Clair.
" 81 Monroe.
" 82 Randolph.
" 83 Washington.
" 84 Perry.
" 85 Jefferson.
" 86 Wayne.
" 87 Edwards.
" 88 Wabash.
" 89 White.
" 90 Hamilton.
" 91 Franklin.
" 92 Jackson.
" 93 Williamson.
" 94 Saline.
" 95 Gallatin.
" 96 Hardin.
" 97 Pope.
" 98 Johnson.
" 99 Union.
" 100 Alexander.
" 101 Pulaski.
" 102 Massac.
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without instrumental aid. There are, however, a few morainic belts, mentioned on another page, and a few ridges with rock nuclei, which are of sufficient prominence to merit a passing word.

The most prominent ridge is that of the so-called Ozark uplift, in the southern end of the State. This consists of a narrow belt of elevated land, scarcely 10 miles in average width, which crosses southern Illinois in an east-west course from near Shawneetown, on the Ohio, to Grand Tower, on the Mississippi. The crest of the ridge stands mainly between 700 and 800 feet above tide, or about 300 feet above border tracts, but, as previously noted, it rises at one point to a height of 1,047 feet. The points which stand much above 800 feet are, however, rare, and in the form of knobs, as may be seen by reference to the contour map (Pl. CVIII). The importance of this ridge in the discussion of water resources consists not so much in the fact of its being a divide between drainage basins as in its influence upon wells, it being difficult to obtain water along its crest.

In a few places along the eastern border of the Mississippi, from the western terminus of this ridge to the mouth of the Illinois, the Lower Carboniferous limestone rises markedly higher than the Coal Measures plain to the east, its general altitude being about 650 feet, while that of the border portion of the Coal Measures plain seldom exceeds 500 feet. In one place, in southern Jersey County, an altitude of over 800 feet is attained.

In the northwestern counties of the State are the so-called "mounds" of Niagara limestone, which rise abruptly 75 to 300 feet above bordering portions of the upland. In the aggregate these mounds cover but a few square miles. They are the remnants of formations which were once continuous over this region, as has been indicated by Professor Worthen.[1]

In the southeastern portion of the State, on the borders of the Wabash, there are a few low ridges and mounds of Coal Measures strata which rise above the general level of the bordering plains to heights seldom exceeding 100 feet. These are of very limited extent, covering in the aggregate but a few townships.

Aside from these instances the rock surface very rarely rises above the general level of the drift cover. It is probable that beneath the drift cover of the State there are forms similar to those of the district bordering the Wabash, and perhaps in the northern portions there are mounds as conspicuous as those of Jo Daviess County which have been covered by the heavier accumulations of drift which occur there. Such reliefs can be made out only by careful study of well borings and a full knowledge of the thickness of the drift.

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[1] Geology of Illinois, Vol. I, 1866, p. 4.

EFFECT OF THE DRIFT UPON TOPOGRAPHY AND DRAINAGE.

The discussion of the drift features will help to an understanding of peculiarities of drainage as well as of the topography, for the drift has a topography of its own, which to a great degree determines the boundaries of drainage basins.

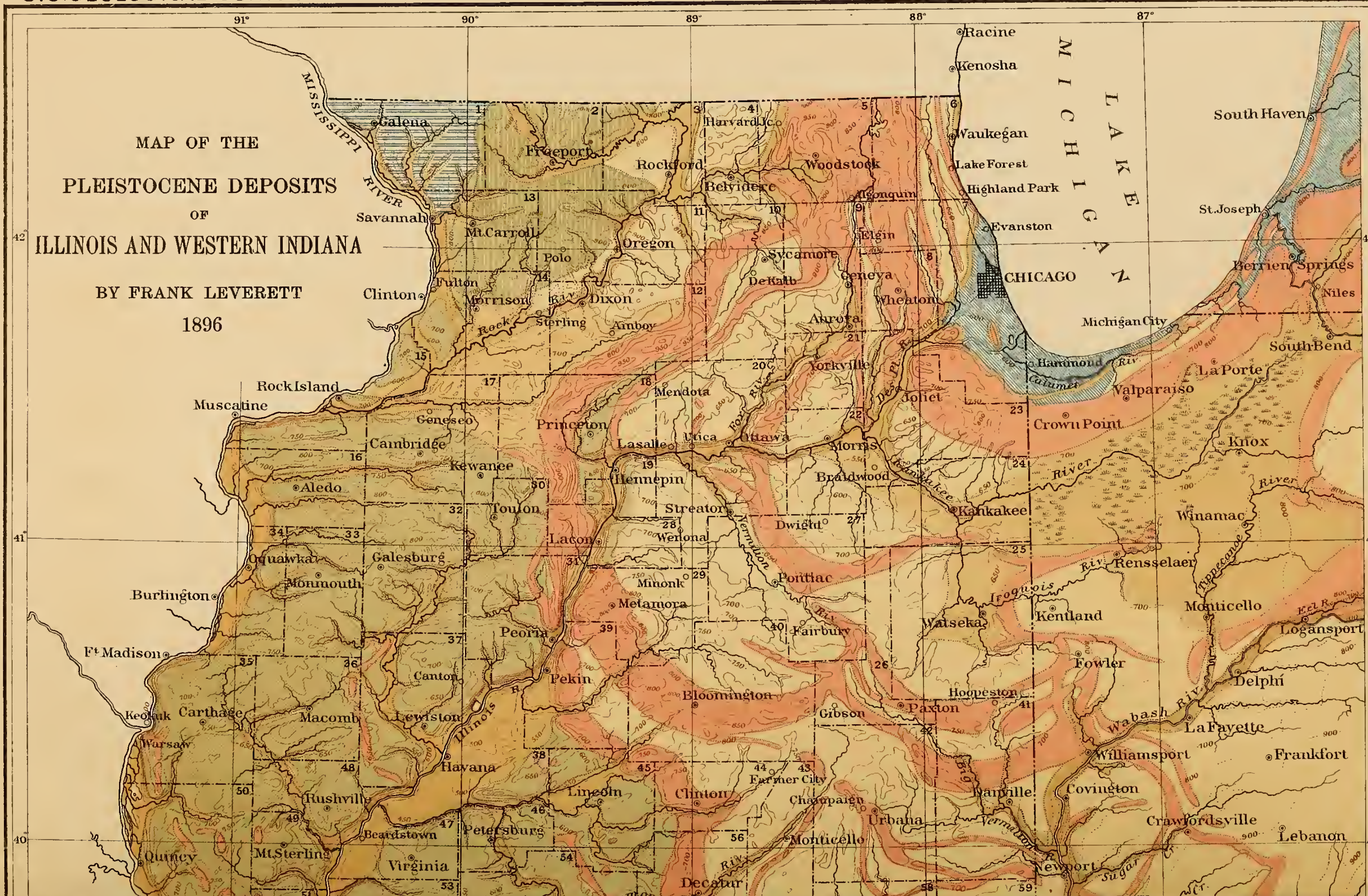
The southern limit of the glacial drift in Illinois is at the northern border of the prominent ridge above noted, which crosses the southern end of the State. Eastward the glacial boundary soon enters Indiana, but northwestward it remains within the limits of the State as far as St. Louis, and leaves the valley nearly free from till as far north as Quincy. Thin deposits of drift cover the greater part of the limestone ridges which appear along the east bluff of that portion of the Mississippi. From Quincy northward nearly to Savanna heavy deposits occur, which have in two cases (at the Des Moines and at the Rock Island rapids) been sufficient to displace the pre-glacial stream and compel it to excavate a new channel—in the Des Moines rapids for a distance of about 12 miles, and in the Rock Island rapids (with the continuation to Muscatine in a narrow valley) a distance of 40 miles. Above Savanna is the driftless area of the Upper Mississippi, which in its Illinois portion covers much of Jo Daviess County and portions of Stephenson and Carroll counties.

In southern Illinois, for about 75 miles north from the extreme limits of glaciation, or to about the latitude of St. Louis, Mo., the drift is so thin that it has not greatly changed the principal pre-glacial lines, its usual thickness being scarcely 30 feet; but north from that latitude the streams rarely for any great distance follow pre-glacial lines. The notable exceptions are the Mississippi, which follows pre-glacial drainage lines throughout much of its course, and the lower Illinois, which from the bend near Hennepin to its mouth, a distance of over 200 miles, is mainly in a pre-glacial valley.

Of the drift-covered district north from the latitude of St. Louis, a large portion has such an amount of drift as to completely conceal the pre-glacial features. This includes almost the entire northeastern third of the State. West and south of this tract of very heavy drift there are many places where the pre-glacial divides can still be discovered, and in a rude way the drainage conforms to that of pre-glacial times; the valleys tend to follow pre-glacial lines, though they seldom coincide with them; the water partings tend to follow pre-glacial divides, but are not strictly coincident with them.

The complete concealment of pre-glacial features is restricted mainly to the limits of the ice invasion which terminated at the Shelbyville moraine, the position of which is indicated on the accompanying glacial map (Pl. CIX). It will be observed that this moraine crosses the Kaskaskia at Shelbyville, the Sangamon a few miles west of Decatur, and the Illinois at Peoria. From Shelbyville it passes eastward into Indiana;

MAP OF THE
PLEISTOCENE DEPOSITS
OF
ILLINOIS AND WESTERN INDIANA
BY FRANK LEVERETT
1896



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from Peoria it passes northward, with an occasional slight curve to the east, into Wisconsin. The drift to the west and south from this moraine is markedly older than the moraine, and is called the older drift. This moraine and the surface portion of the drift in the district between it and Lake Michigan are called the newer drift.

The drainage systems have reached a much more advanced stage in the older drift than in the newer. The difference in stage of development is so marked, as represented in the topographical model of the State, prepared by Professor Rolfe, that it is said to have occasioned much comment from visitors at the World's Columbian Exposition, where the model was exhibited. This feature is apparent also on the topographic map here presented (Pl. CVIII). It can not be urged that greater advantages for the development of drainage lines are to be found in the older drift, for, so far as altitude and slope are concerned, the newer drift has the advantage, it being generally more elevated and more diversified in slope than the older drift. The differences in the structure are not great, the drift throughout both sections being composed mainly of bowlder clay. The bowlder clay of the newer drift is now more easily eroded than that of the older, but the hardness of the older drift may have been acquired since drainage lines were developed in it.

The average thickness of drift for the entire glaciated portion of the State is about 75 feet. The thickness of the drift in the district outside of the Shelbyville moraine is less than half as great as that of the district between the moraine and Lake Michigan. It is estimated that the newer drift of Illinois, although confined to less than half the drift-covered portion of the State, is as great in amount as the older drift. The usual thickness of the older drift, aside from filled valleys, is but 20 to 50 feet, while the thickness where both the older and newer drift are present is usually 100 to 150 feet. This great contrast in thickness is to be seen at the border of the Shelbyville moraine, and is shown by the relief of the moraine above districts west and south of it, as well as by the borings, which reveal corresponding distance to rock. On the contour map (Pl. CVIII) it will be observed that two of the 50-foot contours are usually required to indicate the relief of the moraine above the district south and west of it.

In the portion of the State covered by the newer drift there is a succession of morainic ridges formed by the ice sheet during its retreat from the Shelbyville moraine. These ridges are separated by drift plains or basins from a mile or two up to 30 or 40 miles in width. These plains usually show a gradual rise on their landward (west and south) borders, while on the iceward borders (toward the Lake Michigan basin) they are found to rise abruptly to a moraine. The streams which now drain this region naturally chose the axes of these basins for their main channels, while the slopes carry the tributaries. It is the long slopes on the west and south and the short slopes on the opposite side which have caused the tributaries of the streams to be mainly from the west and south.

In the older drift there are very few morainic ridges, and these have seldom controlled drainage. As a rule, the drainage lines of that part of the State either conform to pre-glacial lines or follow belts where through some incident in drift filling the surface was left slightly lower than the general level. In the newer drift the high ground which determines the position of the main water partings is ordinarily a morainic ridge, but in the older drift it is usually the line of a pre-glacial divide. A brief review of the drainage features will make this apparent.

In southern Illinois the present division of the waters between tributaries of the Wabash and tributaries of the Mississippi corresponds in a rude way with that of pre-glacial times. Many of the small branches disregard pre-glacial lines, but the main streams entering both the Wabash and the Mississippi depart but little from pre-glacial lines of similar-sized streams.

In southwestern Illinois the present water parting between streams flowing northeast to the Sangamon and those flowing southwest to the Illinois conforms to a pre-glacial divide; but the small streams which lead from this divide to the Sangamon and the Illinois are thought to have taken their present courses through some deficiency in the drift-filling, for several of them are cutting new channels in rock in portions of their courses.

In the district lying between the lower course of the Sangamon and the Shelbyville moraine there is a pre-glacial basin filled so heavily with drift that the streams are entirely independent of pre-glacial drainage.

In western Illinois the present water parting between the Illinois and Mississippi apparently follows in the main the pre-glacial divide. In Pike County, however, Bay Creek, a tributary of the Mississippi, was evidently tributary to the Illinois in pre-glacial time, and was forced by the presence of the ice sheet near its mouth to cross an old watershed in its westward course to the Mississippi.

In northwestern Illinois changes of much consequence have occurred. The pre-glacial Rock River appears to have passed southward from Rockford to the Illinois Valley at the bend near Hennepin. The old valley is traceable as a trough, partially filled with drift, to the vicinity of Rochelle, in southeastern Ogle County, where it passes beneath the Shelbyville moraine and its further course is completely concealed. The present stream enters a new valley near the mouth of the Kishwaukee and crosses an old upland through Ogle and northwestern Lee counties, where it enters a lowland known as the Green River Basin. It crosses this lowland tract, and near its mouth enters the uplands again to join the Mississippi in its course across the Rock Island rapids. The stream is therefore not only in a new course, but in a course which shows remarkably little regard for the pre-glacial topography. The lowland referred to was formerly connected with the lower Illinois, but, like the southward course of Rock River, it became completely filled by the Shelbyville moraine, and the drainage was forced westward into the Mississippi either at the time that moraine was formed or at the time of an earlier ice invasion. Green River now furnishes the line of discharge for the main part of this lowland, but drains it very inadequately.

The district to the northwest of Rock River has apparently suffered slight changes of drainage. The main western tributary of Rock River, the Pecatonica, is in its pre-glacial course, but a western branch of that stream (Yellow Creek), entering at Freeport, has been beheaded, the head-water portion having been turned into the Mississippi through Apple River by a deposit of drift in the middle course of the old stream north of Stockton. The drainage of northern Carroll County has also been changed by drift deposits in the old valleys. A good illustration is found in Carroll Creek, which is in a new course at the rapids near Mount Carroll, while its head waters follow an old valley which apparently entered the Mississippi several miles farther south than the present mouth of the stream.

Considering the newer drift, the Shelbyville moraine, although as prominent as any of the moraines in Illinois, does not to any marked degree constitute a water parting. It is crossed by small as well as by large streams which have found their sources in the somewhat elevated plain on its north and east borders.

A prominent water parting is found in a moraine, or rather system of moraines, which north from Peoria is closely associated with the Shelbyville moraine, but which southeast from that city lies much farther north—the system on or near which Bloomington, Gibson City, Paxton, and Hoopston are situated, and which is termed the Bloomington system. From this morainic system the Sangamon and several of its northeastern tributaries lead southwest, the Big Vermilion leads southeast, the south branches of the Iroquois lead north, the Illinois-Vermilion leads northwest, and the Mackinaw leads west.

Between this morainic system and the Shelbyville moraine there is in eastern Illinois a less prominent morainic system, well developed near Champaign, and known as the Champaign moraine, which forms the head of the Kaskaskia and the Embarras rivers. The plain between this moraine and the stronger moraines to the north is drained at the west by the Sangamon and at the east by tributaries of the Big Vermilion and by Little Vermilion River.

The Illinois-Vermilion River drains an extensive plain lying between the Bloomington morainic system and a later morainic system (the Marseilles), following closely the southwest border of the later system.

The Mackinaw River follows for a short distance the inner (northeast) border of the Bloomington morainic system and then turns southwest across it and continues across the Shelbyville moraine into the Illinois. The other streams mentioned, as a rule, take courses directly away from the moraines, though Big Vermilion flows for much of its course in a narrow trough between two members of the Bloomington morainic system, and Little Vermilion follows throughout much of its course the north border of the Champaign moraine. The Iroquois drains an extensive plain or drift basin between the Bloomington and the Marseilles moraines—a basin noted for the flowing wells which it yields—and also a small basin in western Indiana, inclosed by a moraine of the Erie-Saginaw series, through which it passes just west of the State line. (See Pl. CIX.)

North of the Illinois is Fox River, in its lower course draining a plain lying west of the Marseilles moraine, and having tributaries mainly on its west side, because it follows closely the border of the Marseilles moraine. The head-water portion of Fox River for a distance of 75 miles lies in the midst of morainic ridges.

On the inner border of the Marseilles moraine, around the head of the Illinois, is a plain or basin drained in its northern portion by Au Sable Creek and in its southern portion by Mazon Creek. The slope of this basin throws the drainage eastward to the head of the Illinois. Upon entering that stream the water returns westward, passing through the moraine and out of the basin at Marseilles.

A narrow drift ridge (the Minooka moraine) runs south into this basin as far as the head of the Illinois. To the east of this ridge is a narrow plain drained by the Dupage, whose eastern border is the Valparaiso moraine.

From the head of the Illinois a plain some 25 miles in width extends eastward far into Indiana, constituting the main part of the drainage basin of the Kankakee. On its north is the Valparaiso moraine (named from Valparaiso, Ind., which is situated upon it), while on its east and south are moraines belonging to the Erie-Saginaw series. (See Third Ann. Rept. U. S. Geol. Survey, Pl. XXXI.)

Between the Valparaiso moraine and Lake Michigan, Calumet River is found at the east and the Des Plaines and Chicago rivers at the north. Calumet and Chicago rivers discharge into Lake Michigan, but the Des Plaines turns southwest through the Valparaiso moraine, following a former outlet of Lake Michigan to the Illinois known as the "Chicago Outlet." Throughout most of its course before entering the Chicago Outlet the Des Plaines flows in a narrow drift basin having the Valparaiso moraine on its western and a smaller moraine on its eastern border.

The well borings, and also to some extent the valleys of the present Fox, Des Plaines, and Kankakee rivers, throw some light upon the probable position of the pre-glacial divide west of Lake Michigan. They show that the Niagara limestone rises westward from the border of Lake Michigan to an altitude 50 to 100 feet or more above the present lake level, along a line leading southward across northeastern

Illinois. This elevated portion of the limestone is crossed by Fox River below Elgin, by Des Plaines River between Lemont and Joliet, and by the Kankakee a short distance east of the State line. It seems highly probable that this constituted a pre-glacial water parting, and that the head-water portions of Fox, Des Plaines, and Kankakee rivers were in pre-glacial times tributary to the Lake Michigan basin. This ridge is the only probable water parting in the entire region covered by the newer drift of Illinois which the writer was able to recognize.

THE CHICAGO OUTLET OF LAKE MICHIGAN.

The southwestward or "Chicago Outlet" of Lake Michigan, as pointed out some years since by Col. James H. Wilson and William Gooding, C. E.,[1] by Dr. H. M. Bannister,[2] and by Dr. Edmund Andrews,[3] entered the present Des Plaines Valley immediately west of Chicago and passed thence down to the Illinois. The effect of this outlet upon the size of both the Des Plaines and the Illinois is very marked. The upper portion of the Des Plaines down to the point where the ancient stream entered the valley is a small channel, 20 to 30 feet in depth and scarcely one-eighth mile in width, cut into the soft deposits of glacial drift. Upon entering the outlet the stream finds a valley more than a mile in average width, and cut to a depth of 50 to 100 feet or more, the depth varying with the altitude of bordering uplands. The excavation is mainly in drift, but for a few miles above Joliet it extends 25 feet or more into the rock.

The Illinois flows for a few miles in a low drift basin lying west of the Marseilles moraine, in which the ancient stream was expanded into a lake which built beaches instead of eroding a channel; but from the Marseilles moraine onward a large valley is cut, having an average depth of more than 100 feet and a width of about 1½ miles throughout the new course above Hennepin and nearly 3 miles in the old part of the valley below that town.

To appreciate how small a part of this excavation on the Illinois is due to the present drainage lines, one has only to turn to such tributaries as Fox and Vermilion rivers and compare the small channels cut by them with the large valley of the upper Illinois, for they are all cut to about equal proportions in the drift and in rock formations of similar kind. Fox River, which includes about one-fourth of the present drainage of the upper Illinois, has in its lower 75 miles a channel with about one-eighth the width and one-half the average depth of the upper Illinois, and is even better favored than the Illinois in its rate of descent. Instead of 25 per cent of the amount of excavation displayed by the Illinois, this stream has accomplished scarcely one-fourth that amount. It seems probable that at least three-fourths of the excavation of the

[1] Rept. U. S. Army Engineers, 1868, p. 442.
[2] Geology of Illinois, vol. 3, 1868, pp. 240-242.
[3] Trans. Chicago Acad. Sci., vol. 2, 1870, pp. 1-23.

upper Illinois, and even more of the portion of the Des Plaines occupied by the lake outlet, was accomplished by that ancient stream. In the lower Illinois, where the ancient stream worked entirely upon the loose materials of the drift, the excavation was larger in amount, and the valley presents a remarkably low gradient—so low that the present stream is silting up instead of eroding its bed. The fall of the stream in its lower 225 miles is but 30 feet. Whether this very low gradient is entirely due to the lake outlet or has been brought about in part through a warping of the valley has not been determined. It is certain, however, that the valley was opened throughout its entire course to a far greater amount than the present streams could have accomplished. No attempt will be made to discuss here the causes for the change in the outlet of Lake Michigan, since it involves great complications both of glacial retreat and of crust warping, neither of which is as yet well understood.

DRAINAGE BASINS.

The Mississippi receives probably three-fourths of the drainage of Illinois, mainly through the Rock, Illinois, and Kaskaskia rivers. The Wabash and Ohio receive nearly all of the remaining fourth, there being but a very small part of the State tributary to Lake Michigan.

ILLINOIS RIVER.

Of the streams which traverse Illinois, the Illinois is by far the largest, its drainage area being fully half as great as the area of the State and lying mainly within the State boundaries. The drainage area of the Illinois is estimated by Greenleaf, in his report for the Tenth Census, to be about 29,000 square miles. The estimate made by the Chicago Drainage Commission reduces it to 27,914 square miles. This area is distributed in three States, of which the proportion in each State is estimated by Greenleaf as follows: Illinois, 24,726 square miles; Wisconsin, 1,080 square miles; Indiana, 3,207 square miles. The drainage areas of the chief tributaries, given in order from source to mouth, also estimated by Greenleaf, are as follows:

Drainage areas of the chief tributaries of the Illinois River.

Stream.	Square miles.	Stream.	Square miles.
Des Plaines River	*a* 1,758	Mackinaw River	1,182
Kankakee River	*b* 5,302	Crooked Creek	1,286
Fox River	2,697	Sangamon River	5,592
Vermilion River	1,413	Macoupin Creek	1,000
Spoon River	1,905		

a The Chicago Drainage Commission estimates this area as 1,392 square miles.
b Estimated by the Chicago Drainage Commission as about 5,146 square miles.

The drainage area or watershed of the Illinois extends in a broad band, averaging 100 miles in width, in a northeast-southwest direction directly across the center of the State. From the northeastern extremity of this band there are two projections—one north into Wisconsin, including the Fox and Des Plaines river basins; the other east into Indiana, including the Kankakee and its main tributary, the Iroquois. The name Illinois is applied to the river from the junction of the Kankakee and Des Plaines. The western side of the watershed is 20 to 40 miles in width, while the eastern side is 60 to 80 miles.

The Illinois River is a stream showing marked contrasts in the rate of fall. From the junction of the Des Plaines and Kankakee westward for 50 miles, being in a new course, its bed is usually on the rock, and it has an average fall of about 1 foot per mile; but in the remainder of its course to the Mississippi, a distance of about 225 miles, it is in a pre-glacial channel and has, as previously stated, a very slight fall. This portion of the Illinois is discussed more in detail further on.

Des Plaines River.—The Des Plaines is a stream with moderate descent from its source to a point near the line of Cook and Will counties, a few miles southwest of Chicago, where it begins a rapid descent. It makes a fall of about 70 feet in 8 miles, when just below Joliet it reaches a pool known as Joliet Lake, which continues nearly to its mouth.

Kankakee River.—The Kankakee, for about 90 miles from its source, flows through a great marsh and descends scarcely 100 feet; but in the lower 50 miles of its course it descends about 135 feet over a rocky bed. Notwithstanding this rapid descent, the lower course of the river is not subject to disastrous floods, the rise above the ordinary stage being seldom more than 5 or 6 feet. The flow is equalized to some extent by the marsh in its upper section and by sand deposits which border the lower course and receive much of the surplus water from the tributaries.

Fox River.—This river has a length of about 130 miles, and drains a tract 15 to 30 miles in width. In the upper half of its course it winds about sluggishly through sloughs, marshes, and lakes, in the midst of a great system of moraines; in the lower half of its course it is a rapid stream. From the vicinity of Elgin to its mouth its bed is usually in the rock. The fall in its passage through Kane and Kendall counties is about 3 feet per mile, but in Lasalle County it increases to about 5 feet per mile, making a descent of nearly 125 feet in the lower 25 miles of its course. In its upper course tributaries are small and the flow is somewhat regular, but in the lower course several tributaries are received from a district in which slope and structure favor rapid run-off, and these produce the high stages of the river, sometimes reaching 10 or 15 feet above the normal.

Illinois-Vermilion River.—Vermilion River has a length of about 75 miles and drains a till plain perhaps 20 miles in width. This plain descends with the stream northwestward, so that for 50 miles scarcely any valley is formed, though there is a descent of nearly 100 feet. In the lower 25 miles the stream corrades rapidly, making a descent of about 150 feet and cutting its valley mainly in rock. This stream is subject to great variations in water height. It has not the marshy gathering ground of the tributaries just considered, and the drift formations in its basin are mainly of compact till which yields but little water in seasons of drought.

Spoon River.—Spoon River and Crooked Creek, the main western tributaries of the Illinois, have valleys cut mainly in drift, but exposing rock at many points along the base of the bluffs. They probably follow approximately lines of pre-glacial drainage throughout much of their courses, but are not strictly coincident with such lines. The rate of fall is more regular than in the tributaries just described. Spoon River in the lower 80 miles of its course, south from Stark County, descends from 2 to 3 feet per mile. Crooked Creek is nearly as regular in the lower 50 miles of its course, though more rapid. In the head-water portions of both streams the descent is more rapid than in the lower courses, thus reversing the habit of the upper tributaries of the Illinois. Both streams are subject to great variations in water stages because of rapid run-off. The rapidity of run-off is due to rapid fall and the generally well-drained surface. In seasons of drought springs along the valleys and main tributaries afford a considerable supply of the water.

Mackinaw River.—This river drains a somewhat elevated plain in northern McLean County, standing 300 to 350 feet above the Illinois. In its middle course in Tazewell County it breaks through a moraine, and there only has it excavated a valley of much depth. In the lower 20 miles it winds about in the Illinois Valley in a shallow channel, making a descent of about 75 feet. This stream is one of the most variable in the State in quantity of water, being subject to great floods in wet seasons and becoming nearly dry in seasons of drought. The variability is due to several causes—rapid fall, compact drift beds, and absence of head-water marshes being the principal ones.

Sangamon River.—Extensive plains in central Illinois are somewhat inadequately drained by the Sangamon River, whose tributaries do not ramify as thoroughly as is necessary for good drainage, and the area given as its catchment basin represents not that actually drained, but that which may, by extensive ditching, be drained into it.

The length of the river is about 180 miles. It rises in the morainic ridges of McLean County, at an altitude of about 850 feet above tide, or over 400 feet above its mouth (the mouth being 429 feet). In the first 10 miles it makes a descent of 120 feet, thus leaving 300 feet of fall for the remaining 170 miles of its course. The fall is far from regular, there being sections often several miles in length in which it is slight, between which are sections with more rapid fall. Thus in its course through Sangamon County, a distance of 36 miles, it falls only 38 feet, while in crossing Menard County, immediately below, it falls 67 feet in a distance of 30 miles, and in crossing Macon County, just above Sangamon, it falls 50 feet in about 30 miles. In the lower 23 miles, where it crosses the Illinois bottoms, its fall is only 16 feet.

This river in seasons of drought reaches a very low stage, becoming almost dry. The till plain which it drains yields very little water to the streams except immediately after rains have fallen. Freshets now seldom last more than a few days, and are said to be much briefer than before the district was brought under cultivation.

Macoupin Creek.—Macoupin Creek, Apple Creek, and other small tributaries of the lower Illinois show a rapid descent, their head waters being nearly 300 feet above the Illinois. They traverse a district in which drainage lines ramify through nearly every section. The drift being largely a compact till, rainfall is absorbed slowly. These streams therefore carry off a large amount of water, but in dry seasons they almost cease flowing.

ROCK RIVER.

Rock River, which drains much of northwestern Illinois, has a length of nearly 300 miles, its general course being southwest from southern Wisconsin across northwestern Illinois. Nearly one-half its length is in Wisconsin. The drainage basin has an area of about 11,000 square miles, of which slightly more than one-half is situated in Wisconsin. The greatest width is near the State line, where it is about 80 miles. The Wisconsin portion averages 40 or 50 miles, but in Illinois the basin suddenly narrows to 40 miles, and then to 25 miles. It is mainly a prairie region, though bodies of timber of considerable size are found within its limits. Above Janesville, Wis., where it leaves the Kettle moraine of the Green Bay lobe, the basin is characterized by extensive swamps and numerous small lakes which feed it in dry seasons. The Illinois portion is mainly undulating and well drained, though extensive swamps occur along Green River, an eastern tributary. From the Kettle moraine southward to the mouth of the Kishwaukee the river occupies an old valley, but above and below these points it follows new lines because of the filling of the old valley with glacial drift. The river derives its name from the rock ledges which it crosses in the new portions of its course, not only in the upper section but in the lower, as at Sterling, Ill., where there are rapids with a fall of about 15 feet in a distance of 2 miles.

The altitude of the stream at its source is about 875 feet and at its mouth 536 feet. The most rapid section, aside from short rapids, such as those at Sterling, is in southern Wisconsin, from the mouth of the Catfish to the mouth of the Pecatonica, where, for a distance of 30 miles, the average slope is nearly 2 feet per mile. This slight increase of slope is attributable to the greater accumulation of drift deposits in the northern end of the section than in the southern, the northern being in the vicinity of the Kettle moraine, which poured its gravel into the old valley to the south and caused a gradually decreasing amount of filling in passing from the moraine southward.

Rock River has three principal tributaries entering within the State of Illinois—the Pecatonica, the Kishwaukee, and the Green. The drainage area of the Pecatonica lies mainly within the State of Wisconsin. This stream is in a region which is well drained, and in consequence is fed but little during seasons of drought by swamps or lakes. The Kishwaukee River heads in an elevated morainic district and falls rapidly throughout its course, but as it is bordered by extensive deposits of gravel connected with marshes its flow is somewhat regular. Green River, also, is in a region bordered by swamps and gravelly deposits, which keep its flow somewhat regular.

The small tributaries in the Illinois portion of the drainage basin are, in the main, streams with rapid fall, and are usually free from swamps or deposits which will hold water. As a consequence they often become dry throughout portions of the year.

In Wisconsin the small tributaries are usually bordered by swamps, and contribute a somewhat regular flow to the river.

TRIBUTARIES OF THE MISSISSIPPI IN WESTERN ILLINOIS.

Both above and below the mouth of Rock River several small rivers enter the Mississippi, the principal streams above being Fever, Apple, and Plum rivers, and those below, Edwards and Henderson rivers and Bear Creek.

The first-mentioned group lie mainly in the driftless region, and have a very rapid but generally well-graduated descent. The rapid fall promotes a speedy escape of surface water; but, bordered as they are by limestone ledges from which springs issue, the stream beds seldom become dry.

The tributaries south of the mouth of Rock River drain till plains which stand only 200 to 300 feet above the Mississippi. Edwards River, draining parts of Henry and Mercer counties, with a length of nearly 60 miles, has a regular descent and an average fall of about 5 feet per mile. Its tributaries are small and it is seldom subject to freshets. Springs from the drift prevent the stream from becoming as low in seasons of drought as many streams of this size in central Illinois. Henderson River, draining much of northern Henderson, northern Warren, and part of Knox counties, is a more widely branching stream and subject to greater variations in volume than Edwards, though draining about the same amount of territory (450 to 500 square miles). With a length of nearly 50 miles, it makes a somewhat regular descent of 7 to 8 feet per mile to within 15 miles of its mouth, where it enters the Mississippi bottoms and thence falls but little. Bear Creek, draining western Hancock and northern Adams counties, is a widely branching stream, subject to high freshets and very low stages. At times it almost ceases flowing, though it drains an area of about 500 square miles.

KASKASKIA RIVER.

The Kaskaskia, or Okaw, is the principal river traversing southern Illinois. With a length of 180 miles, it drains nearly 6,000 square miles. Its source is in a moraine near Champaign, at an altitude of about 730 feet above tide. Its descent is gradual, even in the head-water portions, there being a fall of only 110 feet in the first 50 miles of its course. Its most rapid section is in its course through Moultrie County, where it makes a descent of 55 feet in about 18 miles, or 3 feet per mile. In places there are pools several miles in length, the most conspicuous of these being found in St. Clair County, where in a distance of over 20 miles the fall is scarcely 10 feet.

The stream is subject to great variations in volume, as it drains a region in which the substrata are of compact clay, which promotes a rapid run-off and furnishes but little water in seasons of drought. A rise of 20 feet in its lower course is not rare, and its flood plain has been built nearly to that height above the stream bed.

BIG MUDDY RIVER.

The only remaining important tributary of the Mississippi is the Big Muddy, a stream draining about 2,400 square miles in the low district lying north of the Ozark Ridge. It is a stream of comparatively low rate of fall, yet it is subject to freshets with a rise of 25 feet or more. Greenleaf reports the rise at Murphysboro to be 30 feet. In dry seasons it almost ceases flowing. Its great fluctuations, like those of the Kaskaskia, are largely due to the compact clays which underlie the region and prevent absorption of the rainfall.

TRIBUTARIES OF THE WABASH.

There are several tributaries of the Wabash, viz, Little Wabash, Bon Pas, and Embarras rivers, which, like the Big Muddy and Kaskaskia, have low rates of descent and yet are subject to great variations in volume, largely because of the compact clay of the region which they drain. The head-water portion of the Embarras, however, north from Cumberland County, drains a district with looser substrata. The Big and Little Vermilion rivers also drain districts in which the substrata are pervious, and in consequence they present a more uniform stream than the tributaries farther south. Big Vermilion, however, because of a very rapid descent in its lower course and the widely branching head waters, is subject to great freshets.

CHAPTER II.

THE RAINFALL.

In its rainfall the State of Illinois is, on the whole, well adapted for profitable agriculture. It is rare that any part of the State is subjected to a complete loss of any of its crops, either by drowning or by drought. The rainfall throughout the entire State, however, is subject to marked variations from year to year.

Records of rainfall are obtainable at a few points in Illinois and on its borders for a period of forty-five years, and at many points for fifteen to twenty years or more. From these records Mr. Harrington, formerly of the United States Weather Bureau, has estimated the average precipitation to be about 38 inches.[1]

The precipitation frequently amounts to several inches more than the normal, and there have been two years in which it exceeded 50 inches; it also frequently falls several inches below the normal, and occasionally is less than 30 inches. There is, therefore, in very wet years nearly twice as much rainfall in the State as in years of extreme drought. If single stations are considered, the wet years frequently show more than twice the precipitation of very dry years. While rainfall records are valuable in showing the average conditions, they are seldom sufficiently complete to indicate the probable effect upon crop production. Even records of daily rainfall are imperfect, since they seldom show the rate of downpour or the condition of the soil at the time of the rainfall, and these are factors of great importance in determining the efficiency of the rainfall in the production of crops. An inch of rain coming gently, when the soil is in condition to absorb it, may have a greater efficiency than several inches of downpour on a soil already saturated.

The tables below set forth as fully as may be in compact form the main results of rainfall records in Illinois and border districts. The first table shows the annual and seasonal averages for Illinois and neighboring States, compiled from Mr. Harrington's results in the bulletin on rainfall and snow. From this table it appears that Illinois is among the most favored of this group of States in the fall of rain during the portion of the year when it is needed for crops, 80 per cent of its comparatively large rainfall being in the spring, summer, and autumn months. As the ground is usually frozen throughout the greater part of the State in the winter months, precipitation, unless in the form of snow, is of little value. A blanket of snow often proves

[1]Rainfall and snow of the United States, compiled to 1891, by Mark W. Harrington: U. S. Dept. of Agriculture, Weather Bureau Bull. C, 1894, p. 56.

of great service in protecting winter wheat and grass lands, and in this respect Illinois is about as well favored as any of these States, and usually better favored than neighboring States to the west.

Table of annual and seasonal rainfall averages for Illinois and neighboring States.

State.	Area.	Spring.	Summer.	Autumn.	Winter.	Annual.	Cubic miles.
	Miles.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
Illinois	56, 650	10. 2	11. 2	9. 0	7. 7	38. 1	34. 0
Missouri	69, 415	10. 0	12. 4	9. 1	6. 5	38. 0	41. 2
Iowa	56, 025	8. 3	12. 4	8. 1	4. 1	32. 9	28. 8
Minnesota	83, 365	6. 5	10. 8	5. 8	3. 1	26. 2	34. 4
Wisconsin	56, 040	7. 8	11. 6	7. 8	5. 2	32. 5	28. 7
Michigan	58, 915	7. 9	9. 7	9. 2	7. 0	33. 8	31. 3
Indiana	36, 350	11. 0	11. 7	9. 7	10. 3	42. 7	24. 2
Ohio	41, 060	10. 0	11. 9	9. 0	9. 1	40. 0	25. 7
Kentucky	40, 400	12. 4	12. 5	9. 7	11. 8	46. 4	29. 3

The following table of yearly variations in rainfall has been compiled from Mr. Harrington's rainfall bulletin for the years 1851–1891, from the report of the Chief of the United States Weather Bureau for 1892 and 1893, and from the official bulletin of the Illinois State Weather Service for 1894 and 1895.[1] With the stations in Illinois have been included those on the immediate border in adjoining States. These are of value, for in the earlier years there were but few stations at which rainfall was recorded.

Table showing yearly variations in rainfall of Illinois.

Year.	Number of stations.	Average.	Range.
		Inches.	*Inches.*
1851	5	54. 1	45. 4–74. 5
1852	5	47. 8	38. 4–59. 4
1853	4	38. 9	30. 9–45. 2
1854	6	34. 1	23. 6–46. 3
1855	6	41. 7	29. 1–50. 5
1856	9	32. 7	23. 3–43. 9
1857	9	34. 1	27. 5–39. 8
1858	13	51. 1	45. 2–68. 8
1859	11	37. 3	26. 5–61. 3
1860	8	33. 9	25. 2–56. 2
1861	13	39. 0	30. 0–68. 6
1862	13	46. 7	34. 9–70. 4

[1] Weather and Crops, by C. E. Linney, director Illinois State Weather Service, Chicago.

Table showing yearly variations in rainfall of Illinois—Continued.

Year.	Number of stations.	Average.	Range.
		Inches.	*Inches.*
1863	11	33.5	25.6-50.4
1864	15	31.4	24.0-38.3
1865	16	40.0	24.5-51.8
1866	17	36.9	30.2-45.3
1867	19	30.2	22.4-40.2
1868	19	38.0	25.9-45.6
1869	20	41.8	30.4-51.5
1870	21	30.0	20.3-41.3
1871	18	32.3	22.6-40.8
1872	19	31.8	24.8-39.5
1873	18	38.3	19.7-54.5
1874	20	33.2	23.8-47.5
1875	20	40.5	26.9-59.5
1876	22	45.3	34.5-62.6
1877	20	41.9	33.3-54.9
1878	20	37.9	31.2-45.6
1879	20	32.0	21.5-52.3
1880	24	39.5	30.6-53.2
1881	22	41.8	32.7-56.4
1882	24	43.8	33.0-70.8
1883	27	44.1	33.7-61.5
1884	25	42.1	32.8-66.6
1885	27	39.5	32.1-50.1
1886	33	34.0	18.9-50.6
1887	33	32.2	16.1-38.3
1888	33	37.3	26.0-62.9
1889	34	34.7	24.4-42.8
1890	34	38.3	23.5-49.8
1891	32	33.0	25.9-45.1
1892	49	41.4	31.1-63.3
1893	53	34.1	20.3-48.8
1894	75	29.3	18.2-40.4
1895	97	31.9	19.7-46.4

The average rainfall shown in the above table is slightly lower than that given by the United States Weather Bureau, being 37.85 inches instead of 38.10. This is due to the exceptionally low rainfall of 1893–1895, which was not included in the estimate by Mr. Harrington. The average of the above table to the close of 1891 is 38.21 inches.

Of the forty-five years' record, it will be observed that twenty-two years are above and twenty-three years below the average (37.85 inches) rainfall. The period of most remarkable precipitation is that of 1875–1885, inclusive. But one year was below the normal, and the average for the period of eleven years is 40.76 inches, or nearly 3 inches above the normal. The succeeding ten years have been marked by equally great deficiency. Only one year has been much above the normal, while seven have been much below, and the average is but 34.62 inches, or more than 3 inches below the normal. This period of drought is generally considered the most severe in its effects since the settlement of the State. It has resulted the past two years (1894–95) in a failure of wells and drying up of brooks and springs to an extent not known before. It has not, however, been remarkably disastrous to crops, since the little rainfall which occurred was adjusted to their needs. Just before the eleven-year period of great rainfall there was a period of twelve years (1863–1874, inclusive) marked by a deficiency in rainfall. Only two years were much above the normal, while seven years were much below it, and three were near the normal. The average precipitation for the twelve years is 35 inches, or nearly 3 inches below the normal. In the twelve years which preceded (1851–1862, inclusive) the few records given show an average of nearly 41 inches. Of these there are five years much above the normal, three years near the normal, and four years much below the normal. It is therefore not so strikingly a wet period as that of 1875–1885, when nearly every year was above the normal. The high average is due to the remarkably great precipitation in the wet years. Reviewing the above observations, the records suggest that there may be an alternation of wet and dry periods with a length of eleven to twelve years. They cover too brief a space, however, to warrant generalizations of much value.

In this connection it may be remarked that the reports of the United States Weather Bureau and the records of the State Weather Service show an apparent periodicity in several other of the North Central States. In Wisconsin, from 1863 to 1874 the average rainfall was but 30.22 inches, and only one year (1870) showed a precipitation greater than the normal. In 1875 to 1885 the average rainfall was 37.66 inches, and in none of these years was the rainfall so low as the normal (32.5 inches). In 1886 to 1895 the average rainfall was only 30.43 inches, and in only two years of the ten was the rainfall above the normal. The wet and dry periods stand out less clearly in Iowa than in Wisconsin and Illinois, but this is largely due to the enlargement of territory over which observations are made in the later periods. Down to 1875 the Iowa observations were mainly in the eastern part of the State, where rainfall is heaviest, while from 1875 onward the observations extend over the less humid western portion. From 1851 to 1862 the rainfall in eastern Iowa was slightly above 40 inches, while from 1863 to 1874 it was about 35 inches. The rainfall of the entire State from 1875 to 1885 was about 36 inches, while from 1886 to 1895 it was only 28.97 inches. The normal for the entire State in twenty years (from

1875 to 1895) is 32.58 inches. In the period from 1875 to 1885 the rainfall in but one year (1879) was markedly below the normal, while in the period from 1885 to 1894 it was but one year (1892) markedly above the normal, though slightly above in one other year (1888).

An examination of the records in Missouri affords little evidence of the periodic variation. Of the States to the north and west of Iowa, Nebraska and South Dakota present, in the last twenty years, a distribution of precipitation above and below normal similar to that shown in the three States just considered, but North Dakota and Minnesota do not show such a distribution, at least not in so marked a degree. In Nebraska the observations prior to 1875 are mainly in the eastern part of the State, and accordingly do not indicate so low a rainfall as would be expected were the more arid western portion included. This eastern portion, however, shows an average rainfall of only about 24 inches from 1868 to 1874, while the records for 1875 to 1885, from a much wider area, show an average rainfall of 28 inches. This was followed by a period of less rainfall, the average for the years 1886 to 1895 being but 22.34 inches. The normal rainfall for Nebraska is about 25 inches. The rainfall was not markedly below this amount in any year between 1875 and 1885, while in the period from 1886 to 1895 it rose above the normal in but one year (1891). In South Dakota the records prior to 1875 are mainly from the southeast portion, which is the most humid, and yet the records from 1869 to 1874 show an average yearly rainfall of but 18.55 inches. From 1875 to 1885 the average was about 25 inches, and throughout much of this period the entire State was fairly well represented by stations. In the period from 1886 to 1895 the average yearly rainfall has been barely 20 inches. In but one year (1892) did it rise to the average rainfall of the preceding decade.

These observations are certainly suggestive of periodic variations in rainfall, covering as they do an area of several States. It will be a matter of importance to note, as time goes on, whether the teaching of the weather records sustains periodicity. If definite alternate wet and dry periods occur, the agriculture can be adjusted to the conditions and shortage of crops of certain kinds be foreseen.

Since making the above estimates from the rainfall records, I have found the following allusion to eleven-year cycles in Davis's Meteorology:

> It is true that slight fluctuations of rainfall and temperature in nearly eleven years, corresponding to the sun-spot cycle, have been made out at certain stations for a moderate number of periods; but the fluctuations have not yet been shown to be general, uniform, and persistent. A longer variation is indicated over Europe and in certain other countries in a period of thirty-six or thirty-seven years, as shown by Brückner's review of all available records of dry and wet years, high and low stages in rivers, abundant and scanty crops, etc.; but at least another century will be needed fully to confirm this result and to extend it over the world.[1]

[1] Elementary Meteorology, by William Morris Davis, 1894, p. 346.

It is deficiency rather than excess of rainfall which injures the crops, even in Illinois, the most humid of the States in the group just discussed. A deficiency of rainfall has never been so serious in Illinois as to cause complete failure of any crop over a great part of the State, such as the less humid States to the west and northwest have experienced. Its greatest danger lies in a deficiency between June and September, there being many years when the corn and other crops which ripen in autumn are shortened by drought at that season. It is often the case that heavy rains and low temperature from April to June keep the ground cold and damp. Then a reversal of conditions suddenly occurs and the ground becomes baked by the hot, dry atmosphere and blazing sun. Much of central and southern Illinois, where the flat surface prevents ready escape, or the nearly impervious subsoil prevents ready absorption of the rainfall, is subjected to this baking process, and the fertility of the soil is greatly checked thereby.

In the following table the range in rainfall is shown at each of the stations in Illinois and on its borders where observations have been kept for periods of several years:

Table showing range in rainfall at the principal stations.

Station.	Years of record.	Lowest.		Highest.		Range.
		Inches.	Year.	Inches.	Year.	
Anna	1876–86	37.6	1881	55.3	1876	17.7
Augusta	1857–80	25.5	1879	54.0	1862	28.5
Aurora	1866–95	30.3	1866	47.9	1892	17.6
Athens	1851–58	25.2	1856	47.3	1858	22.1
Cairo	1872–95	26.6	1872	61.5	1882	34.9
Centralia	1880–91	35.5	1881	59.8	1883	24.3
Chicago	1867–95	22.4	1867	45.8	1883	23.4
Collinsville	1883–91	31.1	1891	44.8	1888	13.7
Dubois	1864–73	26.0	1871	52.7	1873	36.7
Elmira	1866–82	24.4	1867	42.3	1869	17.9
Geneseo	1874–87	23.0	1886	42.6	1877	19.0
Golconda *a*	1879–95	33.7	1887	70.8	1882	37.1
Grand Tower	1886–90	28.9	1887	48.5	1890	19.6
Griggsville	1882–95	25.9	1891	50.5	1894	24.6
Galesburg	1862–71	23.1	1870	42.9	1862	19.8
Greenville	1883–95	33.5	1891	66.6	1894	33.1
Havana	1871–77	30.4	1874	45.6	1876	15.2
Hennepin	1871–78	26.0	1874	37.3	1876	11.3

a By including earlier observations a rainfall of but 30.4 inches is found at Golconda in 1868 and 30.7 inches in 1869, thus increasing the range to 40.4 inches.

Table showing range in rainfall at the principal stations—Continued.

Station.	Years of record.	Lowest.		Highest.		Range.
		Inches.	Year.	Inches.	Year.	
Irishtown	1886–91	31.6	1891	42.8	1888	11.2
Louisville	1870–80	33.7	1872	62.6	1876	28.9
McLeansboro	1882–95	30.0	1887	56.4	1883	26.4
Manchester	1856–72	26.1	1871	49.4	1858	23.3
Mattoon	1880–95	24.2	1895	52.9	1872	28.7
Mount Carmel	1886–95	35.7	1887	59.3	1894	24.6
Marengo	1851–91	24.0	1864	56.9	1851	32.9
Mount Sterling	1870–80	21.7	1879	50.7	1876	29.0
Oswego	1880–95	27.4	1888	43.1	1894	15.7
Ottawa	1856–95	23.6	1887	55.7	1862	32.1
Palestine	1883–95	35.3	1887	54.1	1883	18.8
Pana	1883–93	35.2	1884	63.3	1892	28.1
Philo	1886–95	28.9	1891	41.4	1895	12.5
Peoria	1856–95	23.6	1870	53.4	1862	29.8
Pontiac	1886–91	16.1	1888	30.3	1891	14.2
Rockford	1874–95	23.8	1874	47.5	1884	23.7
Rock Island	1867–91	19.7	1873	43.8	1869	24.1
Sandwich	1860–91	25.9	1868	70.4	1862	44.5
Springfield	1880–95	25.2	1887	58.2	1883	33.0
Sycamore	1882–95	25.3	1889	51.0	1883	25.7
Winnebago	1858–95	26.5	1859	45.2	1858	19.7
Watseka	1886–90	29.4	1888	37.0	1890	7.6
Wyanet	1866–75	27.9	1867	51.5	1869	23.6
New Harmony, Ind	1854–83	23.3	1856	48.9	1880	25.6
Dubuque, Iowa	1861–95	18.3	1894	55.4	1881	37.1
Muscatine, Iowa	1851–94	23.6	1854	74.5	1851	50.9
Fort Madison, Iowa	1856–95	22.2	1879	52.3	1852	30.1
Keokuk, Iowa	1872–95	22.5	1879	51.5	1876	29.0
Louisiana, Mo	1878–94	21.5	1879	41.1	1884	19.6
St. Louis, Mo	1851–95	22.6	1871	68.8	1858	46.2
Beloit, Wis	1861–88	20.3	1870	46.4	1881	26.1

From the above table it appears that 6 of the stations show a range of over 3 feet in amount of yearly rainfall, while 27 of the 49 stations show over 2 feet variation, and the few stations in which there are variations of less than 1 foot are among those which have kept records for only a few years. Of the 24 stations which have kept records for more than fifteen years none show a variation of less than 15 inches. An examination of the dates of highest and lowest rainfall at the different stations shows that they do not correspond in any marked degree to the dates of high and low rainfall for the entire State. At the majority of stations the extremes in precipitation mark simply local excess or deficiency, and they serve to indicate the great influence of such local conditions. As already remarked, so much depends upon several poorly known conditions, such as the rate at which the rain descends, the power of the winds to absorb moisture, and the condition of the soil at the time of a rainfall, that even tables of daily rainfall may convey wrong or inadequate conceptions as to excess or deficiency of precipitation. Much more is this the case where monthly, seasonal, or annual averages are consulted.

It may be said that in general in Illinois a rainfall below 25 inches results unfavorably to crops, but it not rarely occurs that average crops have been grown where there has been for a single year a rainfall slightly below that amount, and where, even for a succession of years, it has been but little above. If, therefore, it is found, as in the above table, that at nearly half the stations the rainfall has been as low as 24 inches, it should not be inferred that the deficiency resulted in serious damage to crops. Often a year with 30 inches or more of rainfall at a given station has a more prolonged and serious drought in the growing season than one with but 24 inches. Judging from the experience in more arid districts to the west of Illinois, a rainfall of but 20 inches in a year, if well adjusted to the needs of crops, may be sufficient to made a region productive.

It may not be safe, however, to assume that a humid region can be reduced suddenly to a rainfall so low as that which will supply an arid region with a sufficient amount of moisture for the growth of cereals. Investigations by Prof. Milton Whitney, of the United States Department of Agriculture, have shown that where the subsoil is dry, as in the arid region of western United States, the rainfall is less liable to be drawn down into the earth to a depth beyond the use of plants than it is where a moist subsoil occurs. Concerning this matter Professor Whitney remarks:

> There is one factor which has a very important bearing upon the conditions in the humid as compared with those in the arid regions. In the humid regions of the Eastern States the soil is continuously moist from the surface down to a depth at which it is completely saturated and from which water is constantly flowing out into wells, streams, and rivers. The water descends through the soil both by virtue of its own weight and by capillary force. According to capillary laws the water is pulled downward when the subsoil contains less water than the soil. Gravity and capillary force are both more effective in moving water through a moist subsoil than a dry one; hence there is danger in the East of the water being pulled down below the reach of plants in time of drought, while in the West, where the subsoil at the depth of a few feet is continuously dry, this could not happen.[1]

In the three following tables are set forth the details of precipitation

[1] Yearbook of U. S. Dept. of Agriculture, 1894, p. 156.

at a few points representative of the State of Illinois, extracted from the reports of the Weather Bureau:

Table of rainfall, by months, in percentages.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.
Cairo, Ill., July, 1871, to Dec., 1891	9.4	9.4	8.9	8.7	8.7	10.3
St. Louis, Mo., Nov., 1870, to Dec., 1891	6.3	8.3	7.9	8.7	10.5	13.4
Springfield, Ill., July, 1879, to Dec., 1891	5.9	9.3	6.7	7.8	12.9	13.2
Keokuk, Iowa, Aug., 1871, to Dec., 1891	4.8	4.8	6.0	8.3	11.4	14.0
Peoria, Ill., *a* 18 years	4.7	5.9	6.8	8.8	10.1	12.7
Chicago, Ill., Nov., 1870, to Dec., 1891	6.2	6.5	7.0	8.8	10.2	10.2
Rockford, Ill., *a* 15 years	6.9	6.1	6.9	8.3	9.0	12.0
Davenport, Iowa, Apr., 1872, to Dec., 1891	5.3	4.7	6.5	8.0	12.4	12.4
Dubuque, Iowa, Aug., 1873, to Dec., 1891	6.4	5.5	6.7	6.1	9.8	12.0
Averages	6.2	6.7	7.0	8.2	10.5	12.2
	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Cairo, Ill., July, 1871, to Dec., 1891	8.2	6.6	5.7	6.4	10.0	7.7
St. Louis, Mo., Nov., 1870, to Dec., 1891	8.9	6.8	8.4	6.8	7.9	6.1
Springfield, Ill., July, 1879, to Dec., 1891	6.4	6.4	8.5	8.5	8.0	6.4
Keokuk, Iowa, Aug., 1871, to Dec., 1891	12.6	8.8	10.0	8.8	5.7	5.4
Peoria, Ill., *a* 18 years	10.2	8.3	10.2	9.2	6.4	6.3
Chicago, Ill., Nov., 1870, to Dec., 1891	10.4	10.0	7.9	9.0	7.6	6.2
Rockford, Ill., *a* 15 years	10.73	9.6	8.0	9.7	6.2	6.0
Davenport, Iowa, Apr., 1872, to Dec., 1891	10.6	11.2	9.4	8.9	5.9	4.7
Dubuque, Iowa, Aug., 1873, to Dec., 1891	11.7	9.8	12.3	8.7	6.1	4.9
Averages	9.9	8.6	9.0	8.5	7.1	6.0

a Taken from charts by Capt. H. H. C. Dunwoody, Signal Office, Washington, 1889.

Table of greatest consecutive number of days with rain.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Cairo, Ill., *a* July, 1871, to Dec., 1891	7	11	7	7	8	13	7	6	8	6	7	10
St. Louis, Mo., Nov., 1870, to Dec., 1891	8	11	6	7	7	9	7	8	5	7	7	10
Springfield, Ill., July, 1879, to Dec., 1891	8	10	7	8	9	7	7	9	5	7	6	7

a In September and October, 1891, 13 consecutive days of rainfall.

Table of greatest consecutive number of days with rain—Continued.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Keokuk, Iowa, *a* Aug., 1871, to Dec., 1891	7	8	7	6	6	7	7	8	6	7	6	8
Chicago, Ill., *b* Nov., 1870, to Dec., 1891	7	12	12	9	10	10	7	10	9	8	12	8
Davenport, Iowa, Apr., 1872, to Dec., 1891	7	8	8	6	9	11	7	9	7	8	6	8
Dubuque, Iowa, Aug., 1873, to Dec., 1891	9	8	6	6	9	11	6	9	7	7	5	6

a In July and August, 1882, 11 consecutive days of rainfall.
b In July and August, 1880, 17 consecutive days of rainfall.

Table of greatest consecutive number of days without rain.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Cairo, Ill., *a* July, 1871, to Dec., 1891	10	9	15	12	13	12	16	16	27	15	12	13
St. Louis, Mo., *b* Nov., 1870, to Dec., 1891	12	12	9	13	11	23	19	23	15	15	14	18
Springfield, Ill., July, 1879, to Dec., 1891	7	8	13	16	10	10	18	15	14	14	10	11
Keokuk, Iowa, *c* Aug., 1871, to Dec., 1891	14	15	13	14	15	16	15	19	16	15	22	16
Chicago, Ill., Nov., 1870, to Dec., 1891	12	21	10	10	16	11	13	16	14	15	16	15
Davenport, Iowa, *d* April, 1872, to Dec., 1891	10	16	12	10	12	9	14	15	15	15	13	14
Dubuque, Iowa, *e* Aug., 1873, to Dec., 1891	14	21	12	16	10	12	11	14	15	14	14	15

a The longest period without rain is 28 days, in September and October, 1891.
b The longest period without rain is 28 days, in June and July, 1871.
c The longest period without rain is 26 days, in October and November, 1879.
d The longest period without rain is 24 days, in August and September, 1888.
e The longest period without rain is 26 days, in September and October, 1888.

In the table of rainfall by months it will be noted that there is a decrease in amount of precipitation in the winter months in passing from south to north. This difference in winter precipitation gives the southern end of the State more rainfall than the central and northern portions, there being very little difference in the amount of rainfall throughout the State in the spring, summer, and autumn months. The month of June has generally, throughout the State, a larger amount of rainfall than any other month. The precipitation in July and August, though averaging nearly as much as that of the spring and autumn months, is subject to great variations, there being in some years but a fraction of an inch in one or the other of these months, while in other years each month may have several inches of rainfall. The rain in these months is also very liable to be in the form of local showers, by which small areas may become well watered though in the midst of a drought-stricken district. The tables indicate that precipitation is greater during these months in the northern than in the central and southern parts of the State, and it is quite generally true that the northern portion suffers far less from the summer drought than the central and southern portions. This should perhaps be attributed only in part to the difference in precipitation, for the northern portion has a soil better adapted to withstand drought than has much of the remainder of the State, as is shown further on. Evaporation would also naturally be less rapid in the northern than in the southern part because of the higher latitude.

The tables of consecutive days with and without rain serve to indicate the comparative length of rainy and dry periods. It will be seen that the greatest length of rainy periods for each month is, with very few exceptions, markedly less than that of dry periods. These tables are nearly in accord with those showing the percentage of days with or without rainfall which appear in the reports of the United States Weather Bureau. At the stations included in the tables given above, the following is the mean percentage of days in which rain fell during the periods covered by the tables: Cairo, 38.5 per cent; St. Louis, 38.4 per cent; Springfield, 42.7 per cent; Keokuk, 35.4 per cent; Chicago, 44 per cent; Davenport, 40.8 per cent; Dubuque, 37.1 per cent.

As the recent great drought is several times referred to in the course of the discussion, a few observations concerning it are made at this point. The drought extended from June, 1894, to the early part of November, 1895, a period involving the whole of one growing season and the greater part of another. It is also the chief part of the season in both years during which evaporation is great. In the seventeen months of this period the rainfall was about 39 inches, or only 1 inch above the normal annual rainfall. The uniform prevalence of the drought is well shown by the records of the State Weather Service stations, which indicate that in 1894 no one of the 56 stations in the State had a precipitation so great as the average normal precipitation, and in 1895 only 7 stations out of 97 in Illinois and on its borders had a precipitation above the normal. The rainfall from April 1 to November 30, 1894, the growing season, was 7.66 inches less than the normal, and in the same part of 1895 it was 5.54 inches less than the normal. In 1895 a heavy rainfall in July (5.36 inches) greatly helped the corn and other crops which mature in the fall, and contrasted strongly with the same month in 1894, when there was but 1.45 inches of rainfall, an amount about half the normal for that month. The general effect of this drought has been no more disastrous to crops in Illinois than that of previous droughts, as, for example, the one which prevailed in 1870, 1871, and 1872; but the recent drought has, as already indicated, produced a greater lowering of the ground water and reduction of the supply in springs and shallow wells than any heretofore experienced.

In a discussion of water resources the minor contributions of moisture in the form of dew merit consideration. This is especially true in a region like Illinois, where in seasons of drought the heavy dews often partially offset the deficiency of rainfall. Very few observations of value have as yet been made upon this subject, and these are mainly based upon the erroneous supposition that dew is contributed almost wholly by the atmosphere. It is probable that the amounts contributed by the several sources—air, earth, and vegetation—vary greatly at different places and at different seasons in a given place, and it may be no easy task to make the discriminations. In damp regions the ground doubtless contributes a large part of the dew, and is probably a chief source of moisture for frost. It has been estimated that the dew precipitated in Great Britain would measure $1\frac{1}{2}$ inches in depth, but as measurements are difficult the estimate may be only a rude approximation.[1] In some seasons of drought the effect of dews upon the crops of Illinois apparently equals a rainfall of 1 inch or more.

The benefit of dew is recognized by observant farmers, and a striking contrast in the effect of droughts which are accompanied by dew and those not so accompanied is appreciated and commented upon. In Illinois, however, there are other conditions accompanying drought which are far more influential than presence or absence of dew. A prevailing cloudiness, or freedom from hot, dry winds from the southwest, often carries a crop through a season of drought more prolonged than could be endured under a clear sky, even though accompanied by dew, to say nothing of one in which there is a clear sky with a scorching southwest blast.

[1] Elementary Meteorology, by W. M. Davis, p. 156.

CHAPTER III.

THE RUN-OFF.

QUALIFYING CONDITIONS.

The run-off for any given area is dependent upon several conditions, the more important of which are rainfall, slope, perfection of drainage lines, geological structure, vegetation, and temperature. For any given locality the slope of surface, stream bed, perfection of drainage, and geological structure may be assumed to be constant, while the other factors are variable. But if we take into consideration a large area like the State of Illinois, all factors are variable.

The slope of stream beds, as indicated above, ranges from the very low rate of descent of the lower Illinois, with a fall of but 30 feet in 225 miles, to a descent, as in the lower portion of the Des Plaines, Kankakee, Fox, and Vermilion rivers, of several feet per mile. Throughout much of the State, however, the main streams depart but little from a fall of 2 feet per mile, while the Mississippi, lower Illinois, and lower Wabash fall much less than 1 foot per mile. The small streams seldom fall at a more rapid rate than 5 to 10 feet per mile, except in the small head-water tributaries. On the whole, therefore, the slope of stream beds is low, and run-off, so far as influenced by them, is moderate.

With very few exceptions the slope of the surface is low. Aside from the rock mounds and ridges above noted and a few sharp drift knolls and prominent morainic ridges, the slopes are seldom greater than 20 feet per mile, and it is estimated that over fully half the State they are less than 10 feet per mile. The slopes in the older drift region (that lies outside the Shelbyville moraine, Pl. CIX) are, as a rule, less rapid than in the newer drift, because of the rare occurrence there of moraines or other drift ridges to give the surface relief. This lack of relief is, however, compensated for in the older drift by greater maturity of drainage systems.

Throughout much of the newer drift area there is a very imperfect system of drainage, with areas often several square miles in extent in which no channel has yet been opened; while in the older drift and in the driftless portions of the State a comparatively perfect system of drainage has been developed. In much of the older drift, drainage lines are so well arranged that there remain only occasional tracts of a few acres along water partings where no surface outlet occurs; such poorly drained tracts seldom reach a square mile in extent. The conditions for escape of water are therefore less favored by original slope in the older than in the newer drift, but are better favored by perfection of drainage lines.

The geological structure presents important variations. Although the single term "drift" is made to cover the surface deposits of much of the State, it does not follow that there is uniformity. The drift deposits vary as greatly in their capacity to absorb the rainfall as do the several rock formations which appear within the State. Were their thickness sufficient to compare with the pervious rock formations, the gravel and sand of the drift would have no equal among indurated rocks in capacity to absorb moisture. On the other hand, the compact clay, such as covers much of southern Illinois, can scarcely be equaled by any of the rock strata of Illinois in its power to withstand the penetration of water. The drift deposits are so variable in structure from place to place, and also in vertical section, that it is difficult to indicate precisely the extent of any particular deposit. On the whole, the surface gravel and sand are of importance only in the northern part of the State. They include much of the Kankakee drainage basin and of the portion of Illinois lying north of the west-flowing part of the Illinois River. The gravel deposits are especially abundant in McHenry, Kane, and Dupage counties, both on uplands and along valleys. In counties farther west they are confined mainly to valleys or lowlands. The effect of these deposits is to give a regular run-off, for they often absorb sufficient rainfall to furnish in seasons of drought a larger amount of water than is supplied by the rainfall of such seasons.

The absorption by the earth, or ground storage, is probably a much more potent factor than any yet mentioned. Throughout the heated term the ground water is usually lowered to such a degree as to give the earth great capacity for absorbing the rain. It thus happens that the heaviest rainfalls of July and August seldom greatly increase the discharge of streams, while those of May or June, even though less in amount, may, because of the saturated condition of the soil and subsoil, produce disastrous floods. A large amount of water is usually to be found in the earth at levels above that of adjacent stream beds. The surface of this ground water corresponds more nearly with the surface of the ground than with the horizon of adjacent stream beds. In wet seasons, in humid districts such as Illinois, it is raised quite to the surface, while in dry seasons it is lowered a few feet by evaporation, by plant absorption, and by escape to streams. It seldom, however, becomes so low as to reach the horizon of stream beds, and therefore contributes water to the streams in dry as well as in wet periods. It thus happens that for a period of several months the run-off from a drainage basin may exceed its rainfall.

Surface storage is another important modifier. Where there are lakes or basins in which the water is collected and fed slowly to the streams, as in the Kankakee and Green River basins, the discharge of streams is equalized and made somewhat uniform throughout the year, even though the rainfall varies greatly in different seasons of the year. Whether or not surface storage greatly diminishes the amount of run-off depends upon the amount of evaporation or absorption, and varies with different drainage basins.

Vegetation may either increase or retard the escape of water, and does not greatly affect the amount discharged. Its retarding effect may be seen by comparing the rapid rise of streams after a heavy rain in districts where there are cultivated fields with the less rapid rise where the streams are bordered by forests or by dense grasses. On the other hand, it is often the case that under moderate rainfall cultivated fields absorb water more rapidly than meadows.[1]

The temperature also modifies the amount of run-off at any given place, there being more rapid disposal of rainfall by evaporation in the heated seasons than in the colder portions of the year.

The above considerations may be embodied in the following statement: The run-off from any district indicates the excess of precipitation over the evaporation and absorption which take place in that district. As evaporation and absorption, as well as precipitation, vary in the different seasons of the year, and to some degree from year to year, the volume of a stream is usually subject to considerable fluctuation, and it becomes not an easy matter to estimate the normal run-off.

USUAL REGIMEN OF ILLINOIS STREAMS.

In Illinois the volume of the streams has a series of seasonal variations, there being three periods when the volume is great, two periods when it is low, and one period when it is moderate.

The order of events is about as follows: During the winter, when the ground is frozen and precipitation is comparatively light, the streams are low. In early spring the thawing of the ground and the greater precipitation lead to a spring freshet, when the streams are often bankfull or even overflowing. This freshet usually occurs in March or early in April. For a few weeks after this freshet the streams are at a moderate stage, slightly above the normal. This is followed by the "June rise," occasioned by the great rainfall which occurs in that month, when streams often reach as high a stage as in the spring freshet. After the June rise the streams usually drop to a low stage and remain low through the heated term, evaporation and absorption being so great as to dispose of nearly all the rainfall. In the autumn, about the autumnal equinox or a little later, heavy rains occur, which cause the streams to become swollen for a few days, or even weeks, but which seldom cause them to overflow their banks. In some years these seasonal variations are slight, and the streams show but little change in volume, but such years are exceptional. The rainfall is seldom sufficient to cause freshets to last for more than a few days. The moderate and low stages are estimated to generally cover ten months of the year, and occasionally eleven months.

[1] For data concerning the effect of different methods of cultivation on the amount of absorption and depth of soil moisture, see discussion by Prof. Milton Whitney, Yearbook of U. S. Department of Agriculture, 1894, pp. 159–162.

During a period of years when the rainfall is above the normal the streams reach a very low stage only for a small part of the year, whereas in periods of low rainfall a low stage is maintained or a large part of the year. Such has been the case in the dry period of 1894 and 1895, there being but a few weeks of the seventeen months covered by the drought in which the rivers rose above the ordinary low flow, and much of the time they were far below it. The run-off for these years amounts to but a small fraction of the ordinary discharge. In streams visited by the writer in southeastern Iowa, it is estimated to be not more than one-tenth. Thus in Skunk River, which is estimated by the proprietors of mills on its lower course to have an ordinary low-water flow of about 600 cubic feet per second, the low-water stage for much of the seventeen months of drought was but 50 to 100 cubic feet per second.

STREAM MEASUREMENTS.

But few measurements or reliable computations have been made on Illinois streams, but such as have been made cover some of the largest streams of the State or its borders. On the Mississippi at Grafton (just below the mouth of the Illinois) and at Hannibal, Mo. (above the mouth of the Illinois), measurements were made by the United States Army engineers, covering the year 1882.[1] Several measurements of the Illinois and its tributaries have been made at different points by the United States Army engineers, by the Chicago Drainage Commission, and by other organizations. Rock River, also, has been measured at different points by competent engineers.

ROCK RIVER.

The discharge from this valley has been estimated by Greenleaf from a careful gaging at Milan, a few miles from the mouth of the stream. The ordinary low-water flow is found to be 3,932 cubic feet per second, or 0.36 second-foot per square mile. Greenleaf estimates the average yearly flow to be 9,944 cubic feet per second, or 0.90 second-foot per square mile.

In September, 1895, careful measurements with gage were made below the mouth of the Pecatonica, near the city of Rockford. The measurements were conducted by E. C. Rae, an electrical engineer from Chicago, who was accompanied by the city engineer of Rockford and an expert hydraulic engineer. The results of the measurements are summarized as follows in Mr. Rae's manuscript report to the mayor and city council of Rockford.[2]

Measurements of Rock River near Rockford, Ill.

	Square feet.
Cross section of river	1,487
Speed of water in feet, per minute	41.36
Flow in cubic feet, per minute	61,502

[1] Report of U. S. Army Engineers, 1883, Appendix TT, pp. 2671-2675.

[2] The writer is indebted to Mr. Daniel W. Mead, C. E., of Rockford, for a copy of the report.

The flow per second is therefore about 1,026 feet, which is only 0.158 second-foot per square mile of area, the area of the portion of Rock River above that point being about 6,500 square miles. Mr. Rae's report also contains the following statements:

From all appearances, and from the evidence at our disposal, the water was at its lowest stage, and as the rainfall has been below the average during the past eighteen months, it will be safe to assume that the results obtained in the gagings show the lowest volume likely to occur. * * * The normal height of the water, however, should be about 2 feet above its surface at the time of gaging, which would of course increase the volume.

The additional 2 feet of depth would increase the flow to about 1,600 cubic feet per second, or nearly 0.25 second-foot per square mile. This may be taken as the ordinary low-water discharge. It is slightly lower than that from the entire basin. Accepting Greenleaf's estimate of the ratio between the ordinary low flow and the average yearly flow (4:10), the latter will be about 4,000 cubic feet per second, or 0.6154 second-foot per square mile of area.

It is thought that the average run-off of Illinois streams will not be greater than that of the upper portion of Rock River, and that it may differ but little from it. In this part of the Rock River basin there is included a variety of drainage which on the whole favors average run-off. It is true that a portion is through swamps and lakes, and a portion through streams with low rate of fall; but a large part is through streams with moderate fall, while in the head-water portions of some tributaries there is as rapid fall as is often met with in Illinois. It is believed, therefore, that the run-off is fully as great as the average discharge from Illinois streams.

A discharge of 0.60 second-foot per square mile is equivalent to 7.282 cubic miles of water per year from the entire State of Illinois. As the annual rainfall of the State, according to Professor Harrington's estimate, amounts to 34 cubic miles, the estimated run-off is about 21 per cent of the rainfall. The rainfall being 38 inches, the estimated run-off is about 8 inches.

This estimate is supported by results from measurements and estimates made in other parts of the country, as may be seen by reference to tables published by Mr. Newell in the Fourteenth Annual Report of the Survey.[1] Mr. Newell estimates that the mean discharge of rivers of small size in the eastern part of the United States is not far from 1.5 to 2 second-feet per square mile, or two to three times that of our estimate for Illinois. In that district the stream discharge is accelerated greatly by the steeper slopes, and also by greater rainfall than in Illinois, which accounts for the greater percentage of run-off.

In a diagram representing the relation of run-off to rainfall[2] Mr.

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[1] Results of stream measurements, by F. H. Newell: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1893, pp. 95–155.

[2] Loc cit., p. 151, fig. 24.

Newell has indicated that for an open country with low slopes, where the mean annual rainfall is 40 inches, a run-off of 15 inches may be expected, while with a rainfall of 30 inches a run-off of about 8 inches is likely to occur; and where the rainfall is 20 inches, only about 3 inches reaches the streams, the quantity, as in the other case, rapidly decreasing with less rainfall. In the case of Illinois, the very low slopes, combined with imperfect development of drainage lines, give results somewhat lower than indicated in the diagram, a rainfall of nearly 38 inches apparently producing a run-off no greater than would ordinarily be expected with a rainfall of but 30 inches.

THE UPPER MISSISSIPPI.

Measurements by the United States Army engineers at Grafton, Ill., show the flow for a year of unusual rainfall, the year 1882. The gage readings range from 31,000 to 392,000 cubic feet per second, with an average of about 150,000. Those at Hannibal for the same year show a range from 17,000 to 292,000 cubic feet per second, with an average of about 111,500. The most important tributary entering the Mississippi between these points is the Illinois, which contributes about 80 per cent of the accession. The discharge of the Illinois for 1882 may therefore be placed at 11,000 to 80,000 cubic feet per second, with an average of about 30,000.

The drainage area of the portion of the Mississippi above Hannibal being about 137,460 square miles (Greenleaf), the run-off ranged from 2⅛ second-feet per square mile to about one-eighth of a second-foot, with an average of about 0.8. On the Illinois, the drainage area being 27,917 square miles, the run-off ranged from nearly 3 second-feet per square mile to 0.4 of a second-foot, with an average of about 1.1.

The year 1882, being one of exceptional precipitation (43.8 inches in Illinois) and being in the midst of a series of years in which the rainfall was above the normal, the run-off is evidently greater than the normal. The above measurements should therefore be considered a maximum yearly run-off rather than a normal one. This is especially true of the Illinois. Gage readings at Kampsville, 30 miles above the mouth of the Illinois, show that the river became bank-full October 4, 1881, and was overflowing or nearly full until July 28, 1882, and that in the last part of the year it was at a low stage (less than 3 feet above low water of 1879) for only twenty-nine days. The average yearly run-off for the Upper Mississippi is probably lower than for Rock River, or not more than 0.6 of a second-foot per square mile of watershed.

ILLINOIS RIVER.

The valley of the Illinois has been made the subject of investigation by the United States Army engineers and by the Chicago Drainage Commission, a commission appointed in 1886 to investigate the subject of the disposal of Chicago sewage. Each organization has given much attention to the question of rendering the Illinois River navigable by supplying it with water from Lake Michigan. A large amount of statistical matter has thus been gathered concerning the regimen of this stream. The statistics pertain, however, not to a stream of normal gradient, but to one which in the lower 225 miles of its course more nearly resembles the Great Lakes than an ordinary river. From these reports such data have been selected as will indicate the regimen of this peculiar river.

Attention has already been called to the river's gradients and the gradients of its tributaries, it being shown that there is a comparatively rapid fall into the lower Illinois from head-water tributaries as well as those which enter its lower course. Professor Cooley has also brought to notice a peculiar grouping of the tributaries. Of the total watershed of the river 11,847 square miles, or 42½ per cent, is above Utica, or in the new portion of the valley, while in the next 86 miles of descent there is an increase of but 12½ per cent; in the following 60 miles 35 per cent is added, leaving only 10 per cent of the catchment area for the lower 65 miles. Concerning the effect of this grouping, Professor Cooley writes as follows:

Over 80 per cent of the entire watershed lies in two distinct basins, each differing in climatic and topographical conditions, the northern one dominating the valley down to Copperas Creek, or even Havana, the central basin of the State entering the middle section and modifying the lower half of the stream. The lower section is affected sensibly by the fluctuations of the Mississippi.

These two basins lie in different storm tracks, so that rain floods may not coincide. The southern basin will usually part with its snow several days sooner in the spring, and more promptly than the northern, as it is more nearly uniform in latitude. Relatively, the floods are probably larger. The sediment from the central basin is doubtless much larger in quantity, as shown by the lower section, which has a much less proportion of deep water and a steeper slope, perhaps ascribable to the influence of the Mississippi in part. Above the Sangamon is a deep pool, and again, Havana Lake, above Spoon River, and finally Lake Peoria, broad and long, the remnant of the ancient stream bed, which demonstrates how little, relatively, has been the detritus from the northern basin, for which the large proportion of marsh and lake sufficiently accounts. These conditions are undergoing change, and the supply of detritus will increase with detrimental effect on all that part of the valley above the Sangamon, and especially above Peoria.

The portion of the lower Illinois above the mouth of the Sangamon has a much smaller prism than the portion below, and Professor Cooley estimates the bank-full capacity at several points as follows:

Bank-full capacity of lower Illinois River.

Locality.	Cubic feet per second.	Remarks.
Peru	18,000–22,000	Measured in 1889. Variation occurs according as river is rising or falling.
Henry	20,000–22,000	Very tentative estimates from dam and prism.
Copperas Creek	18,000–20,000	Do.
Lagrange	30,000	Measured in 1889.
Kampsville	40,000	Estimated from measurements in 1889.

The prolongation of floods in the lower Illinois may be seen by comparing records of overflow with those of points in the upper Illinois. Records at Morris, in the upper Illinois, in the eighteen years from 1871 to 1889 are reported by Professor Cooley to show but 117 days of overflow, or 6½ days per year. At Copperas Creek, on the lower Illinois, the records for the same period (omitting those for 1878, which were not at hand) showed 1,000 days, or 55½ days per year. On the lower section of the lower Illinois the floods are still more prolonged, partly because of influx of water through the Sangamon and partly because of the backwater from the Mississippi. Thus, at Copperas Creek, above the mouth of the Sangamon, in the period from 1883 to 1889, inclusive, the river was out of banks 444 days, or 63½ days per year, while at Lagrange, below the mouth of that stream, it was out 526 days, or 75 days per year. At Morris, for the same period, it was out only 8½ days per year.

Professor Cooley discusses the capacity of the bottoms along the lower Illinois to serve as an impounding area as follows:

An area of 704 square miles, submerged to a uniform depth of 4 feet—this is a flood height of 16 feet and not an unusual occurrence—represents 1.21 inches of water running off the entire watershed and will supply the river at the rate of 110,000 cubic feet at the mouth for 8.26 days, or at half this volume, which is an approximation to the true maximum discharge, for 16.52 days. An overflow of 8 feet, or a flood of 20 feet, which is an extraordinary occurrence, represents 2.42 inches of water running off the entire watershed, and will supply the river at the rate of 110,000 cubic feet for 16.52 days, or at half the volume for 33.04 days.

When it is considered that the water is draining out constantly to the Mississippi, and that the depths of water running off the entire watershed in a brief time must therefore be greater, the conditions are certainly remarkable. An overflow 8 feet deep will supply a bank-full river 21.8 days at Copperas Creek and 36.6 days at Lagrange. The river has been out of banks at these points for 120 days, and for that time a bank-full river at Lagrange will carry 4.8 inches of water from the entire watershed, equal to 5.33 inches of water from the watershed above Lagrange,[1] and the volume flowing in the river course should be greater for the higher stages. Without going into details, it seems as if the volume of water moved mainly in the channel, the bottoms impounding the surplus temporarily until the channel has time to carry it away.

In fact, during flood stages the valley is a great lake of, say, 700 square miles, into which flood waters from above and from tributaries are precipitated, and from the lower end of which they run out more at leisure in reduced and equalized volume.

This general consideration explains why floods are higher and less continuous at Lasalle than at points below, as here the upper section of the valley is mainly fed with the land drainage, to be equalized and prolonged in flow through the reservoir action of the bottoms. The central basin acts similarly on the lower half of the valley, and even backs the waters at times on the upper section, and likewise the Mississippi may back it on the lower section. When the upper river has filled the bottoms at Lasalle and has run out, then occurs the slow discharge of the impounded waters southward with a gradual subsidence, and at such time the flow in the upper end of the impounding area is naturally small, and for weeks there is little apparent discharge over the dam at Henry, and at Copperas Creek the action is only less marked.

[1] A bank-full river at Copperas Creek for 120 days will carry off 5.85 inches of water from the watershed above Copperas Creek.

An illustration of the effects of this impounding area, reported by Mr. E. J. Ward, is found in the flooded stage of the stream in May, 1892. The flood culminated at Morris, May 6, with a discharge of 73,730 cubic feet per second, as determined by an assistant engineer of the Chicago Drainage Commission. It required twelve days for the flood tide to reach the mouth of the river, a distance of only 260 miles, and the flood discharge had increased to 94,760 cubic feet, or only about 21,000 cubic feet per second, as determined by the same engineer. The flood stage at Morris here reported is exceptionally high, being from a drainage area of but 7,360 square miles.

The gage readings at the dams along its lower course show that this portion of the Illinois bears more resemblance to Lake Michigan than to the ordinary streams of this State. It does not show so well as ordinary streams the several alternations of high and low water. On the contrary, it usually maintains high water from the early spring to midsummer, and low water the remainder of the year. Gage readings for Kampsville, Lagrange, Copperas Creek, and other dams are presented by Capt. W. L. Marshall in the report of the United States Army engineers, 1890. The following table of average monthly means, based upon the daily gage readings at the Copperas Creek dam for the years 1879 to 1889, inclusive, serves to illustrate the above statement:

Table showing monthly means of gage readings above and below Copperas Creek dam for eleven years, 1879 to 1889, inclusive.[1]

Month.	Above dam.	Below dam.
	Feet.	*Feet.*
January	9.10	12.31
February	10.42	14.37
March	12.59	17.15
April	11.93	16.50
May	10.44	14.43
June	9.68	13.45
July	8.44	11.44
August	7.25	8.55
September	7.02	7.58
October	7.30	8.52
November	8.04	10.07
December	8.39	11.01
Annual	9.22	12.11

[1] Report of Capt. W. L. Marshall, U. S. Army Engineers, vol. 3, 1890, pp. 2525-2531.

From the above table it appears that on the Illinois a minimum flow is reached in September, near the close of the summer drought. On

Lake Michigan there is but the one fluctuation, but the lowest stage is in February, when the tributaries are frozen and precipitation is low, as may be seen by the following table:

Table showing mean stages of Lake Michigan above Chicago city datum, for thirty years, 1860 to 1889, inclusive. *

Month.	Mean stage.	Month.	Mean stage.
	Feet.		*Feet.*
January	1.573	July	2.503
February	1.562	August	2.455
March	1.731	September	2.290
April	1.935	October	2.051
May	2.192	November	1.803
June	2.428	December	1.572

* Table by L. L. Wheeler, assistant engineer; Rept. U. S. Army Engineers, vol. 3, 1890, p. 2517.

The average run-off at the Copperas Creek dam for the eleven years, 1879 to 1889, inclusive, has been estimated by Prof. L. E. Cooley, from gage readings, to be 10,500 cubic feet per second.[1] The drainage area of the Illinois above this dam is estimated to be 15,250 square miles. The run-off is therefore about 0.688 second-foot per square mile, or very nearly the same as Greenleaf's estimate for the entire basin (0.654 second-foot per square mile). The normal rainfall for the Illinois basin is about 37 inches, of which, as estimated by Greenleaf, 24 per cent, or 8.88 inches, escapes by the stream. As indicated above, this is probably not far from the average run-off for the State.

The low-water volume of the Illinois is exceedingly small, as may be seen by the following statistics compiled by Professor Cooley:

In 1888 the water running over the Henry dam was less than 500 cubic feet per second for 9 days and at Copperas Creek for 20 days. The water at Copperas Creek was at or below the same level in 1887 for 117 days; in 1886, 18 days; in 1879, 44 days; at Henry in 1877, 30 days; in 1875, 47 days, and in 1871 apparently for a longer period. The volume in 1888 was less than that sent through the canal at Chicago for the same period (about 700 cubic feet per second). Lake water from 300 cubic feet upward has been going to the valley ever since July, 1871.[2]

Professor Cooley states that the amount of leakage through the dams at these times is not known. He estimates that since the Bridgeport pumps were erected in 1883 over half the minimum discharge of the portion of the valley above the mouth of the Sangamon has come from Lake Michigan, and about one-third below the mouth of the Sangamon. The river was measured in 1887 at low-water stage at Lagrange, below

[1] Lake and Gulf Waterway, by L. E. Cooley, p. 65.
[2] Ibid, p. 64.

the mouths of all the large tributaries, and found to have a discharge of but 1,685 cubic feet per second.[1] Assuming Professor Cooley's estimate of one-third as due to influx from Lake Michigan, and allowing a slight addition for small tributaries below Lagrange, we have about 1,200 feet as a low-water discharge of the Illinois, a discharge of but 0.043 second-foot per square mile of area.

Summing up results of measurements, it appears that in a wet season the stream discharges range from 0.40 to 3 second-feet per square mile of area, with an average of 1.1 second-feet. In an ordinary season the average discharge is about 0.65 second-foot per square mile. In a season of drought the low-water discharge is but 0.043 second-foot per square mile.

Kankakee River.—Measurements and estimates of the flow of the Kankakee have been made at Wilmington, near the mouth of the stream, by Mr. E. S. Waters, for the period of twelve years ending in 1883. The following statements of results of Mr. Waters's observations are presented by Professor Cooley, in a report to the State board of health.[2]

Volume of the Kankakee River at Wilmington, Ill.

	Cubic feet per second.
Extreme high-water stage	30, 000–35, 000
Ordinary low-water stage	1, 300
Extreme low-water stage	420

This stream, as already noted, is remarkably regular in its flow, because of the great marsh, which acts as a storage reservoir and constant feeder for the lower course. The lowest stages of the river occur when in severe winters the marsh is frozen so solid as to prevent the escape of water to the river.

The ordinary low-water discharge of this river is but 0.25 second-foot per square mile of area, but the average run-off probably reaches that of the entire upper basin of the Illinois (0.688) if it does not exceed it. The period covered by the observations includes both dry and wet years, and probably represents well the ordinary low discharge.

Des Plaines River.—This stream has had an exceptionally interesting history. During the activity of the southwestward outlet of Lake Michigan it was tributary to the lake, entering it at first about 2 miles north of Riverside. As the lake level lowered, the mouth extended south until it reached the site of Riverside. After the outlet was abandoned two courses lay open to the stream, either east into the lake or southwest along the old outlet, for its point of entrance is near the summit in the old outlet. In flood stages the water rose above the level of the summit, and the stream consequently flowed in both directions. It is thought by Professor Cooley that the main discharge of the river for the greater part of the time since the southwestward outlet

[1] Report U. S. Army Engineers, vol. 3, 1890, p. 2443.

[2] Prel. Rept. State Board of Health, on Water Supplies and Pollution of Streams, 1889, p. 79.

was abandoned by the lake has been into Lake Michigan, the southwestward course being occupied only in flood stages. Its present regimen is just the reverse. This opinion of Professor Cooley's is based upon the very small channel cut by the stream in its present course down the outlet. The change to the present course he thinks to be due to an accumulation of the river silts in the lakeward course to such a height as to prevent the low-water flow from taking that course.[1] But at high-water stages it still spreads out to the eastward along the old outlet (now forming an inlet to the lake), and much of its flood enters Lake Michigan.

The Des Plaines has been found to have at Riverside an extreme flood stage of about 10,000 cubic feet per second, with an occasional higher volume, as in April, 1881, when it reached 13,500 cubic feet. It has been estimated by Professor Cooley that, on an average, once in five or six years during the past fifty years the flood has exceeded 10,000 cubic feet, while the ordinary yearly flood, as shown by marks on a dam at Lyons, just below Riverside, is 6,000 to 7,000 cubic feet per second. In these extreme floods nearly half the water has been wont to discharge into Lake Michigan, and in ordinary floods a small discharge has usually occurred.[2]

As a consequence, the flood stages of the Des Plaines are higher above Riverside than those of the lower course of the stream. Professor Cooley estimates the normal extreme flood at Joliet to be but 6,300 feet. At a flood stage in June, 1892, however, the discharge on the lower Des Plaines at Joliet reached 10,500 cubic feet per second (E. J. Ward).

The drainage area above Riverside is scarcely 1,000 square miles. This gives at the maximum extreme flood of April, 1881, a flow of fully 13.5 second-feet per square mile of area. The low-water volume is exceedingly small. Professor Cooley reports that at Riverside, in 1887, it reached a minimum of 4.27 feet per second, and for five months did not exceed $16\frac{2}{3}$ cubic feet per second. He estimates that for nearly every year the extreme low water at Riverside and Joliet reaches about 5 cubic feet per second.[3]

The main tributary of the Des Plaines, the Dupage River, as noted by Professor Cooley, drains a more gravelly tract than the Des Plaines and receives water from springs, so that it sustains a larger low-water flow than the upper Des Plaines, but its extreme low-water flow is still very small; it is estimated by Professor Cooley to not exceed a mean of 50 feet per second in a period of twenty years, and possibly reaches as low as 17 to 20 feet per second in some years.[3] The greater percentage of range of the Des Plaines, as compared with the main

[1] The Illinois River in its relations to sanitary engineering, L. E. Cooley, C. E.: Prel. Rept. Ill. State Board of Health, 1889, pp. 54–55.

[2] Loc. cit., pp. 72–73.

[3] Loc. cit., p. 74.

stream, the Illinois, illustrates a general rule in streams which has been well expressed by Cooley as follows:[1]

The flood volume of a stream is never equal to the combined volumes of the tributaries, and with many tributaries and a large area does not even approach such a volume. The several tributaries will not reach high water at the same time, nor will their floods reach the main stream conjointly; neither do they enter at the same point, but are distributed along the valley. The practical result is that the duration of the flood in the main stream is much lengthened, and the volume is correspondingly less than the aggregate of the tributaries. Alteration in the flood conditions of the tributaries will not materially change the time or order in the contribution to the main stream, and as the results are only partially cumulative the effect is relatively less. In many large basins no sensible change would probably occur.

The reverse is true in a less degree of the low-water volumes. No two tributaries are in exactly the same condition as to low water at exactly the same time, but as the low-water period is very much longer than that of floods, the results are more nearly cumulative. It is found practically that the low-water volume in small basins is less per square mile than in large ones.

Fox River.—The run-off from Fox River, as reported by Greenleaf from measurements by United States Army engineers, is 526 cubic feet per second, or 0.195 second-foot per square mile of its drainage basin. This is thought to be the ordinary low-water discharge. Greenleaf further states that those familiar with the stream claim that it has fallen off one-half in its low-water volume since the clearing and cultivating of the land and the draining of the swamps.

Sangamon River.—The Sangamon River is subject to great variations in volume, there being in the annual flood stages a rise sufficient to overflow banks 8 to 12 feet in height. The river at such times, being a swift stream, probably discharges not less than 15,000 cubic feet per second, and in extreme floods the discharge probably exceeds 20,000 cubic feet per second.

At low water the discharge, as estimated by Professor Cooley, drops to about 350 cubic feet per second. Professor Cooley estimates that the low-water discharge of the lower Illinois is increased about 600 feet by the contributions from the Sangamon and Spoon rivers and Crooked Creek.[2] The Sangamon carries about four-sevenths of this discharge, or about 350 cubic feet, leaving a low-water discharge of less than 200 feet for Spoon River and less than 100 feet for Crooked Creek. As the Sangamon is subject to low stages for a considerable part of the year, its efficiency is to be measured by the low-water flow rather than the average discharge. The average discharge is probably low because of the imperfect drainage lines of its upper course.

STREAMS OF SOUTHERN ILLINOIS.

So far as known to the writer, no accurate gagings of the streams of southern Illinois have been made. No cause for a wide variation from the percentage of run-off in the streams of northern Illinois has,

[1] Loc. cit., p. 57.
[2] Lake and Gulf Waterways, p. 65.

however, been recognized. The southern district has probably a slightly higher rate of evaporation, which would tend to lessen the amount of run-off; but it has, on the other hand, a more perfect system of drainage, which would tend to increase the percentage of run-off. Similarly, the lesser relief of the southern Illinois district tends to lower the run-off, but the greater perfection of drainage tends to increase it. The run-off of between six and seven tenths of a second-foot per square mile of watershed area, found for the Rock and Illinois, seems likely to be shown also by streams of southern Illinois.

CHAPTER IV.

NAVIGABLE WATERS.

The State of Illinois has possibilities in navigation not excelled by any other State so far removed from the seaboard. Touching as it does upon Lake Michigan, it is connected with the Eastern seaboard, and, bordered as it is by the Mississippi, it is connected with the Southern States and the Gulf of Mexico, and also with States to the north. On the Ohio, also, it is connected with a navigable waterway eastward to Pittsburg. Through the midst of the State passes the Illinois River, which, by the aid of dams and locks in its lower course, has been made navigable in ordinary low water as far as Peru for small river vessels. From Peru to Chicago the Illinois and Michigan Canal affords passage for canal boats between Lake Michigan and the Illinois.

The lower Illinois River at very low stages has but 1½ to 2 feet of water on the bars. At such times navigation must of course be suspended. The present dams and locks are of service only at ordinary low water. It is evident that the present system of navigation by dams and locks interferes with rather than aids the stream in its effort to form a channel adapted to the small volume of water which it has carried since the lake outlet was abandoned. Any obstruction to the flow must decrease the effective work of the stream. Measures looking to an increase of volume in the river seem to be the natural remedy. For some years such measures have been under consideration, both by the United States Army engineers and by the Chicago Drainage Commission. Work was begun in 1892 on a large channel which will extend from Lake Michigan southwestward through Chicago and along the line of the abandoned lake outlet to Joliet. A sanitary district was organized in 1890 under the general law for incorporating sanitary districts enacted by the Illinois legislature in 1889, and is known as the Sanitary District of Chicago. From its last report (April, 1895) the following statistics concerning the channel have been gathered: The channel is excavated partly in earth and partly in rock. The grade in the earth portion, which leads from Chicago nearly to Lemont, is 1 foot in 40,000, while in the rock section it is 1 foot in 20,000 feet. The bottom of the channel at its lakeward end is to be 24.448 feet below the city datum (which was extreme low water in Lake Michigan in 1847 and 578.56 feet above mean tide in the Gulf of Mexico). The channel has in the rock section a capacity of 10,000 cubic feet per second. The southwestern terminus will be near Lockport, where the channel enters the Des Plaines River. Controlling works will be constructed at that point for conducting the flow from the channel, in conjunction with the waters of the Des Plaines River, down the declivity through the city of Joliet. When completed, this channel will be a free waterway navigable for any vessel drawing less than 22 feet of water. The cutting to be made by the sanitary district is estimated to cover about two-thirds of the entire cost of a channel from Chicago to the Mississippi which would be navigable for the largest boats able to ply between St. Louis and New Orleans. The expense assumed by the sanitary district is about $21,600,000, of which nearly $13,000,000 had been expended at the date of the last report, April 1, 1895.

The commercial value of such a channel will no doubt lead sooner or later to its completion and give to the State of Illinois one of the greatest waterways of this country.

A small canal is under construction which will connect the Mississippi at Rock Island with the Illinois at Hennepin, known as the Hennepin Canal. The feeder will be Rock River, and will lead southward from a point near Dixon. The restrictions in the volume of water obtainable through this feeder will necessarily prevent the opening of a canal of great size, but it promises to afford navigation for the small vessels which now ply the Upper Mississippi and the Illinois.

The construction of a canal past the lower rapids on the Mississippi near Keokuk has rendered that stream navigable in low stages as far as St. Paul, for the upper rapids are usually navigable for such boats as are in use between St. Paul and St. Louis—boats which do not draw more than 6 feet of water.

CHAPTER V.

WATER POWER.

In his report for the Tenth Census, Prof. J. L. Greenleaf has discussed in considerable detail the water power of Illinois streams, with the exception of those tributary to the Wabash.[1] As the present writer has made no special study of water power, he will only review briefly the results given by Professor Greenleaf in the light of a study of the physical features.

The northern part of the State is shown by Professor Greenleaf to be far better fitted than the southern for the utilization of water power. The streams of the northern portion have, on the whole, a more rapid descent than those of the southern portion, because of the generally greater relief of that part of the State above the main valleys. The discharge of streams is also more uniform in the northern portion because of a loose-textured drift which absorbs the rainfall and feeds the streams through seasons of drought, and because of marshes and lakes which also serve to impound water and feed the streams in dry seasons. A striking contrast is therefore found in the use of water power. In the northern portion of the State not only the large streams, such as the Kankakee, Fox, Rock, Kishwaukee, and Pecatonica, have mills using water power, but smaller streams, such as Apple Creek, Yellow Creek, Sugar Creek, Carroll Creek, Elkhorn Creek, Rock Creek, and Piscasaw Creek—streams whose gathering grounds are but a few hundred square miles in extent—also afford power which is used by mills throughout most of the year. The only important exception in northern Illinois is Green River, a tributary of Rock River, which, with a watershed of 1,131 square miles, drains a large swampy basin and has a sluggish stream with low banks. This stream naturally has no developed water power.

In western Illinois, Spoon River, a tributary of the Illinois, has several mills using water power which is ordinarily sufficient for milling purposes. Edwards and Henderson rivers and Pope Creek, tributaries of the Mississippi, have mills using water power, but the power is rather uncertain because of floods and very low stages.

From the Illinois River southeastward the use of water power is largely abandoned. Vermilion River, Sangamon River, Kaskaskia River, and

[1] The water powers of the Mississippi and some of its tributaries, by J. L. Greenleaf: Tenth Census of the United States, Vol. XVII, 1880, pp. 119-276.

other streams upon which mills using water power were constructed in pioneer days, have scarcely any mills remaining. The poor sites for dams in deposits of clay or sand, the great variation of water height, and the comparatively low fall of streams, combine to make the water power of little value to the miller or the manufacturer. The Big Vermilion, a tributary of the Wabash, has several mills using water power, though in some cases not entirely dependent upon it. This stream is well calculated in its lower course, by rapid fall and by rocky beds and banks for dam foundations, to furnish power, and the high stages are less liable than are streams of lower rate of descent to produce back water; but it is subject to very low stages, in which the discharge is insufficient to produce the power necessary to run the mills.

CHAPTER VI.

WATER SUPPLIES FOR CITIES AND VILLAGES.

GENERAL STATEMENT.

Throughout much of Illinois several sources of water supply are available for domestic use. Chicago and the smaller cities bordering Lake Michigan may obtain water from the lake, from artesian wells, or from shallow wells. The cities along the main streams, with the exception of those on the lower Des Plaines and the Illinois, where the water is contaminated by sewage, may generally use the stream water with safety. In addition to this they have usually an available supply of good water from wells of slight depth, and in much of northern and western Illinois a fair quality of water may be obtained from artesian wells. The cities not located near large streams or the lake, resort in some cases to storage reservoirs, formed by damming small streams, for a part of their supply, but the greater number depend entirely upon wells, and of these wells but few are artesian. In rural districts and in the villages which have no waterworks the supply is mainly from shallow wells, though deep wells are not rare.

A study of the development of the water supply in cities shows that they have, in the early days, almost without exception, used shallow wells, but with the growth of the city often these either have become inadequate or are found to be contaminated. A change is then made to streams, if these are available, and if not deep wells are sunk. In a few places, however, among which Peoria is a conspicuous instance, there has been a return to shallow wells because of the unpleasant taste of water from deep wells.

In addition to the sources named, a large amount of the water supply is from cisterns which collect the rain water from the roofs of dwellings or other buildings. Inasmuch as the well water and stream water are usually so strongly charged with lime as to be too hard for laundry purposes, rain water is in demand in both city and country. Cisterns are the main dependence in a few small districts, notably the driftless portions of the State and places where the drift is thin. In places where the drift, though thick, contains a very small sandy ingredient and few sand pockets or beds, good wells are so difficult to obtain that cisterns have come into use for all domestic needs. These districts are small, however, comprising scarcely one-tenth the area of the State. The drift usually affords abundance of excellent water at convenient depth.

SURFACE WATER.

The extent to which surface water is used may perhaps be best shown by a list, nearly complete, of the cities and villages in which this is the chief source of supply. With the source of supply are included statistics concerning the cost of waterworks and systems used; also the running expenses per annum. In most instances these have been furnished by the officers in charge of the waterworks.

The increase in the population since the last census was taken (in 1890) has been more rapid in Chicago and some of the other leading cities than in the villages and rural districts. There is, therefore, a larger proportion of the population in these cities, and consequently a larger proportion using surface water now than in 1890. In 1890, with a total population of 3,826,351, there were probably 1,375,000 people, or slightly more than one-third, using surface water. It is estimated that the present population is about 4,500,000, and that 1,800,000, or about two-fifths of the population, depend mainly upon surface water.

The State board of health has made analyses of water used by several of these cities, and they may be found in the tables of sanitary analyses given later in this paper. There is usually but little contamination from city sewage. The Chicago intakes are affected by sewage only when the Chicago River is at high stages, which seldom amounts to more than a few days each year. At such times it becomes necessary to boil the water before drinking. Cities located upon streams usually obtain water at points above where the sewage enters.

Cities and villages using surface water.

Place.	Population in 1890.	Source.	Waterworks.	
			Cost *a*.	System.
Alton	10,294	Mississippi River	(?)	Pump to standpipe or direct.
Cairo	10,422	Ohio River and wells.	$125,000 Ex. 20,000	Pump to standpipe; Herdic system.
Carlinville	3,293	Macoupin Creek	(?)	(?)
Carlyle	1,784	Kaskaskia River	35,000 Ex. 1,000	Pump to standpipe.
Centralia	4,763	Crooked Creek and wells.	45,000 Ex. 2,500	Direct pressure.
Charleston	4,135	Embarras River	40,000 Ex. 3,000	Do.
Chicago	1,099,850	Lake Michigan	(?)	Tunnel and pumps.
Danville	11,491	North Vermilion River.	(?)	Pump to standpipe.
Decatur	16,841	Sangamon River	200,000 Ex. 25,000	Holly system (direct).
Dundee	2,023	Springs	40,000 Ex. 800	Hydraulic ram to reservoir.
East St. Louis	15,169	Mississippi River	(?)	Holly system.

a "Ex." in this column means running expenses per annum.

Cities and villages using surface water—Continued.

Place.	Population in 1890.	Source.	Waterworks.	
			Cost *a*.	System.
Elgin	17,523	Fox River	$173,622 Ex. 8,766	Pump to standpipe and direct.
Evanston	12.762	Lake Michigan	124,000 Ex. 7,300	Holly system.
Highland Park	2,163	....do	60,000	Dean pumps.
Hillsboro	2,500	Group of springs	18,000 Ex. 400	Elevated tank; also direct pressure; Worthington pump.
Kankakee	9,025	Kankakee River	100,000	Pump to standpipe.
Lake Forest	1,203	Lake Michigan	(?)	
Lincoln	6,725	Salt Creek	40,000	Do.
Litchfield	5,811	Shoal Creek	50,000 Ex. 2,000	Reservoir on creek; Holly system.
Metropolis City	3,593	Ohio River	40,000	Dean pumps.
Moline	12,000	Mississippi River and artesian wells.	(?) 44,270 Ex. 11,878	Direct pressure.
Morrison	2,088	Natural spring	40,000 Ex. 2,500	Reservoir; direct pressure.
Mount Vernon	3,233	Creek reservoir	(?)	(?)
Murphysboro	3,880	Big Muddy River	60,000 Ex. 4,000	Pump to standpipe.
Newton	1,428	Embarras River	*b* 5,000	Direct pressure.
Olney	3,831	Fox River and wells	4,000	Pump to standpipe.
Oregon	1,566	Rock River	15,000	Pump to reservoir.
Ottawa *c*	9,985	Springs	(?)	Reservoir in South Ottawa from springs.
Pecatonica	1,059	....do	(?)	Pump from reservoir to standpipe.
Quincy	31,494	Mississippi River	(?)	Pump to filter gallery, then to mains and reservoir.
Rochelle	1,789	Springs in quarry	Ex. 486	Pump to standpipe.
Rock Island	13,674	Mississippi River	35,000	Holly system (direct pressure); standpipe for elevated part of city.
Shelbyville	3,162	Kaskaskia River	60,000	Pump to standpipe.
Springfield	24,963	Sangamon River	(?)	Gallery system from river, with direct pressure.
Staunton	2,209	Dam on brook	39,000	Pumped from reservoir on brook.
Streator	11,414	Vermilion River	(?)	Pump to standpipe and direct pressure.
Venice	932	Mississippi River	(?)	Pumped in open reservoir.
Waukegan	4,915	Lake Michigan	60,000 Ex. 4,000	Dean pumps.
Wilmington	1,576	Kankakee River	10,000	Direct pressure (Holly system).
Winnetka	1,079	Lake Michigan	(?)	Pump to water tower.
Yorkville	375	Springs in moraine	6,000	Gravity to reservoir.

a "Ex." in this column means running expenses per annum.
b Cost of pumping station, etc., exclusive of laying mains.
c Derives water from about 200 artesian wells.

SHALLOW WELLS IN VALLEYS.

Several cities obtain their water supply from shallow wells which in some cases reach no lower than the alluvial deposits of the valley, though in other cases they pass into glacial deposits beneath the level of the stream bed. Those cities which obtain a supply from alluvium usually take the precaution to locate the waterworks wells above the city, where the danger from contamination will be at a minimum. Those whose wells enter glacial deposits have not in all cases taken this precaution. For example, Pekin has its waterworks in the lower end of the city. The wells are using water from a level below the Illinois River, and probably receive but little contamination from city sewage and filth. There is, however, no thick bed of clay or impervious stratum above the beds which yield the water. In Bloomington, also, the wells are located near the central part of the city, where contamination may occur, though the clay cover would seem to be a sufficient protection. At Peoria the waterworks are located above the city and the water-bearing bed is overlain by bowlder clay; there seems, therefore, little danger of contamination at that point.

The villages which have no waterworks, and hence derive their supply from the wells located within the village boundaries, are, on the whole, more liable to suffer from water pollution than the towns having waterworks. The writer has noted instances where the village authorities have been so unwise as to put down wells at public-school buildings on the downstream side of the privy vaults, sometimes within 50 feet of the vaults. Such ignorance or rashness can not be too strongly condemned.

In the following table, which embraces towns deriving water from shallow wells in valleys, the character of the cover is indicated:

Cities and villages using shallow wells in valleys.

Place.	Population in 1890.	Depth.	Water bed.	Cover.	Waterworks.	
					Cost. *a*	System.
		Feet.				
Algonquin	(?)	2– 20 60– 80	Gravel do	Gravel Till 40 feet		None.
Amboy	2, 257	12– 20	Gravel and rock	Gravel or sand		Not from shallow wells.
Aurora	19, 688	20– 40	Gravel	Mainly gravel		Do.
Beardstown	4, 226	30 W. W. 50 +	do do	Sand Gravel	$35, 000	Pump to standpipe.
Belleville	15, 361	42	do	Till 40 feet	(?)	Do.
Bloomington	20, 484	65	do	Blue clay 32 feet	200, 000 Ex. 9, 000	Pump to standpipe, and direct.
Chillicothe	1, 632	40– 80	do	Gravel		(?)
Chester	2, 708	River level	Sand	Sand		None.
Dallas City	747	10– 32	Sand or limestone	Clay or limestone		Do.
Dundee	2, 023	River level	Gravel	Gravel		Not from shallow wells.
Equality	622	30– 40	Clay and clay shale	Clay		None.
Erie	535	18– 30	Fine gravel	Clay 2–11 feet		Do.
Forrest	1, 021	10– 12 25– 30	Gravel do	Brown clay Blue clay 16–18 feet		Do.
Freeport	10, 189	44	Sand	Alluvium	(?)	Pump to standpipe, and direct.
Golconda	1, 174	30– 40	Rock	Limestone or sandstone		None.
Grafton	927	20– 35	Sand or gravel	Clay and gravel		Do.
Havana	2, 525	74	Sand and gravel	Clay 10 feet	32, 000 Ex. 3, 100	Dean pumps.
Hennepin *b*	574	100	Coarse gravel	Loam and clay 50 feet; gravel 50 feet.		None.
Henry	1, 512	60– 70	Sand	(?)		Do.
Hutsonville	582	9– 30	Sandstone	Sandstone		Do.
Joliet *b*	23, 264	35	Gravel	Clay, 6 feet		Not from shallow wells.

Kankakee	9,025	20–40	.....do	Clay or gravel		Do.
		30–50	Limestone			
Keithsburg	1,484	20–50	Sand	Clay, 1–8 feet	(?) Ex. 1,000	Holley system.
Lasalle *b*	9,855	5–40	Sand and gravel	Variable; pervious		Not from shallow wells.
Lawrenceville	865	12	Sand	Clay		None.
Lewistown *b*	2,166	20	.....do	Sand	Ex. 1,200	Pump to standpipe.
Marengo	1,445	20–25	Sand and gravel	Sand and gravel		Not from shallow wells.
		125	.....do	Clay, etc		
Marseilles *b*	2,210	25–30	Gravel	Gravel		Do.
		100–200	Sandstone	Sandstone, etc		
Momence	1,635	12–30	Limestone	Limestone		None.
Mount Carmel *b*	3,376	25	Sand and gravel	Sand and gravel	65,000 Ex. 3,600	Dean pumps to standpipe; also direct.
Naperville	2,216	20–40	Gravel	Yellow and blue clay		None.
Oregon *b*	1,566	30	Sand and gravel	Sand and gravel		Not from shallow wells.
Pekin *c*	6,347	80	.....do	Thin clay bed	(?)	Pump to standpipe.
Peoria *c*	41,024	50	Gravel	Bowlder clay	(?)	Standpipe and Worthington pumps.
Petersburg	2,342	25–60	Sand	Clay, 15 feet	19,000 Ex. 1,500	Pump to standpipe.
Shawneetown	2,620	25–40	Gravel	Clay and gravel		None.
Taylorville	2,829	20–40	Sand	Clay, 20 feet	20,000	Holley system.
Thebes	673	20	.....do	Sand and clay		None.

a "Ex." in this column means running expenses per annum.
b Many shallow wells in use, though the waterworks have another source of supply.
c Breweries use water from Illinois River or from artesian wells. Pekin City Park has a 1,000-foot well.

WELLS IN GLACIAL DRIFT.

A large number of cities and villages obtain their entire supply of water from the glacial drift. In the following table, which embraces the principal towns depending upon such wells, the character of the water bed and of the cover is shown. The water-bearing beds have in most of these towns proved adequate, and usually supply a good quality of water, superior either to surface water or to water from wells in the rock. It will be observed that a few cities are included in this list which have populations of several thousand each.

Cities and villages using wells from glacial drift.

Place.	Population in 1890.	Depth.	Water bed.	Cover.	Waterworks.	
					Cost. *a*	System.
		Feet.				
Alpha	200	15–30	Gravel	Mainly loess		None.
Arcola	1,733	102	Sand and gravel	Till	(?)	Pump to standpipe.
Astoria *b*	1,357	20–40	Sand	Yellow and blue till		None.
Atlanta	1,178	W. W. 151	Sand and gravel	Till	(?)	Pump to standpipe.
Augusta *b*	1,077	20–60	Gravel or sand	Mainly till		None.
Avon *b*	692	20–40	Sand or shale	do	(?)	Pump to tank on mill.
Bement	1,129	W. W. 150	Sand and gravel	do	$13,000 Ex. 600	Fairbanks system.
Blue Mound	696	15–40	do	do	6,000	Pump to small tank.
Braceville	2,150	30–40	Sand	Sand		None.
Braidwood *b*	4,641	8–18	do	do	(?)	For fire purposes only.
Bunker Hill *b*	1,269	20–30	do	Blue till		None.
Bushnell	2,314	W. W. 115	Gravel	Mainly till	30,000	Pump to standpipe and direct.
Caledonia *b*	184	20–40	Clay	Till		None.
Cambridge *b*	940	35–75	(?)	Mainly till		Do.
Camp Point *b*	1,150	25–30 45–50	Till or gravel	do		Do.
Carbondale *b*	2,382	15–20	Clay	Mainly loess		Do.

Casey	844	18–60	(?)	(?)		Under construction.
Centralia *b*	4,763	14–30	Clay or gravel	Till	45,000 Ex. 2,500	Direct pressure.
Champaign with Urbana.	9,350	157–162	Sand and gravel	Mainly till	175,000 Ex. 12,000	Do.
Charleston *b*	4,135	20–40	do	Blue clay		Not from drift wells.
Chatsworth	827	15–100 W. W. 65	do	Till	8,000	Windmill and tank.
Coal City	1,672	8–10	Sand	Sand		None.
Clinton	2,598	56–120	Sand or gravel	Till	(?) Ex. 3,000	Holley system.
Delavan	1,176	W. W. 160	Sand and gravel	Mainly till	30,000	Standpipe or direct pressure.
Duncanville *b*	(?)	18–20	Sand	Till		None.
Du Quoin *b*	4,052	15–40	(?)	Mainly till		Do.
Dwight	1,354	W. W. 135	Gravel	do	15,000 Ex. 1,800	Dean pump, direct pressure.
Earlville *b*	1,058	30–60	do	Till		Not from drift wells.
Edwardsville	3,561	20–80	Till	do		None.
Effingham *b*	3,260	18–20	Till and shale	do		Do.
Elmwood	1,548	25–40	(?)	Mainly till		Under construction.
Elpaso	1,353	W. W. 105	(?)	do	20,000 Ex. 1,000	Pump to tank.
Elvaston	307	12–30	Gravel	Till		None.
Eureka	1,481	15–105	do	Sand and gravel	10,000	Holley system.
Farmer City	1,367	W. W. 176	Sand	Mainly till		Pump to standpipe.
Forreston *b*	1,118	25 35–40	Gravel (?)	Clay Till	8,000 Ex. 400	Not from drift wells.
Gardner	1,094	20–30 40–50	Gravel and sand	Mainly till		None.
Galesburg	15,264	W. W. 70–80	Sand	Mainly sand	100,000	Direct pressure.
Genoa	634	25–60	Sand and gravel	Mainly till		None.

a "Ex." in this column means running expenses per annum.
b Occasional wells are in the rock.

Cities and villages using wells from glacial drift—Continued.

Place.	Population in 1890.	Depth.	Water bed.	Cover.	Waterworks.	
					Cost.*a*	System.
		Feet.				
Gibson City	1,803	18–24 40–45 86–110	Sand	Variable	$30,000	Tower and reservoir; Dean pumps.
Gilman	1,112	12–16 75–150	do	Mainly till		None.
Greenfield	1,131	18–30	Gravel and clay	Loess and till		Do.
Greenville	1,868	W. W. 35	Sand and gravel	Clay	16,000	Direct pressure.
Hamilton *b*	1,301	20–30	Sandy clay	Loess and sand		None.
Harvard *b*	1,967	35±	Gravel	Clay	(?)	(?)
Hillsboro *b*	2,500	15–62	Sand	Variable		Not from drift wells.
Hoopstown *b*	1,911	80–160	Mainly gravel	Sandy clay		Do.
Indianola	472	20–40	Sand and gravel	Mainly clay		None.
Kansas	1,037	8–40	Blue clay	Mainly till		Do.
Laharpe	1,113	100	Sand	Mainly till, 60 feet	(?)	(?)
Lanark	1,295	85–90	Gravel and sand	Mainly till, 75 feet	(?)	Standpipe.
Lebanon *b*	1,636	30–40	Gravel	Mainly till		None.
Leroy	1,258	W. W. 110	Sand	do	7,600 Ex. 500	Pumped to tower.
Litchfield	5,811	25–40	(?)	do	50,000 2,000	Not from drift well.
Macon	819	120	Sand and gravel	do		(?)
Marion	1,338	20	Sand	Clay		None.
Maroa	1,164	W. W. 100±	Gravel	Blue till	12,000	Elevated tanks; also steam pressure.
Martinsville *b*	779	15–20	Clay and sand	Mainly till		None.
Mason City	1,869	35 130	Sand and gravel do	Sandy clay (?)	(?)	(?)

Matteon	6,833	15–30	....do	(?)	(?)	Pump to standpipe and direct.
		W. W. 60–70	....do	Blue till		
Mendota *a*	3,542	12–20	Clay and sand	Till		Not from drift wells.
Metamora	758	40–85	(?)	(?)	(?)	Pump to tank; gaseline engine.
Monticello	1,643	W. W. 212 and 316	Sand and gravel	Till and sand	26,000 Ex. 1,000	Pump to tank, and direct pressure.
Morrisonville	844	25–30	Sand	(?)	(?)	Standpipe with force pump.
Mount Pulaski	1,357	30	Sand and gravel	Loess and till		Under construction.
Mount Sterling *b*	1,655	16–25	Sandy clay	Mainly loess	(?)	(?)
Nauvoo *b*	1,208	12–40	....do	Loess, sand, and clay		None.
Neoga	829	17	Sand	Loess and till		Do.
Normal	3,459	26	Gravel	(?)	(?)	(?)
Oakland	995	20	Sand	Blue clay		None.
Odell *b*	800	30–168	Gravel	Mainly blue till		Do.
Olney *b*	3,831	12	....do	Silt and till		For fire purposes from Fox River.
Onarga	994	10–20	Sand	Sand		Under construction.
		90–160	Gravel	Blue till		
Pana	5,077	18–48	Sand and gravel	Mainly till	44,000	Pump to standpipe.
Paris	4,996	60	Sand	Clay 50 feet	(?) Ex. 10,000	Blake, Worthington, and Cook pumps.
Paxton	2,187	W. W. 150	Sand and gravel	Mainly till	(?)	Elevated tank.
Plano (Mead)	1,825	16	Gravel	Blue clay	(?)	(?)
Polo *b*	1,728	30	....do	Loess and till	18,000 700	Not from drift wells.
Rantoul	1,074	80–200	Gravel and sand	Mainly till	25,000	Direct pressure.
Ridgefarm	757	10–20	Sand	Till		None.
Roodhouse *b*	2,360	14–24	Gravel	....do		Do.
Rushville *b*	2,031	16–30	Clay	Loess and till		Not from drift wells.
Salem	1,493	20	Sandy clay	Mainly till		None.
Sandoval	834	14–18	Blue sandy clay	....do		Do.
Sandwich	2,516	W. W. 110	Sand and gravel	Thin clay beds with sand and gravel.	25,000	Pump to standpipe.
		20–35	Gravel			

a "Ex." in this column means running expenses per annum.
b Occasional wells are in the rock.

Cities and villages using wells from glacial drift—Continued.

Place.	Population in 1890.	Depth.	Water bed.	Cover.	Waterworks. Cost.*a*	Waterworks. System.
		Feet.				
Shelbyville	3,162	30– 50	Sand	Mainly till		Not from drift wells.
Sidney	581	30– 70	(?)	do		None.
Staunton	2,209	16– 40	Sand	Clay		Not from drift wells.
Steelville	401	18– 22	Clay	do		None.
Stewardson	617	20– 40	(?)	"Joint clay" (till ?)		Do.
Sullivan	1,468	W. W. 100–125	(?)	Mainly till		Pump to elevated tank.
Sumner	1,037	15– 20	Sand and gravel	Clay		None.
Sycamore	2,087	30–100+	do	Variable	$60,000	Pump to standpipe and direct pressure.
		W. W. 65	do	Blue clay	Ex. 1,500	
Toledo	676	10– 60	do	Mainly till		None.
Tuscola	1,897	174	Gravel	do	(?)	Pump to standpipe.
Upper Alton *b*	1,294	30– 50	Sandy clay	Loess and sandy clay		Under construction.
Urbana	3,511	10–200	Sand and gravel	Mainly till	175,000	See Champaign.
Vermont *b*	1,158	25– 35	(?)	do		None.
Virginia *b*	1,602	25– 50	Sand and gravel	do		Do.
Washington	2,301	25– 70	Quicksand	Blue till	15,000 Ex. 1,470	Morgan pumps.
Watseka	2,017	100–150	Sand and gravel	Mainly till	(?)	Pump to standpipe.
Waverly *b*	1,337	20– 50	(?)	Blue till		None.
Winchester *b*	1,542	20– 30	(?)	(?)		Do.
Winnetka	1,079	20– 50	(?)	Yellow and blue clay		Not from drift wells.
Wenona	1,053	16– 60	Sand	Mainly till		Under construction.
Whitehall *b*	1,961	25– 50	Gravel	Blue till		None.
Woodstock	1,683	20– 60	Sand and gravel	Mainly till		Not from drift wells.
Wyoming	1,116	22– 50	Gravel	Loess and till		None.

a "Ex." in this column means running expenses per annum.
b Occasional wells are in the rock.

In many instances the supply of water from the drift beds far exceeds the demands of a city, and there is no need to look to any other source for a supply. Where small wells are inadequate to supply a city it has been found of advantage to excavate a large well for a reservoir, from the bottom of which several small wells are bored into the main water bed. The rise of water is usually such as to cause it to enter the reservoir. In the following table the strength and head of some of the most important drift wells are shown:

Strength and head of certain drift wells.

Locality and owner.	Depth.	Head below surface.	Amount available per day.
	Feet.	*Feet.*	*Gallons.*
Beardstown waterworks	70	20	Unlimited.
Bement waterworks	155	25	100,000
Bloomington waterworks	65	25	500,000
Champaign waterworks	160	(?)	950,000+
Clinton waterworks	110	20	100,000+
Decatur private wells	100	20	(?)
Delavan waterworks	160	90	Unlimited.
Dwight waterworks	135	5	75,000+
Elpaso waterworks	105	40	Unlimited.
Eureka waterworks	105	60	Unlimited.
Galesburg waterworks	80	30	650,000
Gibson City waterworks	55	20	Unlimited.
Havana waterworks	74	25	(?)
Hoopstown private wells	80	20	150,000+
Keithsburg waterworks	50	25	Unlimited.
Leroy waterworks	110	50	Unlimited.
Macon waterworks	120	60	Unlimited.
Marengo waterworks	80	18	Unlimited.
Maroa waterworks	100	60	Unlimited.
Mattoon waterworks	70	(?)	(?)
Monticello waterworks	212	25	(?)
Paris waterworks	60	20	(?)
Paxton waterworks	150	50	Unlimited.
Pekin waterworks	80	42	3,000,000+
Peoria waterworks	50	10	8,000,000+
Rantoul waterworks	80	40	(?)
Sandwich waterworks	110	28	(?)
Sullivan waterworks	100	40	(?)
Washington waterworks	67	42	70,000+

SHALLOW WELLS IN ROCK.

A few villages obtain water from shallow wells in rock. This source of supply seems to be less reliable than that of wells in the drift. In the list of villages here given several having a population of 1,500 to 2,000 or more have not yet constructed waterworks, and the delay is largely due to insufficiency of water from shallow wells. Only two villages in this list obtain a supply for waterworks from shallow wells, viz, Earlville and Wheaton. The contrast in this respect with wells obtaining water from drift is striking, there being a large number of the latter which have a waterworks system.

Cities and villages using shallow wells in rock.

Place.	Population in 1890.	Depth. *a*	Water stratum.	Drift cover.	Rock cover.	Rise of water.
		Feet.				
Abingdon	1,321	20– 30	Coal Measures?	(?)	(?)	(?)
Anna	2,295	20– 60 40	Limestone	Drift, 6–8	Rock, 12–50	6–7 feet.
Ashley	1,035	8– 40 28– 35	Sandy shale	Drift, 8–15	Rock, 0–25	Slight.
Chenoa	1,226	10–150 100–150	Coal Measures	(?)	(?)	10 feet from surface.
Columbia	1,267	20– 45	Limestone	Clay, 10–20	Shale, etc., 10–20	(?)
Dallas City	747	10–150	do	Drift, 2–4	Limestone, 8–110	Various.
Equality	622	30– 40	Sandy shale	Clay	Clay shale	(?)
Fairfield	1,881	15– 20 50– 70	do	Clay, 4–6	Shale, 10–20	12 feet from surface.
Freeport *b*	10,189	10– 90	Galena limestone	Drift, 6–30	Limestone	(?)
Fulton	2,099	60– 70	Limestone	Loess, 12	do	(?)
Golconda	1,174	30– 40	do	None	Limestone and sandstone	(?)
Hutsonville	582	9– 30	Sandstone	(?)	(?)	3–4 feet.
Kinmundy	1,045	10– 30	do	Drift, 12±	Shale, etc	5–20 feet.
Knoxville	1,728	20– 40	Coal Measures	Drift, 10±	Shale	10–20 feet.
Lawrenceville	865	12– 60 60	Sandstone	Drift, 12	Sandstone, etc	20 feet from surface.
Lebanon	1,636	150–200	(?)	(?)	Coal Measures	8–12 feet.
Marshall	1,900	12– 45	Sandstone	Drift, 10–20	Sandstone, etc	(?)
Martinsville *b*	779	70– 80	(?)	Drift ?	(?)	(?)
McLeansboro	1,355	10–160 10– 12	Sandstone	Clay, 6 or 8	Shale, 4	(?)
Millstadt	1,186	25– 40	Limestone	Loess, 10	Limestone	6–12 feet.
Momence	1,635	12– 80 30	do	(?)	do	16–18 feet from surface.

Morrison *b*	2,088	35–80 75	....do	Drift, 8–20	....do	(?)
Mount Carmel *b*	3,376	15–40	Limestone ?	Drift, 12–15	Sandstone, etc	(?)
Nashville	2,084	14–45	Sandstone	Drift clay, 10	Shale. sandstone, etc	10 feet.
Pecatonica	1,059	8–125	Limestone	(?)	Limestone	40 feet.
Quincy *b*	31,494	90–200	....do	(?)	....do	60 feet from surface.
Red Bud	1,176	20–80 40	Limestone or sandstone	Drift, 8–12	Limestone shale	(?)
Robinson	1,387	12–25	Sandstone	(?)	Shale sandstone, etc	3–5 feet.
Rochelle *b*	1,789	20–60 30–40	Sandstone ?	(?)	Limestone	(?)
Shannon	591	(?)	Limestone	Till, 10–15	....do	(?)
St. Francisville	432	15	(?)	(?)	(?)	4–6 feet.
Vienna	828	25–60 50	Limestone	(?)	Limestone	20–30 feet.
Virden	1,610	15–50 15–25	Sandstone, etc	Drift, 10–20	Shale, etc	20 feet from surface.
Warren	1,172	50–125 80	Limestone	Clay, 15	Limestone	35–50 feet.
Waterloo	1,860	20–80	....do	Drift, 10–30	Limestone, etc	(?)

b Where there are two sets of numbers in this columu the lower ones indicate the main water horizon.
b Only a small portion of the water supply is from this class of wells.

DEEP WELLS IN ROCK.

About 75 towns in Illinois obtain a portion of their water from wells which have been carried several hundred feet into the rock strata. With a few exceptions, the water is made use of in dwellings as well as for manufacturing purposes, and seldom has a disagreeable taste. It is probable that in many wells the water has been freshened and rendered more agreeable by the addition of water from the glacial deposits, for there are few wells in which the casing entirely shuts out such water. The degree of salinity of several water horizons apparently increases in passing from north to south, as is shown in the discussion of artesian wells. In consequence of this salinity, the use of such water is mainly in the north end of the State. There are very few wells in the eastern part of the State to the south of the Kankakee and Illinois rivers. In the western part, however, artesian wells are scattered widely and are in but few instances unfit for domestic use.

Cities using water from deep wells.

City.	Population in 1890.	Depth.	Diameter.	Capacity per minute.	Head from surface.	Waterworks.	
						Cost. *a*	System.
		Feet.	*Inches.*	*Gallons.*	*Feet.*		
Aledo	1,601	3,115	(?)	...	— 75	Ex. $1,200	Pump to standpipe.
Amboy	2,257	2,000	...	...	3	...	Incomplete.
Arlington Heights	1,424	...	...	...	...	...	
Aurora, No. 1	19,688	1,388	...	350	...	320,000 Ex. 10,733	Pump to standpipe.
Aurora, No. 2		2,270	...	...	60	...	
Aurora, No. 3		2,255	...	...	60	...	
Austin	4,051	1,205	...	...	...	...	
Barry	1,354	2,510	6	100+	—135	13,000 Ex. 550	Tank; pumped from well.
Belvidere	3,867	1,932	8-6	200	— 6	...	Pump to standpipe.
Canton, No. 1	5,604	2,500	4	125	— 30	...	Pump to standpipe, and direct.
Canton, No. 2		1,646	6	260	+ 14		
Carthage, No. 1	1,654	1,700	5-3	(?)	— 16	10,000	Pump to elevated tank.
Carthage, No. 2		1,000	8	...	— 20	...	
Collinsville	3,498	573	...	17	—120	21,500 Ex. 1,000	Pump to standpipe.
Dekalb, No. 4	2,579	890	6	300—	— 65	30,000 Ex. 1,470	Pump to standpipe, and direct.
Dixon	5,161	1,640	...	525	8	100,000	Do.
		1,730	...	...	...	...	
		1,810	...	...	...	...	
Earlville	1,058	150	...	...	— 15	...	
East Dubuque	1,069	940	5	420	95	...	
Elgin (hospital)	...	2,026	6	(?)	— 4	...	
Fairbury	2,324	2,002	...	...	— 60	25,000 Ex. 1,200	Fairbanks, Morse & Co.
Forreston	1,118	300	8	...	— 25	8,000 Ex. 400	Pump to water tower.

a "Ex." in this column means running expenses per annum.

Cities using water from deep wells—Continued.

City.	Population in 1890.	Depth.	Diameter.	Capacity per minute.	Head from surface.	Waterworks.	
						Cost. *a*	System.
		Feet.	*Inches.*	*Gallons.*	*Feet.*		
Fulton	2,099	1,246	(?)	300	60 20	$11,000 Ex. 1,500	Elevated underground reservoir; pump from well.
Galena	5,635	1,509	8	166	85	(?)	Pump direct from well.
Geneseo court-house.	3,182	2,250	6	200	25	(?)	(?)
Geneva	1,692	2,500	(?)	(?)	(?)	....	
Hamilton Sanitarium.	1,301	680	(?)	(?)	63	....	
Harvard (railroad well).	....	900	7	100+	— 41	9,000	Pump to tank.
Harvey	(?)	1,300	(?)	250	— 10	100,000 Ex. 5,800	Pump to standpipe, and direct pressure.
Hennepin	574	800	4	80	50	....	
Henry	1,512	1,355	3½	32	(?)	....	
Highland Park	2,163	2,200	5	150	0	60,000	Dean pumps.
Hinsdale	1,584	864	(?)	(?)	(?)	(?)	Pump to standpipe.
Hoopeston	1,911	350	8	175	— 20	50,000 Ex. 2,500	Pump to reservoir, then to standpipe.
Ipava	667	1,570	4	60	— 16	3,100 Ex. 365	Pump to standpipe.
Jacksonville Jacksonville, No. 2	12,935	2,343 3,028	6 5⅝	30 500	— 15 — 30	200,000 Ex. 7,000	Pump to reservoir.
Jerseyville	3,207	2,003	6–3	55	—100	35,000 Ex. 1,800	Gravity and pump direct.
Joliet	23,264	1,200 1,700	(?)	570	— 16	(?) Ex. 13,500	Holley system.
Kewanee	4,969	1,480	6	125	—150	(?) Ex. 4,000	Direct pressure.
Kewanee, No. 2		1,050	4	75	—150	....	
Kewanee, No. 3		1,050	4	50	—150	....	
Lagrange	2,314	2,014	(?)	(?)	(?)	(?)	Pump to standpipe.
Lasalle	9,855	502	6	200	(?)	(?)	Direct pressure.
Lemont	6,000	1,366	(?)	(?)	60	(?)	(?)
Lockport	2,449	(?)	(?)	(?)	(?)	(?)	(?)
Macomb	4,052	1,350	(?)	(?)	— 55	30,000 Ex. 1,500	Pump to standpipe, and direct pressure.
Marseilles (275 wells).	2,210	100 150 200	2±	6 1½	5	....	Private wells.
Mendota	3,542	400	(?)	70	— 40	50,000 Ex. 3,280	Direct pressure.
Minonk	2,316	1,755	6	100	—150	20,000	Pump to standpipe.
Monmouth	5,936	1,400	6–4	210	— 60	(?) Ex. 4,000	Holley system.
Morgan Park	1,027	1,046	(?)	(?)	— 46	(?)	(?)
Morris	3,653	600	(?)	16	12	32,000 Ex. 1,500	Holley system.
Mount Carroll	1,836	2,502	5	....	— 20	(?)	Pump to standpipe.

a "Ex." in this column means running expenses per annum.

Cities using water from deep wells—Continued.

City.	Population in 1890.	Depth.	Diameter.	Capacity per minute.	Head from surface.	Waterworks.	
						Cost. *a*	System.
		Feet.	*Inches.*	*Gallons.*	*Feet.*		
Oakpark	4,771	1,565	6¼	500	— 12	$400,000	Air compressor and Worthington pumps.
Oakpark, No. 2		2,180	6	175	— 12	....	
Ottawa (200 wells)	9,985	400 ±	4–6	....	....	....	Private wells.
Parkridge	987	1,500	6 3½	(?)	— 8	(?)	(?)
Polo	1,728	2,100	(?)	(?)	— 70	18,000 Ex. 700	Morgan pumps.
Princeton	3,396	2,095	4⅝	320	— 72	95,000	Pump to standpipe.
Riverside	1,000	1,300	3½	1,000?	(?)	(?)	Air compressor: pump to standpipe.
Riverside, No. 2		2,200	(?)	....	(?)	....	
Rockford	23,584	400	6	(?)	8	538,121 Ex. 17,452	Direct pressure.
Rockford, No. 2		1,300	6	250	5	....	
Rockford, No. 3		2,000	6	220	8	....	
Rushville	2,031	2,500	(?)	(?)	(?)	20,000 Ex. 720	Pump to standpipe.
Savanna	3,097	1,430	....	500	83	....	Pump to reservoir on hill.
Seneca	1,190	350	(?)	(?)	(?)	....	None.
Seneca, No. 2		650	4	(?)	22	....	
Sparta	1,979	450	(?)	(?)	— 30	....	Do.
Steeleville	401	312	2	2	+?	....	Do.
Sterling	5,824	1,450	5–6	900	+?	50,000 Ex. 3,000	Pump to standpipe.
Utica	1,594	325	(?)	140	50	(?)	Hydrants on wells.
Warsaw	2,721	560	6	200	100	....	Natural pressure.
Washington Heights.	2,253	1,308	(?)	(?)	(?)	(?)	(?)
Wenona	1,053	1,854	(?)	100	—125	....	Under construction
Wheaton	1,622	178	10	300	— 20	33,600	Pump to standpipe.
Wilmington	1,576	635	4½	(?)	46	10,000	Direct pressure.
Winnetka	1,079	1,900	(?)	(?)	(?)	80,000	Worthington pumps to water tower.
Woodstock	1,683	1,014	(?)	500	(?)	30,000	Pump to standpipe.

a "Ex." in this column means running expenses per annum.

CHAPTER VII.

WATER SUPPLIES FOR RURAL DISTRICTS.

GROUND-WATER WELLS.

This term covers a class of shallow wells which derive much of their water from the ground immediately surrounding them, and which are directly dependent upon its saturation. These wells are to be distinguished from wells that derive their supply from a distance, whether those wells be deep or shallow. Ordinarily, they are called surface or seep wells, and the local source of supply is thus recognized.

In ground-water wells the level of the water is about the same as in the bordering formations, and rises and falls with the fluctuations of the ground water, being near the top of the well in wet seasons, when the ground is saturated, but at a considerably lower depth in seasons of drought. The fluctuation of such wells has been carefully studied by Prof. F. H. King, of the Wisconsin Agricultural Experiment Station, at Madison, and the results appear as a bulletin of the Weather Bureau.[1] Professor King finds that the fluctuations are very complex. There are not only high and low stages due to the amount of rainfall, but changes due to soil temperature and to barometric pressure, and even slight oscillations caused by the passage of a heavily loaded railway train. The influence of rainfall is, however, the only one of the several modifying influences which greatly affects the value of a well, for the changes effected by soil temperature, barometric pressure, etc., amount to but few inches.

The several deposits that form the immediate surface of the State include bowlder clay or till, loess, compact silts, sand, gravel, and the various rock formations with their several varieties of limestone, shale, and sandstone. The rock formations are throughout much of the State so deeply buried beneath the drift that they are not reached by ground-water wells. In the portions of the State where the rock formations are near the surface they are usually mantled by one or more of a variety of deposits, including the several classes of drift and silts of Glacial age, as well as residuary clays. But it is often the case that this mantle is too thin to hold sufficient water to supply a well, and then the rocks are drawn upon. If a well from the rock derives its supply by percolation from the soil on its immediate borders, it is as

[1] Fluctuations in the level and rate of movement of ground water, by Franklin H. King: U. S. Department of Agriculture, Weather Bureau Bull. No. 5, Washington, D. C., 1892, 75 pp.

truly a ground-water well as one which obtains its supply without entering rock. On low ground, shallow wells in the rock, and also wells in the drift, may be fed from a distance, in which case they are not of this class. The ground water often saturates a rock formation in a wet season nearly or quite to the surface, and in such case the well, as in drift deposits, may become lowered to a depth of several feet in seasons of drought. The ground-water wells are therefore not limited to any one class of formations, but, on the contrary, they may be found in nearly every formation represented in the State.

As the surface formations vary greatly in their capacity to furnish water to wells, the strength of wells may be expected to vary also. Wells in porous formations, as gravel or sand, or in sandstone, are, as a rule, far stronger than wells in compact deposits, such as bowlder clay, shale, or limestone.

The bowlder clay shows, perhaps, greater variations in texture than any other of the formations mentioned. It ranges from a close-textured and oily clay without joints to a very coarse-textured deposit with a matrix nearly as pervious as water-bedded sand. In places, also, it is broken by frequent joints, through which water finds passage. This is more conspicuously the case in the older drift than in the newer. Such joints are usually filled with coarse material carried by the percolating streams, and thus have the appearance of veins of sand or fine gravel. Wells of considerable strength are found if water-bearing joints or veins are struck, while neighboring wells which miss such joints may be weak. Bowlder clay is also often intimately associated with deposits of sand or gravel. When such deposits are of limited extent, and completely inclosed by bowlder clay, they are of value only in extending the reservoir beyond the limits of the well; but when of great extent they usually furnish strong and lasting wells. The value of a well may also depend largely upon its position. If on the brow of a bluff or the terrace of a stream, it may be subject to greater fluctuations than a well in similar formations on the uplands. Wells made in the sand or other porous deposits of a river terrace will often fluctuate as greatly as the stream, even though distant several miles from it. Conspicuous examples occur on the Wabash, Illinois, and Mississippi terraces. In general it may be said that fluctuation in the level of ground-water wells is proportioned to the nearness to a drainage line. But there are frequent exceptions, which occasion remark by the residents, and which may usually be attributed to structural conditions that prevent escape to the valleys. The valley naturally exhausts first the water contained in the formations on its immediate borders, and then lowers the water level at greater distance. Just so a well, as indicated by Professor King, drains the strata for but a short distance in wet seasons, but greatly extends its drainage area in seasons of drought.

In Illinois bowlder clay is by far the most important source of supply for ground-water wells. It is only in the portion of the State lying north of the Kankakee and the west-flowing portion of the Illinois that such wells are largely derived from sand and gravel, and only in a few counties in the southeastern part of the State are they derived to any great extent from sandstone and sandy shales. Limestones supply only small areas in northeastern Illinois, a limited district in the northwestern corner, and a narrow strip on the western border and in the southern part of the State; while Tertiary deposits of sand and gravel supply the extreme southern end of the State.

On the accompanying map (Pl. CX) the extent of these districts may be seen. The elevated driftless tracts of the northwest corner and the southern end of the State obtain wells almost entirely from the rock, the only exceptions being along valleys, where they are obtained from alluvium. Occasional weak wells are obtained, however, at the base of the loess, which mantles much of these districts to a depth of several feet. In these elevated districts, ground-water wells are not in such general use as in the remainder of the State. Cisterns are relied upon in southern Illinois, while wells 50 to 150 feet or more in depth, which are independent of the percolations of the immediate border, are numerous in northwestern Illinois. In each district, however, there are quite extensive areas where shallow wells may be obtained.

In the sandstone district of southeastern Illinois wells frequently enter rock at a depth of 8 to 10 feet and obtain a water supply at depths of but 20 to 30 feet. The only notable exception is on the narrow ridges or mounds of rock, where they are deeper. In the limestone district bordering the Kankakee and Des Plaines and extending into southern Kendall County water is usually obtained at 25 to 40 feet. In the region of thin drift in northwestern Illinois the majority of ground-water wells obtain their supply without entering the rock, at depths of 15 to 30 feet, but they have frequently to be supplemented by cisterns.

There are very extensive districts in western and southern Illinois (indicated on the map, Pl. CX) where wells for household use are mainly in the drift, but the stock wells are frequently sunk into the rock. Wells of sufficient strength for household use, with a capacity of 1 to 5 barrels per day, may usually be obtained throughout these extensive districts at the convenient depths of 15 to 25 feet. The majority have probably a daily capacity of not more than 2 barrels, and many will become dry in seasons of extreme drought. It is very seldom, however, that the weakness of the wells causes serious inconvenience, as in almost every village a few wells may be found which will yield enough to supply several families. In farming districts where it is impracticable to puncture the earth with numerous borings and thus obtain the best shallow wells, it becomes necessary in many cases to sink deep wells. Such wells are usually put down to sufficient depth to derive their supply from wide areas, and are thus removed from the class of wells under discussion.

With the exception of several small areas (represented on the map, Pl. CX) in which the drift is so thin that a part of the wells must be sunk into the rock, the northeastern part of Illinois, including, perhaps, one-third of the State, has a coating of drift so thick that it is a rare occurrence for a well to penetrate it. The average thickness of the drift is estimated to be not less than 100 feet, while in places it exceeds 300 feet. If ground-water wells prove too weak, the wells are sunk, not to rock, but to deep-lying and somewhat extensive water-bearing beds, which are there inclosed in the drift. This region is variable in its advantages for ground-water wells. In the northern part, from the Kankakee and Illinois rivers northward, there is usually an adequate supply at convenient depths, because of the presence of sand and gravel in large amount. In the district south and east from the Illinois the ground-water wells are often weak, because of the very compact character of the upper part of the bowlder clay. In this district, however, the bowlder clay is quite extensively underlain by beds of sand and gravel, which furnish strong wells at moderate depths—50 to 150 feet.

The effect of the droughts of 1894 and 1895 upon ground-water wells was more severe than that of any other drought since the settlement of the State. In many localities where such wells before yielded a sufficient supply a large number became entirely dry because the available ground water was exhausted. The depth to which exhaustion extended varied greatly. In some localities it affected only wells less than 20 feet in depth, while in others it included wells 30 feet or more in depth. The writer's studies in the season of 1895 were mainly in southeastern Iowa, a district underlain by a compact bowlder clay broken by frequent joints and differing but little from that of western Illinois. Wells 30 feet in depth were affected by the drought, and in consequence a large number have been extended to a depth of 50 feet or more. In its deeper portion the clay has been found to yield water in about as great amount as is yielded by the upper portion in ordinary seasons. In southeastern Iowa many shallow wells are made by farmers at convenient places on the farm for watering stock. Such wells are often not in use for long periods because of a shifting of pasture fields to other parts of the farms. When the drought came on and the wells in use gave out, the farmers turned to such wells, expecting to find a supply of water, but in a great many instances the wells were found to be empty. It is therefore evident that the ground water which usually feeds such wells had been completely exhausted, at least to the depth of their bottoms. To obtain wells in new places it is necessary to sink to greater depths than formerly. What was observed by the writer in southeastern Iowa appears from correspondence to be generally true over till-covered areas in the entire district affected by the drought, which includes most of the central portion of the Mississippi Basin. Observations were made by the writer at many freshly dug wells in southeastern Iowa to determine to what depth the subsoil had become dry. The subsoil is a compact loess, such as requires tile


MAP OF
ILLINOIS AND WESTERN INDIANA
SHOWING THE RELATION OF THE
DRIFT
TO THE ORDINARY WELLS
BY FRANK LEVERETT
1896
LAKE MICHIGAN
MISSISSIPPI RIVER
CHICAGO
Racine
Kenosha
Waukegan
Lake Forest
Highland Park
Evanston
South Haven
St. Joseph
Berrien Springs
Niles
Michigan City
South Bend
La Porte
Valparaiso
Hammond
Crown Point
Knox
Winamac
Rensselaer
Monticello
Logansport
Delphi
La Fayette
Frankfort
Williamsport
Covington
Crawfordsville
Lebanon
Newport
Galena
Freeport
Rockford
Belvidere
Harvard
Woodstock
Algonquin
Elgin
Savannah
Mt. Carroll
Oregon
Polo
Sycamore
DeKalb
Geneva
Wheaton
Clinton
Fulton
Morrison
Dixon
Sterling
Amboy
Aurora
Yorkville
Joliet
Rock Island
Muscatine
Mendota
Princeton
Geneseo
Cambridge
Kewanee
Lasalle
Utica
Ottawa
Morris
Braidwood
Kankakee
Aledo
Hennepin
Streator
Toulon
Dwight
Wenona
Lacon
Oquawka
Galesburg
Monmouth
Pontiac
Minonk
Metamora
Burlington
Watseka
Kentland
Fowler
Peoria
Fairbury
Ft. Madison
Canton
Pekin
Bloomington
Hoopeston
Dixon
Gibson
Keokuk
Carthage
Macomb
Lewiston
Warsaw
Havana
Lincoln
Clinton
Farmer City
Champaign
Urbana
Danville
Rushville
Beardstown
Petersburg
Monticello
Quincey
Mt. Sterling
Virginia
Decatur
Wabash Riv.
Iroquois Riv.
Kankakee
Rock Riv.
Illinois
Vermilion
Tippecanoe
Calumet
Sugar Cr.
91°
90°
89°
88°
87°
42°
41°
40°

LEGEND.
Unglaciated Paleozoic (Wells in Rock)
Unglaciated Tertiary (Wells in Sand or Gravel)
Drift, 10-50 Feet (Best Wells Usually in Rock)
Drift, 25-75 Feet (Wells Frequently Enter Rock)
Drift, 100 Feet or More (Wells Seldom Enter Rock)
Scale
0 5 10 20 30 40 50 60 70 MILES
LIST OF COUNTIES
No. 1 Jo Daviess.
" 2 Stephenson.
" 3 Winnebago.
" 4 Boone.
" 5 McHenry.
" 6 Lake.
" 7 Cook.
" 8 Du Page.
" 9 Kane.
" 10 Dekalb.
" 11 Ogle.
" 12 Lee.
" 13 Carroll.
" 14 Whiteside.
" 15 Rock Island
" 16 Mercer.
" 17 Henry.
" 18 Bureau.
" 19 Putnam.
" 20 Lasalle.
" 21 Kendall.
" 22 Grundy.
" 23 Will.
" 24 Kankakee.
" 25 Iroquois.
" 26 Ford.
" 27 Livingston.
" 28 Marshall.
" 29 Woodford.
" 30 Stark.
" 31 Peoria.
" 32 Knox.
" 33 Warren.
" 34 Henderson.
" 35 Hancock.
" 36 McDonough.
" 37 Fulton.
" 38 Mason.
" 39 Tazewell.
" 40 McLean.
" 41 Vermilion.
" 42 Champaign.
" 43 Piatt.
" 44 Dewitt.
" 45 Logan.
" 46 Menard.
" 47 Cass.
" 48 Schuyler.
" 49 Brown.
" 50 Adams.
" 51 Pike.
No. 52 Scott.
" 53 Morgan.
" 54 Sangamon.
" 55 Christian.
" 56 Macon.
" 57 Moultrie.
" 58 Douglas.
" 59 Edgar.
" 60 Clark.
" 61 Coles.
" 62 Cumberland
" 63 Shelby.
" 64 Montgomery
" 65 Macoupin.
" 66 Greene.
" 67 Calhoun.
" 68 Jersey.
" 69 Madison.
" 70 Bond.
" 71 Fayette.
" 72 Effingham.
" 73 Jasper.
" 74 Crawford.
" 75 Lawrence.
" 76 Richland.
" 77 Clay.
" 78 Marion.
" 79 Clinton.
" 80 St. Clair.
" 81 Monroe.
" 82 Randolph.
" 83 Washington.
" 84 Perry.
" 85 Jefferson.
" 86 Wayne.
" 87 Edwards.
" 88 Wabash.
" 89 White.
" 90 Hamilton.
" 91 Franklin.
" 92 Jackson.
" 93 Williamson.
" 94 Saline.
" 95 Gallatin.
" 96 Hardin.
" 97 Pope.
" 98 Johnson.
" 99 Union.
" 100 Alexander
" 101 Pulaski.
" 102 Massac.
ST LOUIS
MISSISSIPPI RIVER
MISSOURI R.
OHIO RIVER
Wabash
Cumberland Riv.
Tennessee Riv.
White Riv.
91° 90° 89° 88° 87°
39° 38° 37°
JULIUS BIEN & CO. N.Y.

draining. It was found generally to be dry to a depth of but 3 to 4 feet, though the upper 10 feet were seldom sufficiently moist to be easily spaded. As the loess is but 6 to 8 feet thick, the upper part of the underlying till is affected. The heavy rains which fell in December, 1895, are reported to have moistened the ground only to a depth of 4 to 6 feet. At the present writing (April, 1896) they have not had an appreciable effect upon the wells.

It is quite generally believed by the old settlers of Illinois and bordering States that the shallow wells are becoming permanently lower, but in the absence of statistics only the probable influence of settlement upon such wells can be considered. Much of Illinois, covered as it was with a heavy and tangled mass of prairie grass, had originally a poor surface drainage. In consequence the ground became completely saturated by the heavy rains. The effect of settlement has been to afford better surface drainage by opening ditches and removing obstructions, and thus to lessen the amount of saturation. Cultivation of fields, leading as it usually does to a more rapid escape of water over the surface, also tends to lessen the degree of saturation. A somewhat reduced supply to shallow wells and a more frequent failure of such wells than in the days of early settlement are therefore to be expected.

In Illinois the value of ground-water wells as a source of water supply is vastly greater than that of all other wells combined. There are probably 20 such wells for every deep well in the State, there being on an average not fewer than 10 wells for every mile of the 56,000 square miles of land surface. The value of the wells is not so much in the quantity of water furnished as in its ready accessibility. The wells for household use probably yield an average of but 2 barrels per day, and these comprise fully 75 per cent of the wells, or not fewer than 420,000. The stock wells of this class yield on an average perhaps 5 barrels per day. The total supply from this source is therefore about 840,000 barrels for household consumption and 700,000 barrels for stock, or about 1,500,000 barrels per day. About one-half the population of the State is thus supplied with water for cooking and drinking, the other half being supplied mainly from Lake Michigan and from the streams; deep wells, as is indicated further on, furnishing the supply for but a small part of the population.

The dependence upon ground-water wells being so great, it becomes a matter of much importance to insure favorable sanitary conditions. In this respect the people of Illinois are exceedingly careless. It is estimated that at least one-half the wells are so situated as to invite pollution. Many of them are placed at the side of the house where slops are emptied, and it is certain that a considerable percentage of such wells receive the slops without much filtering. In not a few cases the wells are so situated as to be within the range of drainage from privies. Nearly every farm furnishes an example of a well situated in the midst of the barnyard, where manure heaps readily drain into it, and these wells are used by the men when about the work of the barn. In not a few instances the writer has found the pollution of such wells to be so great as to be detectable by the odor and the color of the water, and the farmer often observes this condition and is yet too careless to avoid using the water.

A circular letter sent out by the writer to the principal villages and cities of Illinois, Indiana, and Ohio contained the questions: "Are the shallow wells obtained below a bed of clay or impervious stratum of sufficient thickness to prevent contamination of the water from cesspools or other sources? What is the thickness and what the character of such overlying beds?" In at least 90 per cent of the replies the first question was answered in the affirmative, and yet in many cases the further statement is made that the impervious bed is but a few inches in thickness. From personal observation of the position of village wells in reference to cesspools the writer is convinced that the majority are liable to contamination from that source. It seems not at all remarkable, therefore, that typhoid fever so often becomes epidemic both in the villages and in the country districts of Illinois. In the country districts there is certainly abundant space for the proper distribution of privies, wells, and barnyards, and everywhere it is possible to greatly improve the relative position of privies and wells and to avoid throwing slops and refuse matter where a well will be apt to receive them.

DRIFT WELLS WITH WIDE OR REMOTE ABSORPTION AREAS.

In the wells just described the water supply is derived from the ground immediately surrounding the well mouth. In the class of wells now to be discussed the supply depends scarcely at all upon the ground around the well mouth. They are usually so deep that no water gains access to them from this source, though in some cases, as in valleys, they are shallow and are fed from the immediate borders as well as from a distance. Commonly their supply is derived from beds of gravel or sand which are interbedded with the sheets of till. They are supposed to be fed, like the water supplies found in the rock strata, from surface outcrops of the water-filled beds or through joints or other openings in the overlying drift sheet. Like artesian wells, they usually show a marked rise of water above the level at which water is struck, and in many cases they overflow. This class of wells is represented very widely in the State, and yet such wells are certain to be obtained in only a few localities, since the proper arrangement of drift beds for the concentration of water in underground sheets does not prevail widely.

The limits of districts where they may be found are not yet ascertained, and will be known only after a thorough testing by well borings. Perhaps the most extensive district in the State is found in Iroquois County, where, as shown below, flowing wells from the drift abound.

The water-bearing beds here appear to derive their supply from the bordering moraine and other elevated tracts on the south and west. Another large district is found on the plain lying east of the Marseilles moraine and bordering the head of the Illinois River. In that district there is usually a marked rise in the water when found in sand or gravel below till, and there are occasional flowing wells. The source of the water is thought to be in the bordering moraine. Another large district where wells rise nearly to the surface and occasionally overflow is found on the west side of Fox River from the Illinois River northward beyond the State line. In the southern part of this district the wells are located on a plain with elevated moraines on the west border, from which the water supply is probably derived. In the northern part of the district the wells which show a marked rise are found in the narrow plains and low tracts between the morainic belts. Still another extensive district characterized by occasional flowing wells and by a general rise in water found in sand or gravel beds lies along the east slope of the Valparaiso moraine in Lake, Cook, and Dupage counties. Here also the supply appears to be from the moraine.

The districts just mentioned are more uniformly favored with strong wells and with a marked rise of water than any other portions of the State. The drift beds of the moraines appear to dip toward and pass under the plains on their north and east borders, as is to be expected if we consider the method of drift deposition.

In many places in central and eastern Illinois where the drift is very thick, wells of this class are found, but the chances of striking strong wells are fewer, and the rise of water is less uniform and on the whole less pronounced than in the districts just mentioned. Notwithstanding these uncertainties, there are hundreds of successful wells. Several cities in that region have found abundant supplies of water from the drift beds, among which are Peoria, Bloomington, Lincoln, Champaign, Mattoon, and Paris, each of which has a population of several thousand. By reference to the list of towns which obtain water supplies from the drift many others may be added. Such wells are in great demand by stock raisers, and are therefore rapidly coming into use in rural districts.

In western Illinois the wells of this class are numerous, but there is even less certainty of finding a strong well than in central and eastern Illinois, for the drift contains on the whole a smaller proportion of sand and gravel and is a thinner deposit.

In southern Illinois, from the Shelbyville moraine southward, this class of wells is to be found only in a few localities of small extent. They usually occur along the line of pre-glacial valleys, where the drift is exceptionally thick, and where it shows a tendency toward a sandy constitution.

Wells of this class are of inestimable value to the many villages and cities where they may be obtained and to the stock raisers in the rural districts. The quality of water is the best to be found at any horizon, for there is freedom from the contamination to which surface water and water from shallow wells is liable. There are also very few wells in which the mineral ingredients are at all objectionable. These wells should displace the ground-water wells wherever practicable.

The average depth of these wells probably does not exceed 100 feet, but even where it is necessary to sink a well to a depth of 200 or 300 feet the excellent quality and large quantity of water usually justify the outlay. To wells of this class it is customary to attach a windmill, and thus dispense with the labor of drawing water by hand. The wells in the rural districts are ordinarily not more than 4 inches in diameter. Unless they will stand a test of 4 gallons per minute they are considered too weak to justify the erection of a windmill. But there is scarcely a township of the district included by the Shelbyville moraine, except where drift deposits are thin, which does not already show several of these strong wells with windmill attached; and in the most favored districts, as outlined above, there is scarcely a square mile without its strong well and windmill pump. In western Illinois the number of strong wells is nearly as great as in the district included by that moraine, but there is a large percentage which have been extended into the rock.

FLOWING WELLS FROM THE DRIFT.

GENERAL STATEMENT.

In a few small areas the drift has furnished an overflow of water from wells. These areas are usually on the slopes of moraines or along valleys in which there is a thick filling of drift. The water appears to be derived from the moraines, or, in the case of valley wells, from the higher ground bordering the valley. This class of wells differs from the class just considered only in the matter of overflowing. The rise of water is in many cases no greater than in wells which do not overflow. The overflow is due to the low altitude of the surface rather than to exceptionally great rise of water.

The principal districts with this class of wells are shown on the artesian-well map (Pl. CXIII). The largest district characterized by this class of flowing wells is found in a drift basin in Iroquois County and the border portions of adjacent counties in eastern Illinois. It comprises an area of at least 500 square miles. A small district is found in northern Vermilion County, near the Middle Fork of Vermilion River. There are also small districts near Plattville, in Kendall County; near Earlville, in northern Lasalle County, and adjacent portions of Lee and Dekalb counties; near Sycamore, in northern Dekalb County; near Palatine, in northern Cook County, and along Salt Creek Valley, in northern Cook and eastern Dupage counties. A few flowing wells are found also along the North Fork of Chicago River, in northern Cook County and southern Lake County. Flowing wells are also common in the low-lying tracts among moraines of Lake, McHenry, and Kane counties. The combined area of all these small districts will probably not greatly exceed that of the Iroquois district (500 square miles). Flowing wells are frequently obtained on the Sangamon and its tributaries, especially those which head within the limits of the Shelbyville moraine, among which may be mentioned Vermilion, Mackinaw, Kaskaskia, and Embarras rivers. These valleys are not, however, generally favorable localities for such wells.

It will be observed that all the flowing-well districts above mentioned lie within the limits of the Shelbyville moraine, and that the scattering wells are mainly to be found within the same limits. In the outlying portion of the State these wells are confined to a few valleys, and are seldom in areas of sufficient size to merit mention.

FLOWING-WELL DISTRICT OF IROQUOIS AND ADJOINING COUNTIES.

The northern boundary of this district, from Watseka, in Iroquois County, to Piper City, in Ford County, lies parallel to and about 3 miles distant from the north side of the Toledo, Peoria and Western Railway. On the west and south the boundary lies near the border between the plain and the morainic tract southwest of it. It passes from Piper City through Thawville and Bulkley to the extreme southern part of Iroquois County, thence up Fountain Creek Valley a short distance into Vermilion County, and thence northeast to within 2 miles of Wellington, Iroquois County. The eastern boundary has a somewhat sinuous course, following approximately the line of the Chicago and Eastern Illinois Railroad from the vicinity of Wellington to Watseka.

Aside from the main belt, there is a narrow belt along the Vermilion marsh north of Piper City, where a few flowing wells have been obtained. There is also a narrow flowing-well district along the Iroquois River from Sugar Island, in northern Iroquois County, Ill., up to Rensselaer, Ind. Similar narrow belts extend for several miles up the tributaries of the Iroquois in northern Iroquois County. In these narrow belts along the Iroquois and its tributaries the wells, as a rule, overflow at the surface only when obtained on the low bottom, which is subject to inundation when the streams are high. It is probable that wells along the upper portion of the Iroquois derive water from a source independent of that which supplies the main district.

In the midst of the main district, leading from Milford westward past Onarga, there is an undulatory belt having a width of 3 miles or more where the water fails to reach the surface by a few feet.

In the main well district two serious elements of uncertainty occur: First, the uncertainty of striking a water-bearing bed at any given depth, for the beds are usually thin and subject to interruptions; second, the danger of the surface elevation being too great, since where the flows are successful the water rises to a height of but a few feet above the surface.

The first element of uncertainty has proved in many cases to be of little consequence, since the artesian water is found at not less than three different levels, and it is rare that all three water-bearing beds are absent in any one boring. It is often the case, however, that only very weak flows are obtained.

The second element of uncertainty necessarily affects much of the district, since a rise of ground of but 5 to 10 feet often makes a flow impossible, even in places where veins are struck from which water rises in great volume, there being insufficient head to reach the surface. The uncertainty is very great all along the borders of the main district and in quite an extensive tract south and east of Gilman.

Outside of the territory described above as the flowing-well district there is over a considerable tract a rise of water nearly to the surface. In the sand-covered belt north of the Iroquois River water rises to within 10 to 15 feet of the surface, except on high points near the border of the Erie-Saginaw moraine. On the opposite side of the Iroquois, between the flowing-well district and the Marseilles moraine, water rises to within 25 feet of the surface on the higher portions of the plain and almost flows in low ground near the creeks. East from the flowing-well district as far as the Indiana line there is considerable rise of water in deep wells.

The only member of the drift series within this flowing-well district which possesses anything like uniformity of distribution and thickness is a sheet of slightly pebbly, compact blue clay, which immediately underlies the yellow clay subsoil and overlies the first water bed from which flows are obtained. This blue clay is 50 to 75 feet in thickness. Beneath it, to a depth of 50 to 100 feet farther, are alternations of sand or gravel in thin beds with beds of compact stony clay of considerable thickness. These beds of sand and gravel yield the artesian water. In much of the district a bed of buried peat is found associated with the first water-bearing sand, showing that it was a marshy land surface prior to the deposition of the overlying blue clay. In a few places beds of peat have been found at two levels in a single well.

Table showing depths to water-bearing strata and heights to which water will rise above surface.

Locality.		Depth.	Height above surface.
		Feet.	*Feet.*
East side of Vermilion marsh		60	4- 5
West side of Vermilion marsh, 1 vein at		75	1
Piper City, 1 vein at		65	1- 2
South of Piper city		9- 23	1- 2
Near county line southeast of Piper City.	First vein	26- 40	1- 2
	Second vein	70- 87	2- 4
Near Ridgeville	First vein	40- 45	Surface.
	Second vein	75	1- 2
Near Lahogue		70- 80	10
Gilman		70-165	1- 4
Near Crescent City		80-120	1- 6
Spring Creek east of Gilman		100-120	(?)
Spring Creek southeast of Onarga		50- 90	(?)
Shavetail Slough		95-100	Surface.
In and near Watseka	First vein	85- 90	1- 6
	Second vein	160-165	1- 6
Ash Grove and vicinity	First vein	40	2- 4
	Second vein	55	2- 4
	Third vein	70- 75	2- 4
Near Cissna Park		48- 55	4- 8
Near Clayton		60- 70	9
Fountain Creek south of Clayton	First vein	50- 55	Surface.
	Second vein	75- 80	1- 2
	Third vein	135-140	3- 4
Near Bulkley	First vein	40- 50	3- 6
	Second vein	80-110	3- 6

The rate of flow varies from a feeble stream, amounting to but 1 to 2 gallons per minute, to a stream flowing 60 or more gallons per minute. Many of the wells flow only 4 or 5 gallons per minute. In most of the wells the stream has a gentle flow, though occasionally it issues from the pipes with considerable force, but even in such instances the water can be made to rise only a few feet above the height at which it pours forth rapidly.

The city of Watseka, with a population of over 2,000, obtains a supply for its waterworks from a single well, though pumps are necessary to obtain an adequate supply. In nearly every village of the district wells may be found having sufficient strength to supply a waterworks system.

In many of the wells a loss of head has been reported amounting to 3 to 4 feet, and occasionally to as much as 8 to 10 feet, in which event they have ceased to flow. A few cases of stoppage of flow occur because of the boring of a well in the vicinity at a lower level, the latter well being sufficiently strong to draw off the head. After a series of dry years, such as have just been experienced, the head appears to have been affected. At Watseka it has decreased about 7 feet in the past few years, so that flows are now obtained only in the lower parts of the town. Many wells show a loss of head amounting to a foot or more, and a still larger number are reported to show a decrease in the rate of flow. It is frequently observed that several wells in close proximity have a tendency to lessen the average rate of flow, and sometimes when a strong well has been obtained in the vicinity of several weak ones the weak wells decrease in flow or stop entirely. These phenomena show that there is a limit to the water supply, and that if the whole region were to be honeycombed with wells the aggregate amount of flow would not increase at anything like the ratio of increase in the number of the wells.

In some cases the wells have ceased flowing because they have become choked with sand. Instances occur where wells have thrown out great quantities of sand and then stopped flowing. It is thought that in such cases the overlying beds may have settled down and shut off the flow, since this phenomenon occurs only where the water bearing sand bed is very thin, and since it is often the case that borings made within a few rods of a well that has stopped flowing will open a fresh flow.

It has been suggested by Mr. Daniel W. Mead[1] that these wells have their source in the St. Peter sandstone, which he supposes to be covered in this region only by the drift deposits.

No evidence of such a relationship of the sandstone to the drift has been found so far as the writer is aware. Furthermore, as shown below, the supply is from the south instead of the north.

It is generally supposed by the residents of the district that the source is from the great marshes along the Kankakee, which are much of the year covered with water. This can not be the case, however, since the altitude of the marshes is lower than the head of water at the wells.

The source of supply is, without doubt, from the elevated country bordering the well district on the south and west. The gathering ground may include not only the moraine immediately bordering the district but also a plain of considerable elevation lying between it and another moraine a few miles to the southwest. This plain is underlain in places by gravel or material which is quickly absorbent of water, and since the ridge which lies between it and the artesian-well district appears to have been pushed out upon the plain tracts it seems not improbable that the water which falls on the plain may pass northward beneath the ridge along sand or gravel sheets. It appears from borings in the moraine (as indicated further on) that it is composed

[1] Hydrography of Illinois, p. 21.

largely of till. Should this be the case the somewhat elevated plain southwest of it is probably the chief absorbing area.

The following table of surface elevations and water levels shows an increase in head in passing southward toward this elevated country. The elevations are taken from the profile of the Illinois Central Railway. The water levels in 1895 are slightly lower than shown in this table, but the difference seldom exceeds 5 feet.

Surface elevations and water levels in Iroquois and adjoining counties.

Station.	Distance from Ashkum.	Elevation above tide.	Water level above tide.
	Miles.	*Feet.*	*Feet.*
Ashkum	0	679	657
Danforth	4	667	660
Gilman	7	666	667
Onarga	11	689	674
Ridgeville	13	681	681
Spring Creek Station	14	677	682
Thawville	17	699	697
Bulkley	20	713	697

It appears from this table that there is an increase of head toward the south of nearly 2 feet per mile. An east-to-west line shows a similar rise toward the moraine on the west. Extending the comparisons east from Gilman, it is seen that at Watseka, 12 to 13 miles distant and at an elevation 20 to 25 feet lower than at Gilman, water rises only 2 to 4 feet above the surface, or about the same as at Gilman, while at Iroquois village, 8 to 9 miles farther east, it rises only to the flood-plain of the Iroquois River, which is 10 to 15 feet lower than the height at which it will flow at Watseka. Upon passing to the east from Iroquois into western Indiana, however, there appears to be an eastward rise in the head, a fact which indicates that the supply in that region is not from the southwest, as in the main district, but more probably from the sandy belt around the head of the Iroquois River.

It should perhaps be stated that the rock floor of this flowing-well district stands higher on its north and east borders than beneath the well district, the difference in altitude being 150 feet or more. This rise would cause an upward bending of the drift beds on the border of the district. This bending of the beds may so interrupt the passage of water down the slope toward the northeast as to improve the conditions for obtaining a flow. The great loss of head in that direction seems, however, to indicate that there is a fair escape for waters.

So far as the writer is aware, no chemical analyses of the water from any of these wells have been made. The waters are chalybeate and have laxative properties. They contain so little lime that it is scarcely necessary to "break" the water for laundry purposes. In this respect the deep wells are in striking contrast with the shallow wells that obtain water in or above the blue clay, the latter being strongly impregnated with lime. It is claimed for these waters that no bad effects result from drinking large quantities, where an equal amount of hard water from the shallow wells would be injurious. It is also said that cattle, horses, and other stock prefer the water from flowing wells and keep in better condition when using it than when they drink the hard water of the shallow wells.

The temperature of several of the wells was taken during the autumn months and was found to be quite uniform at about 50° F.

Along the moraine southwest of this district several deep borings have been made for water between Paxton and Roberts, which usually penetrate a large amount of blue till, beneath which sand of considerable depth is often found. The water rises in the wells but does not overflow because of the high altitude of the ridge. A well in sec. 11, T. 24, R. 9 E., reported by George Leeper, of Paxton, penetrates 98 feet of pebbly clay, then 85 feet of sand, and the water rises 130 feet in the well. A well in sec. 2, T. 24, R. 9 E., reported by Mr. Flora, of Roberts, penetrates 120 feet of clay, then 80 feet of sand; the height to which water rises was not ascertained, though it comes nearly up to the surface. A well in sec. 7, T. 25, R. 9 E., also reported by Mr. Flora, penetrates 190 feet of pebbly clay, then 20 feet of sand, and the water rises 150 feet. A well in sec. 31, T. 26, R. 9 E., reported by Mr. Flora, penetrates clay 130 feet, then sand 110 feet, and the water rises 170 feet or to within 70 feet of the surface.

FLOWING WELLS IN NORTHERN VERMILION COUNTY.

Near Marysville, in northern Vermilion County, on a low plain between drift ridges, several flowing wells have been obtained. A number of these wells were made by Mr. George Platt, a well driller, formerly residing at Watseka. Mr. Platt kept no records of individual wells, but furnished the following general statement:

There are three veins of artesian water within 150 feet of the surface, the first being at a depth of 80 to 90 feet, the second at about 125 feet, and the third at 140 to 150 feet. The water will rise 8 to 10 feet or more above the surface, and some of the wells have a flow of several gallons per minute. The following section illustrates the character of the drift penetrated:

Representative section near Marysville, Vermilion County, Ill.

	Feet.
1. Yellow pebbly clay	10-12
2. Blue clay, soft like putty, and containing few pebbles	60-70
3. Hard, stony clay	3
4. Sand and gravel with artesian water	6-10
5. A hard, partially cemented sandy clay	25-30
6. Sand and gravel with artesian water	5
7. Hard, partially cemented sandy clay	15-20
8. Sand and gravel with artesian water	Several.
Depth	140-150

EARLVILLE FLOWING-WELL DISTRICT.

Near Earlville, in northern Lasalle and southwestern Dekalb counties, there is a tract including an area of 30 to 40 square miles in which flowing wells have been obtained. They are found in the southeastern part of T. 36, R. 2 E., the northwestern part of T. 36, R. 3 E., and the southern part of T. 37, R. 3 E.

The wells are seldom more than 50 feet in depth, and a few are scarcely 20 feet. They vary in depth when near together, but this is to be accounted for in part, though not entirely, by the greater depth to which some of them were sunk into the sand from which the water flows. In no instance does water rise more than 10 feet above the surface, and in most cases it rises only 2 to 3 feet. Where the rise is more than 3 feet the wells are favored by being near streams where there is a lower level than on the plain. In some instances there are singular variations within short distances in the absolute height to which water rises. A well at Charles Pratt's residence, in sec. 5, T. 36, R. 3 E., falls short 6 feet of flowing, but a well a few rods from his house on ground 3 feet above the level of the other well rises 1 to 2 feet above the surface. It seems scarcely probable that the two wells have the same source of supply. During seasons of excessive drought nearly all the wells in this district are said to show a lowering of head of a foot or more.

Water will not flow at Earlville, although the level at Big Indian Creek is several feet lower than in section 6 of the same township, where water rises 10 feet above the surface.

It seems probable that the gathering ground for the water is to be found in a sandy tract north of the well district on the inner slope of the moraine. The water which permeates these porous formations would naturally seek outlet in the direction of surface slope unless checked by some obstruction. This course would take it directly beneath the flowing-well district, and the conditions at Earlville suggest the nature of the probable obstruction to the southeastward passage of these subterranean streams. There is here a considerable rise in the rock strata above their level in the flowing-well district. The drift beds sinking into the concavity north of this ledge would produce such an arrangement of the drift strata as would admit the water to the lower beds beneath the flowing-well district, but at the same time not permit it to have adequate outlet over the arching portion at Earlville. Hence, borings made in the region where the water has accumulated, even though at a higher level than the surface near Earlville, afford a freer outlet for the water than its subterranean course.

These flowing wells usually penetrate the following series of drift beds: (1) Soil, (2) yellow pebbly clay, (3) blue bowlder clay, (4) sand or gravel. Occasionally a well penetrates no blue clay, being in pebbly yellow clay to the water-bearing stratum. In some of the shallower wells water is obtained from sand and gravel between the yellow and blue clays. In a few borings, instead of yellow clay there is sand or gravel, underlain by blue clay, beneath which water is obtained.

The water in nearly all the wells is chalybeate, and is considered very wholesome.

The temperature of the wells was taken in the month of September, and in nearly every well it was about 50° F. The flow is very weak in the majority of cases, being scarcely 1 barrel per hour, but a few wells near Big Indian Creek flow several gallons per minute.

Southeast from Earlville about 3 miles, in the valley of Big Indian Creek, are two flowing wells which are only 12 to 15 feet in depth and scarcely differ from the springs abounding along the creek. Both the wells and the springs are slightly chalybeate.

AU SABLE CREEK FLOWING WELLS AND SPRINGS.

In the vicinity of Plattville, in southern Kendall County, there are several flowing wells. Those which flow are confined to the low ground along the creek, but there is a rise of water nearly to the surface on much of the plain lying east of the Marseilles moraine in Kendall and Grundy counties.

The majority of the wells are but 30 to 45 feet in depth, and penetrate about 30 feet of till before entering the water-bearing sand bed. The absorption area is apparently the slope of the moraine to the northwest of the wells, there being a tract of several square miles in which the drift is somewhat sandy and sufficiently porous to absorb much water. The head at Plattville is about 20 feet above the level of Au Sable Creek bed, or not far from the level of the village, 600 feet above tide (Rolfe). The temperature of several of these wells was taken in the month of August and found to be 48° to 50° F. The water is slightly chalybeate. One of the wells belonging to Daniel Platt was found to have a flow of 10 gallons per minute from an aperture with one-half inch diameter. The pipe had a diameter of 2 inches, and the flow is said to be sufficiently strong to fill it with a rapid stream.

Before any wells had been sunk at Plattville this portion of the valley of Au Sable Creek had a group of springs of local reputation, known as the "Au Sable Springs." They appear for more than a mile from a point one-half mile above Plattville to about the same distance below the village. They have apparently the same source as the flowing wells, and the water probably rises through the till which overlies the water bed.

About 1½ miles east of Plattville a flowing well was obtained at a depth of 80 feet after penetrating about 40 feet of rock. This water has a sulphurous taste. Its source is not apparent.

At Millington, about 10 miles west from Plattville, in the valley of Fox River, shallow flowing wells are obtained from the St. Peter sandstone, and similar wells are obtained at Marseilles, as shown further on. In these cases the source of water is probably from the outcrops of the sandstone rather than from the drift.

PALATINE FLOWING-WELL DISTRICT.

In northern Cook County there is a small district, having a radius of about 2 miles, with the village of Palatine as a center, where flowing wells are obtained. In 1887 there were 8 of these wells in the village of Palatine, and at least 25 in the township. The writer has obtained no later information concerning this district. The depth of the wells ranges from 70 to 170 feet, the majority of them being from 125 to 170 feet in depth. Occasionally a well has struck two or more veins from which water will flow, though usually there is but one vein. In the village of Palatine the water rises from the three strongest wells about 10 feet above the level of the track at the depot. These wells do not obtain water from exactly the same depth, but are among the deepest wells in the village. The head is lower in the shallow wells, water rising in some cases but about 5 feet above the level of the depot. It was not determined to what height water rises in wells outside the village as compared with those in the village, since they are scattered widely, and no levelings have been made between the wells. The rate of discharge varies greatly even in the village of Palatine. The strongest well, which is at the cheese factory, flows 60 gallons per minute. The other wells in the village flow but 1 to 6 gallons per minute, and the wells at the farmhouses outside the village seldom flow more than 5 gallons per minute. The water is slightly chalybeate in every well which was examined, and varies greatly in hardness in the different wells. All the water, however, is so hard that it is necessary to "break" it before using it for laundry purposes.

There are many deep wells in the vicinity of Palatine which do not flow even when the surface level is lower than that at the flowing wells. The water supply is apparently from veins whose collecting areas vary in altitude; otherwise the water level would be more uniform.

The collecting area is thought to be in the portion of the moraine west and north of Palatine. The moraine west of Palatine attains an altitude of 100 to 120 feet above the station, and the crest of the moraine in Lake County, a few miles to the north, has nearly as great an altitude. The superficial drainage is very poor north of Palatine, on the divide between Salt Creek and Buffalo Creek, and it is also poor west of Palatine, for there is no stream nearer than Fox River to receive its waters. Consequently, much of the water must evaporate or find outlet by underground passages. There seems to be a sufficient collecting area and also a sufficient variation in altitude to account for the wells and their different water levels.

SALT CREEK FLOWING-WELL DISTRICT.

South of Palatine Township, along Salt Creek and its tributaries, flowing wells are frequently obtained. They differ but little from springs which occur along the creek. There are at least 6 such wells along a tributary of Salt Creek in the eastern part of Schaumburg

Township (T. 41, R. 10 E.), none of which exceed 45 feet in depth. Those along Salt Creek, from Plum Grove, in southern Palatine Township, to the latitude of Elmhurst, in York Township, seldom exceed 30 feet in depth. In Itasca there are a few flowing wells along a tributary of Salt Creek. Of these, the deepest one is but 28 feet. The water here will not rise more than 3 feet above the bed of the creek. This level is 65 to 70 feet lower than the level of the flowing wells in Palatine.

FARMER CITY WATERWORKS WELL.

At Farmer City, in northeastern Dewitt County, some very strong flowing wells have been obtained from the drift. The city well, which supplies the waterworks, is reported to furnish a rapid flow, filling an 8-inch pipe at a level 3 feet above the surface. The well is 176 feet in depth, and has maintained its strong flow from the time it was made, in 1892.[1] The water is described as "soft, with iron," and it is very wholesome

SYCAMORE WATERWORKS WELLS.

The city of Sycamore, the county seat of Dekalb County, is supplied by flowing wells 65 feet in depth. The superintendent of waterworks, Mr. Pike, has estimated the force of the current to be 90 feet per minute from a 2-inch pipe at a level 6 feet above the surface. The water will rise but a few feet higher. The flowing wells can be obtained only on low ground near the Kishwaukee.

WELLS OF MODERATE DEPTH IN ROCK.

In portions of the State where the drift does not furnish an abundance of water wells are frequently sunk into the rock to a moderate depth. They are usually drilled, and have a diameter of about 4 inches. Usually these wells find sufficient water to justify the erection of a windmill, the yield being at least 3 to 4 gallons per minute and in some cases many times that amount. In this class of wells the head is seldom such as to cause an overflow, and is usually but a few feet above the level at which water is struck.

The data concerning this class of wells (set forth in the following table) have been mainly obtained in response to the circular of inquiry concerning city water supply, and in answer to the two questions: "At what depth is water most abundant in the wells?" and "What range in depth have the wells?" The replies to these questions are given in the majority of the schedules, and it appears that but a small part of the towns have found their most abundant supply of water from this class of wells. In many cases, however, no tests have been made, for the shallow wells have proved sufficient for ordinary demands. The conditions in neighboring rural districts, as well as in villages, are represented.

[1] The writer visited this well in June, 1896, and found that its head had become lowered to about 5 feet below the surface.

Table of wells from rock at moderate depths.

Locality.	Best water horizon.	Deepest wells.
	Feet.	*Feet.*
Amboy	20	(?)
Anna and vicinity	40	60
Ashley	33	40
Augusta and vicinity	60	265
Barry	65	90
Cairo	70	200
Casey	25	60
Chenoa	150	150
Columbia	30	45
Dallas City	30	150
Earlville	150	150
Equality	30	40
Erie and vicinity	30	30
Fairfield and vicinity	50 to 70	300
Forreston	50 and 300	300
Freeport	Variable.	90
Gardner coal shafts	100	....
Geneseo	120	....
Golconda	30 to 40	40
Hutsonville	30	30
Ipava and vicinity	100	150
Kankakee	Variable.	70
Kinmundy	20	30
Knoxvillo	20 to 40	40
Lawrenceville	60	60
Lebanon and vicinity	150 to 200	200
McLeansboro	Variable.	160
Marseilles (artesian)	150	200
Martinsville	Variable.	80
Mendon	70 and 200	400
Mendota	175 to 400	400
Millington (artesian)	50	70
Momence	30	80
Morrison	35 and 75	75
Mount Carmel	Variable.	40
Mount Sterling	Variable.	75
Nauvoo	Variable.	40
Nashville	Variable.	45
Neoga and vicinity	(?)	285
Oakland	120	120
Oregon	30	200
Pecatonica	80 to 125	125

Table of wells from rock at moderate depths—Continued.

Locality.	Best water horizon.	Deepest wells.
	Feet.	*Feet.*
Quincy	90 to 200	200
Redbud (artesian)	40	....
Rochelle	30 to 40	60
Sterling (artesian)	35	....
Virden	30	50
Vienna	50	60
Warren	80	125
Waterloo	Variable.	80
Wheaton and vicinity	150 to 200	200
Whitehall	50	50

CHAPTER VIII.

ARTESIAN WELLS.

GENERAL STATEMENT.

Since the essential conditions for obtaining artesian wells have been discussed at some length by Prof. T. C. Chamberlin in a report of this Survey,[1] only a brief outline of these conditions is here attempted. That report now being out of print and perhaps not accessible to everyone interested in the subject, reference is also made to Johnson's Cyclopædia, which contains a brief discussion of artesian-well conditions by Mr. F. H. Newell.[2] A similar discussion, by Mr. Robert T. Hill, appears in a recent number of the Popular Science Monthly.[3]

The essential conditions for artesian wells are: (1) A suitable exposure of a porous rock in a humid region, i. e., a favorable absorbing area; (2) the extension of this porous bed from the absorbing area out underneath regions having a lower altitude, i. e., a favorable transmitting area; (3) a partial or full obstruction to the escape of the waters at

FIG. 66.—Section illustrating the aid afforded by a high water-surface between the fountain head and the well. (After T. C. Chamberlin; see Fifth Ann. Rept. U. S. Geol. Survey, fig. 15, p. 140.)

a lower level than the absorbing area. The porous rock is usually confined between beds which are less porous and which act as a partial or complete obstruction to the escape of the waters. It is not necessary, however, that these beds should be perfectly water-tight; indeed, such is rarely the case. It is only necessary that the confining beds should be such as to prevent most of the water from escaping.

In some cases the water contained in semiporous beds overlying the porous rock aids in preventing the escape of water from the porous bed at points between the absorbing area, or fountain head, and the well. This is illustrated in the section (fig. 66), and as it is a condition which prevails quite extensively in northern Illinois the subject is worthy of discussion in this place.

The absorbing area for the artesian waters of northern Illinois is in southern Wisconsin, the porous rock thence dipping southward to

[1] Requisite and qualifying conditions of artesian wells, by T. C. Chamberlin: Fifth Ann. Rept. U. S. Geol. Survey, 1885, pp. 131–173.

[2] Johnson's Universal Cyclopædia, Vol. I, 1893, Artesian Wells, pp. 347–349.

[3] Artesian waters in the arid region, by Robert T. Hill: Pop. Sci. Monthly, March, 1893.

northern Illinois. Between this absorbing area and the wells is a district in which the porous bed is overlain by limestone or semiporous rock and also by drift beds which afford much opportunity for transmission of water. These overlying beds, however, have altitudes fully as great as portions of the absorbing area, and hence, when filled with water, the downward pressure equals or exceeds that of the upward pressure of water from the porous bed, and thus they prevent escape as effectually as a series of impervious beds. In connection with his illustration of this condition, Professor Chamberlin remarks (p. 140):

> I conceive that one of the most favorable conditions for securing a fountain is found where thick, semiporous beds, constantly saturated with water to a greater height than the fountain head, lie upon the porous stratum and occupy the whole country between the well and its source, as illustrated by fig. 15.[1] This is not only a good but an advantageous substitute for a strictly impervious confining bed. Under these hydrostatic conditions limestone strata reposing on sandstone furnish an excellent combination.

Professor Chamberlin's ideal section should be compared with the similar actual section from the Wisconsin River southward across Illinois (fig. 67), and with the section from Galena to Olney, Ill. (fig. 68).

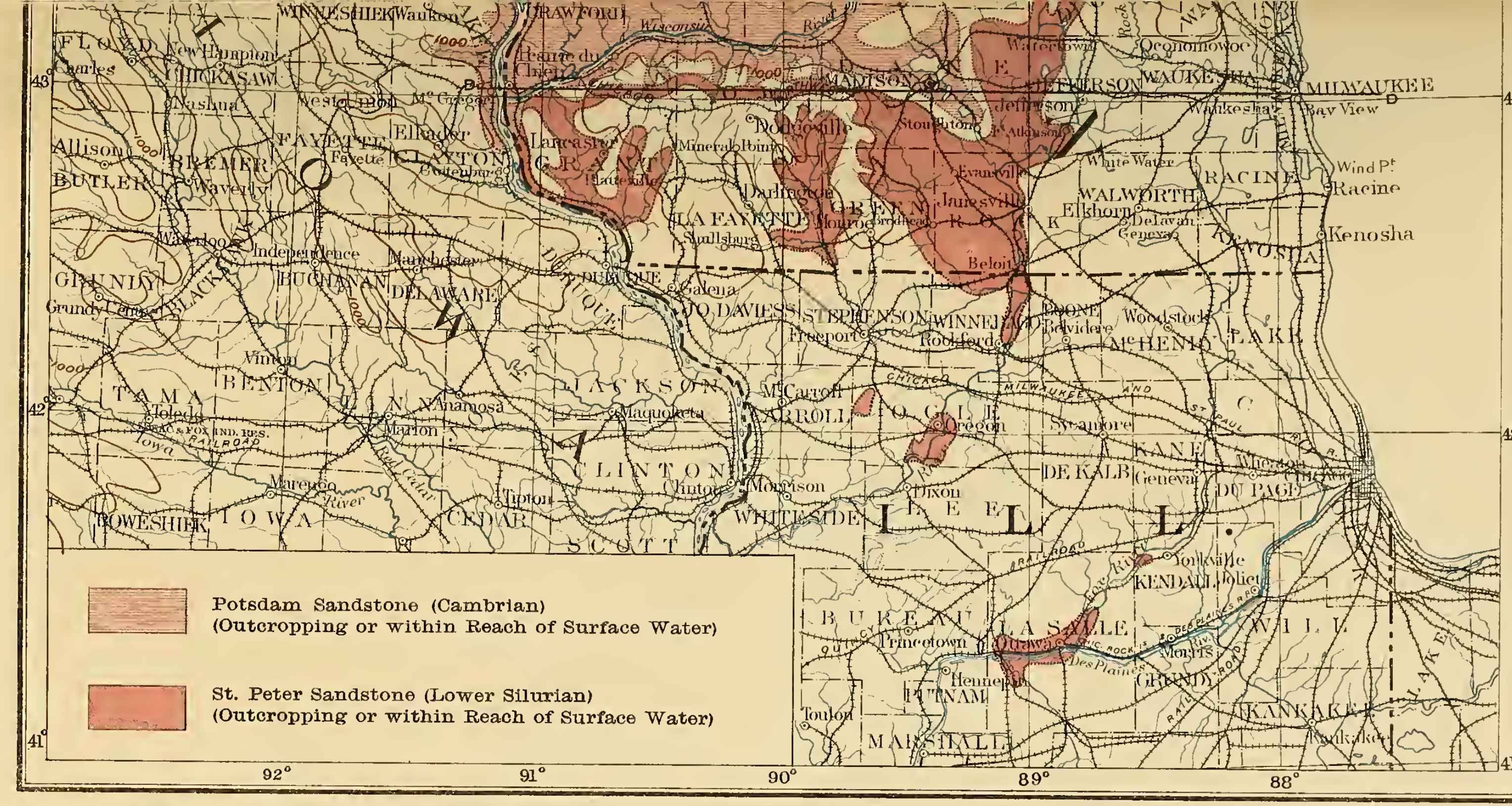
The variability of head displayed by wells in northern Illinois which obtain their main supply from the St. Peter formation is probably largely due to the influx of water from overlying beds in the district between the fountain head and the well. In the northeastern counties of Illinois, especially where the drift deposits are very thick and contain a large body of sand or gravel filled with water, the head is found to be above the normal. In such cases the collecting area or fountain head should perhaps be made to include the elevated semiporous beds as well as the outcrops of the porous beds. In some districts there is danger of loss of head by escape downward from the porous bed, but in Illinois, although these underlying beds are usually semiporous, the conditions are very unfavorable for the escape of water, for they have few outcrops at points below the level of the fountain head.

The comparatively low altitude of the absorbing area presents a disadvantage. It contains but little ground exceeding 1,000 feet above tide (see map, Pl. CXI), and much of its surface is below 800 feet. Some outcrops along the valleys of Wisconsin are but little above 600 feet. Therefore, with excellent conditions for preserving the head, flows can scarcely be expected at altitudes much greater than the lowest outcrops. It is a matter of surprise that in places they rise above 700 feet.

It is not easy to separate wells which flow from those which do not. In many cases the head is so nearly coincident with the altitude of the well mouth that a well may flow under favorable conditions and cease to flow under unfavorable conditions. For example: In Chicago the water in wells first sunk rose several feet above the surface; but when

[1] Fig. 66 in this report, on next preceding page.


93°
92°
91°
90°
89°
88°
87°
46°
45°
44°
WISCONSIN
MICHIGAN
MINN
Iron River
Crystal Falls
Florence
FLORENCE
Hayward
LAC COURT OREILLE IND. RES.
LAC DE FLAMBEAU
SAWYER
PRICE
ONEIDA
FOREST
Phillips
Rhinelander
Crandon
Dunbar
MENOMINEE
BURNETT
Grantsburg
Shell Lake
WASHBURN
POLK
BARRON
St. Croix Falls
Barron
Osceola Mill
CHIPPEWA
TAYLOR
LINCOLN
LANGLADE
MARINETTE
Medford
Merrill
Antigo
Washington
Pt. Rochereau
BAY
Menominee
Marinette
Peshtigo
ST. CROIX
Hudson
Wausau
MENOMINEE IND. RES.
STOCKBRIDGE IND. RES.
Oconto
OCONTO
DOOR
DUNN
Menomonee
Chippewa Falls
Eau Claire
MARATHON
SHAWANO
Shawano
PIERCE
Prescott
Ellsworth
EAU CLAIRE
CLARK
Augusta
Neillsville
Stevens Point
GREEN BAY
Sable Pt.
Sturgeon Pt.
Ahnapee
KEWAUNEE
Kewaunee
Red Wing
GOODHUE
Lake City
Wabasha
BUFFALO
Alma
TREMPEALEAU
Whitehall
WOOD
PORTAGE
WAUPACA
OUTAGAMIE
Green Bay
BROWN
Waupaca
New London
Grand Rapids
WABASHA
Black River Falls
JACKSON
Appleton
Twin River Pt.
Two Rivers
Manitowoc
MANITOWOC
CALUMET
Neenah
Mantorville
Rochester
Winona
WINONA
MONROE
WAUSHARA
Wautoma
Oshkosh
Chilton
DODGE
OLMSTED
Friendship
WINNEBAGO
St. Charles
LA CROSSE
Sparta
ADAMS
Tomah
JUNEAU
MARQUETTE
Montello
Ripon
Chatfield
La Crosse
Mauston
Fond du Lac
FOND DU LAC
Sheboygan
Sheboygan Falls
SHEBOYGAN
Lanesboro
Preston
HOUSTON
FILLMORE
MOWER
Austin
Caledonia
VERNON
Viroqua
Reedsburg
Baraboo
Portage
COLUMBIA
Fox Lake
Horicon
Port Washington
Cresco
MITCHELL
Lansing



MAIN ABSORBING AREAS FOR THE POTSDAM AND ST. PETER FORMATIONS

COMPILED CHIEFLY FROM STATE GEOLOGICAL MAPS

BY FRANK LEVERETT, 1896

Scale

25 0 25 50 75 100 Miles

JULIUS BIEN & CO. N.Y.

the number of wells had greatly increased and large drafts were made by pumping, the wells ceased flowing. There are portions of Chicago near

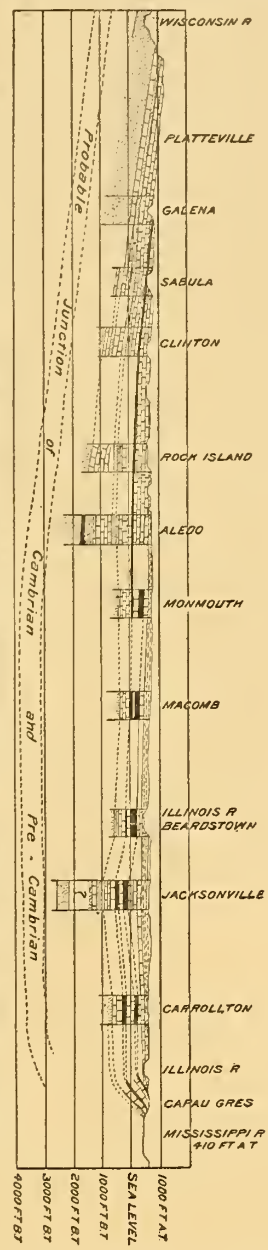


FIG. 67.—Section A-A, from the Wisconsin River in western Wisconsin southward to Cap au Grès, near the mouth of the Illinois.
This section shows a line through a region where wells are very successful. Northward from Aledo the section shows but one shale bed (the Hudson River), and this is wanting north from Galena. But south from Aledo the Kinderhook and Coal Measures shales comprise a considerable portion of the section. Vertical scale is 40 times the horizontal.

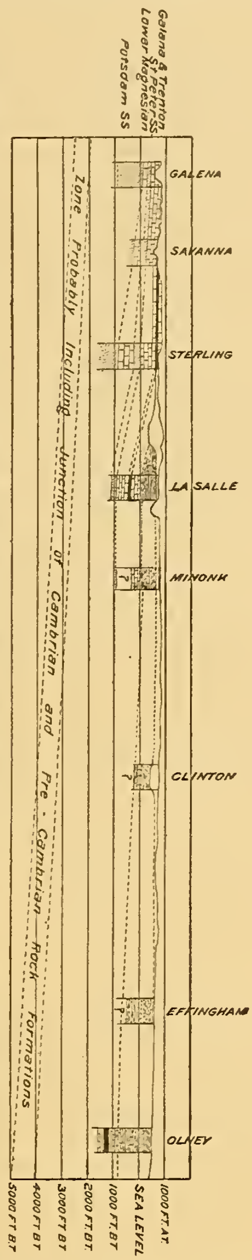


FIG. 68.—Section B-B, from Galena to Olney, Ill.
This section leads through the deep part of the Coal Measures basin from Lasalle to Olney. Wells are successful from Minonk northward. Vertical scale is 40 times the horizontal.

the stock yards where it is reported that wells do not flow except for a brief period each week after the Sunday intermission from pumping.

In some towns wells flow if properly constructed, while others at similar altitudes do not quite reach the surface. It seems scarcely legitimate to restrict the term "artesian" to wells which chance to be so favorably situated or constructed as to flow, and to exclude those which are less fortunately situated or constructed, for the class of well is the same in both cases. Furthermore, the matter of flow is of little consequence to many of the prospectors of wells, for it is found that by the use of pumps a larger amount of water can be obtained than from the natural flow. In such cases the water surface is kept down by the pumping much of the time below the level of the well mouth. In the present paper the term artesian is applied to wells which flow and also to those which do not flow but which have a head similar to that of the flowing wells and are derived from the same water-bearing rock formations.

In the tables a few wells appear which have a remarkably high water level. For example, the Dekalb waterworks well, which obtains much water from the St. Peter sandstone, stands at 772 feet above tide, and others in the city at over 800 feet, but those wells receive also the water from glacial deposits, which has a greater head than that from the St. Peter sandstone. It is thought also that the well at Harvard has its head raised to the high level of 894 feet by access of surface water. The well at Amboy, with a head 781 feet above tide, began flowing when only 390 feet in depth, and though the lower water beds increase the quantity, they do not increase the head; indeed, it is not improbable that the head from these lower veins is lower than that from the upper.

Wells along the Mississippi, on the Iowa side of the river, are included in the tables, since they aid in showing the conditions on the extreme border of the State.[1]

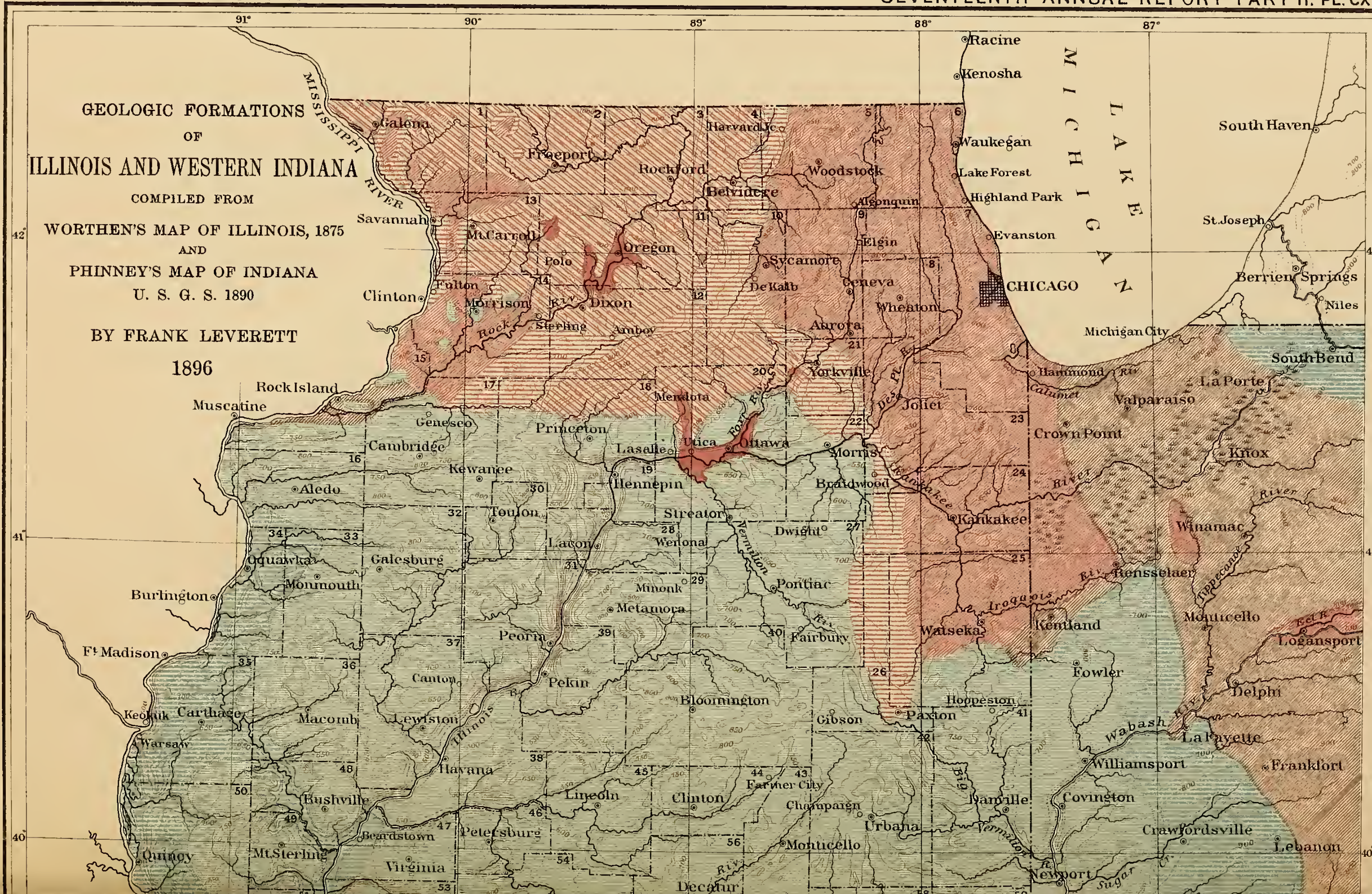
Before entering upon the discussion of the wells, a brief review of the rock formations of the region will be of advantage.

THE PALEOZOIC ROCKS IN ILLINOIS.

DISTRIBUTION OF OUTCROPS.

The indurated rocks of Illinois, so far as exposed in outcrops or by borings, are all included in the Paleozoic system. The Tertiary formations of the southern end of the State and the glacial deposits which mantle much of the State are in the main but partially lithified. The extent of each of the main rock formations is indicated upon the geological map (Pl. CXII), which is based upon Worthen's map of Illinois, published in 1875, and Phinney's Indiana map, published in the Eleventh Annual Report of the United States Geological Survey.

[1] The conditions for artesian wells in Indiana will be discussed in another paper, for which considerable material is already collected. The artesian wells of Iowa are now under investigation by Prof. W. H. Norton, of the Iowa Geological Survey, and will be discussed by Mr. Norton in an early report of that Survey.


GEOLOGIC FORMATIONS
OF
ILLINOIS AND WESTERN INDIANA
COMPILED FROM
WORTHEN'S MAP OF ILLINOIS, 1875
AND
PHINNEY'S MAP OF INDIANA
U. S. G. S. 1890
BY FRANK LEVERETT
1896
LAKE MICHIGAN
MISSISSIPPI RIVER
Racine
Kenosha
Waukegan
Lake Forest
Highland Park
Evanston
CHICAGO
Michigan City
South Haven
St. Joseph
Berrien Springs
Niles
South Bend
La Porte
Valparaiso
Crown Point
Hammond
Knox
Winamac
Rensselaer
Kentland
Monticello
Logansport
Delphi
La Fayette
Frankfort
Fowler
Williamsport
Covington
Crawfordsville
Lebanon
Danville
Newport
Hoopeston
Paxton
Gibson
Urbana
Champaign
Farmer City
Monticello
Decatur
Clinton
Bloomington
Lincoln
Galena
Freeport
Rockford
Harvard Jc.
Woodstock
Belvidere
Algonquin
Elgin
Sycamore
De Kalb
Geneva
Wheaton
Aurora
Yorkville
Joliet
Savannah
Mt. Carroll
Oregon
Polo
Dixon
Fulton
Clinton
Morrison
Sterling
Amboy
Rock Island
Muscatine
Mendota
Utica
Ottawa
Lasalle
Morris
Braidwood
Kankakee
Watseka
Geneseo
Cambridge
Princeton
Kewanee
Aledo
Hennepin
Streator
Dwight
Wenona
Toulon
Lacon
Galesburg
Oquawka
Monmouth
Burlington
Minonk
Metamora
Pontiac
Fairbury
Peoria
Pekin
Ft. Madison
Canton
Keokuk
Carthage
Macomb
Lewiston
Warsaw
Havana
Bushville
Beardstown
Petersburg
Quincy
Mt. Sterling
Virginia
Illinois
Rock Riv.
Fox Riv.
Des Pl. R.
Kankakee River
Iroquois Riv.
Vermilion
Calumet
Tippecanoe
Wabash
Eel R.
Sugar Cr.
91°
90°
89°
88°
87°
42°
41°
40°


LEGEND.
Tertiary
Coal Measures (Carboniferous)
Lower Carboniferous (Including Kinderhook)
Devonian
Niagara, etc. (Upper Silurian)
Hudson River Shales (Lower Silurian)
Trenton and Galena (Lower Silurian)
St. Peter Sandstone (Lower Silurian)
Scale
0 5 10 20 30 40 50 60 70 MILES
LIST OF COUNTIES
No. 1 Jo Daviess.
" 2 Stephenson.
" 3 Winnebago.
" 4 Boone.
" 5 McHenry.
" 6 Lake.
" 7 Cook.
" 8 Du Page.
" 9 Kane.
" 10 Dekalb.
" 11 Ogle.
" 12 Lee.
" 13 Carroll.
" 14 Whiteside.
" 15 Rock Island.
" 16 Mercer.
" 17 Henry.
" 18 Bureau.
" 19 Putnam.
" 20 Lasalle.
" 21 Kendall.
" 22 Grundy.
" 23 Will.
" 24 Kankakee.
" 25 Iroquois.
" 26 Ford.
" 27 Livingston.
" 28 Marshall.
" 29 Woodford.
" 30 Stark.
" 31 Peoria.
" 32 Knox.
" 33 Warren.
" 34 Henderson.
" 35 Hancock.
" 36 McDonough.
" 37 Fulton.
" 38 Mason.
" 39 Tazewell.
" 40 McLean.
" 41 Vermilion.
" 42 Champaign.
" 43 Piatt.
" 44 Dewitt.
" 45 Logan.
" 46 Menard.
" 47 Cass.
" 48 Schuyler
" 49 Brown.
" 50 Adams.
" 51 Pike.
No. 52 Scott.
" 53 Morgan.
" 54 Sangamon.
" 55 Christian.
" 56 Macon.
" 57 Moultrie.
" 58 Douglas.
" 59 Edgar.
" 60 Clark.
" 61 Coles.
" 62 Cumberland.
" 63 Shelby.
" 64 Montgomery.
" 65 Macoupin.
" 66 Greene.
" 67 Calhoun.
" 68 Jersey.
" 69 Madison.
" 70 Bond.
" 71 Fayette.
" 72 Effingham.
" 73 Jasper.
" 74 Crawford.
" 75 Lawrence.
" 76 Richland.
" 77 Clay.
" 78 Marion.
" 79 Clinton.
" 80 St. Clair.
" 81 Monroe.
" 82 Randolph.
" 83 Washington.
" 84 Perry.
" 85 Jefferson.
" 86 Wayne.
" 87 Edwards.
" 88 Wabash.
" 89 White.
" 90 Hamilton.
" 91 Franklin.
" 92 Jackson.
" 93 Williamson.
" 94 Saline.
" 95 Gallatin.
" 96 Hardin.
" 97 Pope.
" 98 Johnson.
" 99 Union.
" 100 Alexander.
" 101 Pulaski.
" 102 Massac.
Hannibal
Barry
Pittsfield
Winchester
Carrollton
Hardin
Jerseyville
Alton
ST LOUIS
East St. Louis
Belleville
Waterloo
Red Bud
Sparta
Chester
Murphysboro
Carbondale
Jonesboro
Anna
Vienna
Mound City
Cairo
Metropolis City
Golconda
Elizabethtown
Shawneetown
Equality
Harrisburg
Marion
Benton
McLeansboro
Carmi
Fairfield
Albion
Mt. Carmel
Olney
Flora
Louisville
Salem
Centralia
Mt. Vernon
Nashville
Carlyle
Edwardsville
Greenville
Vandalia
Hillsboro
Litchfield
Carlinville
Taylorville
Pana
Shelbyville
Sullivan
Charleston
Mattoon
Paris
Marshall
Toledo
Effingham
Newton
Robinson
Lawrenceville
Vincennes
Sullivan
Terre Haute
Brazil
Greencastle
Danville
Martinsville
Spencer
Bloomington
Bloomfield
MISSISSIPPI RIVER
MISSOURI R.
OHIO RIVER
Wabash Riv.
White Riv.
Embarras Riv.
Kaskaskia Riv.
Cumberland RIVER
Tennessee Riv.
Eel Riv.
Raccoon
91°
90°
89°
88°
87°
39°
38°
37°
JULIUS BIEN & CO N.Y.

In the northern part of the State, Lower Silurian limestones of the Trenton group and Upper Silurian of the Niagara group constitute the chief surface rocks. The former group is found over several counties in the northwest corner, while the latter overlaps it on the east and south. The intermediate Hudson River or Cincinnati group consists largely of shales and shaly limestones, and has but a limited outcrop. When unprotected by the Niagara it has been unable to resist erosion. It usually appears, therefore, only for a short distance beyond the borders of the Niagara.

The St. Peter sandstone, which underlies the Trenton limestone, is well exposed for a few miles above Utica, on the Illinois, and on the lower courses of Fox and Vermilion rivers. It is exposed for a few miles on Rock River and its tributaries in the vicinity of Oregon, and also for a few miles near the head of Elkhorn Creek, 6 or 8 miles northwest from Polo. The only remaining known outcrop of this sandstone in the State is near the junction of the Illinois and Mississippi, where an upheaval brings it to view.

A limestone which underlies the St. Peter sandstone, and which is known in Illinois and Wisconsin by the rather vague term "Lower Magnesian limestone," has a very limited outcrop at Utica and also on Elkhorn Creek near Polo. It is supposed by Hon. James Shaw, formerly of the Illinois Geological Survey, to be exposed in the bed of Rock River a few miles below Oregon.[1]

A line running from Rock Island eastward across the State to Kankakee passes near the south border of the main Silurian outcrops. South from this line the surface rocks are mainly Coal Measures, consisting chiefly of shales and shaly sandstones, with which thin beds of limestone, coal, etc., are associated. In southern Illinois, however, heavy sandstone and conglomerate beds occur at the base of the Coal Measures. Limestones of the Lower Carboniferous, or Mississippian series, form the surface rock along the Mississippi throughout most of the western boundary south from Rock Island, Coal Measures strata in the immediate bluffs occurring only for a few miles south from Rock Island and for a few miles below Alton, and Devonian and Silurian strata only at a few points where upheavals have been sufficient to bring them to view. Lower Carboniferous limestones also border the lower course of the Illinois for a distance of about 80 miles. They appear also on the south slope of the Ozark ridge, in southern Illinois. In the district above the mouth of the Illinois, the Lower Carboniferous rocks consist of the St. Louis, Keokuk, and Burlington limestones. Below the mouth of that stream St. Louis limestone and Chester limestone and sandstone constitute the main representatives, though thin beds of Burlington and Keokuk outcrops occur where upheavals have brought them to view.

[1] Geology of Illinois, Vol. V, pp. 118, 119.

ALTITUDE AND ATTITUDE OF THE STRATA.

By combining the records of wells and coal shafts or borings with the study of outcrops a general conception may be obtained of the folds and inclinations of the rock formations. A north-to-south section shows a general but very gradual southward dip of the formations, terminated at the south by the axis of upheaval which, as above noted, leads eastward across the State from Grand Tower to Shawneetown. The descent probably amounts to 2,500 to 3,000 feet in the 350 miles from the north to the south end of the State. It is probable that any meridian chosen as a line for a section would show slight undulations, carrying the strata up or down 100 to 200 feet or more from a uniform grade, but so far as known no prominent west-to-east axis of upheaval crosses the State north of the one just noted. Mention should be made of a low arch separating the Illinois-Indiana coal field from the Michigan coal field, which is traceable from Lasalle County eastward, and which connects on the southeast with the "Cincinnati arch." This arch is, however, so low in eastern Illinois as to bring the Lower Silurian strata scarcely 200 feet above their level 20 or more miles to the north. This southward rise of perhaps 10 feet per mile for a distance of 20 miles is but a slight deflection in the long line of southward descent from Wisconsin to southern Illinois, in which the formations descend not less than 2,500 feet.

West-to-east sections are less uniform in the inclination of strata than the north-to-south sections. Sections across the northern part of the State present two blocks of strata, each dipping gradually to the east, separated by an abrupt fold or line of disturbance. At this fold the block on the east rises abruptly several hundred feet above the neighboring portion of the western block. It is along this line of disturbance that the St. Peter and Lower Magnesian strata are brought to view on the Illinois and Rock rivers and on Elkhorn Creek. Its trend from the Illinois River northward is about southeast to northwest. Sections in the lead region indicate that it continues in subdued form some distance into southwestern Wisconsin. Its southward continuation from the Illinois is readily traceable as far as Livingston County by disturbances shown in coal shafts, as noted by the Illinois Survey. Farther south its course is less definitely known, the only source of knowledge being the records of borings which have been put down to test the field for coal, gas, oil, or water. These indicate a condition similar to that of northern Illinois, at least as far south as Tuscola, in Douglas County. The borings show that the base of the Coal Measures is reached at a much higher level along a line leading from Utica southward to Tuscola than along a parallel line a few miles to the west, and slightly higher than on a parallel line a few miles to the east. This may be seen by the following table:

Altitudes of the base of the Coal Measures along three lines.

West of fold:
- Lasalle, sea level.
- Fairbury, 120 feet above tide, or less.
- Clinton, 200 feet below tide.
- Decatur, 200 feet below tide.

On the fold:
- Utica, 580 feet above tide.
- Chatsworth, 515 feet above tide.
- Champaign, 317 feet above tide.
- Tuscola, 473 feet above tide.

East of fold:
- Morris, 430 feet above tide.
- Milford, 466 feet above tide.
- Danville, 300 feet above tide.
- Montezuma, Ind., 200 feet above tide.

This disturbance has been made a subject of special study by Prof. J. A. Udden at the point where it crosses the Illinois, and he gives the following description of the structural features along a line leading from Rock Island eastward through this point to eastern Illinois. The section from Davenport eastward past Joliet (fig. 69) follows nearly the line here described.

We see two blocks of horizontal or only very slightly inclined strata separated by a monoclinal fold. The downthrow and the trough limb is on the west, while the upthrow and the arch limb is on the east. The total displacement of the Silurian strata amounts to 1,575 feet, while the Carboniferous beds are displaced only about 625 feet. The trend of the axis of disturbance is considerably west of north, the strike of the outcrops of the upturned Coal Measures being about N. 30° W. The average dip in the displacement at Lasalle is about 22° for the Silurian rocks and about 8° for the rocks of the Coal Measures. The block of strata west of the monocline is nearly horizontal in an east-to-west direction from Rock Island to Annawan and from Princeton to Lasalle, but between Princeton and Annawan there is a dip to the east of about 25 feet to the mile, or there is a concealed displacement of that extent between these two places. This dip may be partly accounted for by the dip to the south which is found along the whole section. The block of strata on the east of the monocline has a nearly uniform dip to the east of about 12 feet to the mile.[1]

The Coal Measures strata of central Illinois apparently reach about their lowest level along a line shown in fig. 68, leading from Lasalle southward parallel with the line of disturbance and but a few miles west of it. There is over much of western Illinois a gradual descent from the western border of the State to this line, averaging in the latitude of Peoria about 7 feet per mile and in the latitude of Springfield about 10 feet per mile. The eastward descent across western Illinois appears to continue gradual as far south as the Cap au Grès upheaval, near the mouth of the Illinois, and, so far

[1] Final Report, Illinois Board of World's Fair Commissioners, 1895. pp. 144, 145.

as known to the writer, there is no marked disturbance along the Mississippi north from that point.

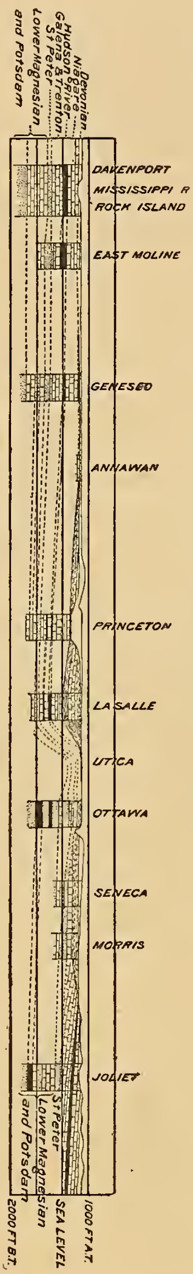


Fig. 69.—Section C–C, from Davenport, Iowa, to Joliet, Ill.

This section shows the monoclinal fold which passes just east of Lasalle, with the nearly horizontal blocks on either side. Vertical scale is 20 times the horizontal.

From the Cap au Grès disturbance southward to the Ozark ridge, in southern Illinois, a different field is entered. Disturbances are frequent along the Mississippi. There is also in this district a great descent in the floor of the Coal Measures within a few miles east of the Mississippi. Thus, in passing from the east bluff of the river in western St. Clair County eastward to Belleville a descent of 650 feet is made within a distance of 10 miles. In the vicinity of Murphysboro the Coal Measures floor ranges from 200 feet below sea level to 800 feet above within a distance of 10 miles. The deep portion of the Coal Measures basin seems, therefore, to approach the Mississippi closely from near the mouth of the Illinois southward, and, so far as can be learned from borings, extends eastward at least to the Indiana line. The lowest known points in the Coal Measures floor are in the southeastern part of the State—their level at Olney being about 800 feet and at Shawneetown 1,100 feet below sea level. A great depth is reached in southwestern Illinois, however, the floor at Coulterville, in Randolph County, only 25 miles from the Mississippi, being 325 feet below tide, and at Highland, about 25 miles from East St. Louis, the level is apparently 477 feet below tide.

ALTITUDE OF THE BASE OF THE COAL MEASURES.

In the following table an alphabetical list of the principal borings in the coal field of Illinois is presented which throws light upon the altitude of the floor of the Coal Measures basin. Where borings reach a definite horizon near the base of the Coal Measures, estimates have been made for the level of the floor, and are so indicated. When borings have apparently reached the lower coal, but not the rock floor, a minus sign is affixed to indicate that the base is still lower.

Table showing altitudes of base of Coal Measures.

Location.	Altitude.		Situation.
	Above tide.	Below tide.	
	Feet.	*Feet.*	
Annawan	466	....	On western block.
Beardstown (est.)	450	....	Do.
Belleville	0	....	Basin in southern Illinois.
Braidwood	446	....	On eastern block.
Canton	360	....	On western block.
Carrollton	545	....	Do.
Champaign	317	....	On eastern block.
Chatsworth	515	....	Do.
Clinton	....	200	In trough.
Coulterville	....	325	Basin in southern Illinois.
Danville	300	....	On eastern block.
Dawson (est.)	....	85	On western block.
Decatur (est.)	....	200	In trough.
East Peoria	185	....	On western block.
Effingham (est.)	....	775	Basin in southern Illinois.
Fairbury	120—	....	In trough.
Franklin	341	....	On western block.
Gardner	420—	....	On eastern block.
Geneseo	520	....	On western block.
Gibson	575?	....	On eastern block.
Girard (est.)	50	....	On western block.
Hennepin	....	130	In trough.
Highland	....	477?	Basin in southern Illinois.
Hillsboro	....	160	On western block.
Ipava	497	....	Do.
Jacksonville	350	....	Do.
Jerseyville (est.)	600	....	Do.
Lasalle	0	....	In trough.
Litchfield	....	142	On western block.
Macomb	555	....	Do.
Marseilles	417	....	On eastern block.
Mattoon	....	270	In trough.
Millstadt	375?	....	Basin (rim) southern Illinois.
Milford	466	....	On eastern block.
Morris	430	....	Do.
Monmouth	666	....	On western block.
Montezuma, Ind	200	....	On eastern block.
Murphysboro	....	192	Basin in southern Illinois.
Olney	....	795	Do.
Pana (est.)	....	325	In trough.

Table showing altitudes of base of Coal Measures—Continued.

Location.	Altitude.		Situation.
	Above tide.	Below tide.	
	Feet.	*Feet.*	
Peoria	186		On western block.
Pontiac	407—		On eastern block.
Prairie City	467		On western block.
Princeton	120		In trough.
Riverton		112	On western block.
Rock Island	600		Do.
Shawneetown		1, 100	Basin in southern Illinois.
Smithboro		250	Do.
Sparta	138		Basin (rim) in southern Illinois.
Steeleville	150		Do.
Streator	377		On eastern block.
Tuscola	473		Do.
Waverly	286		On western block.
Winchester	450		Do.

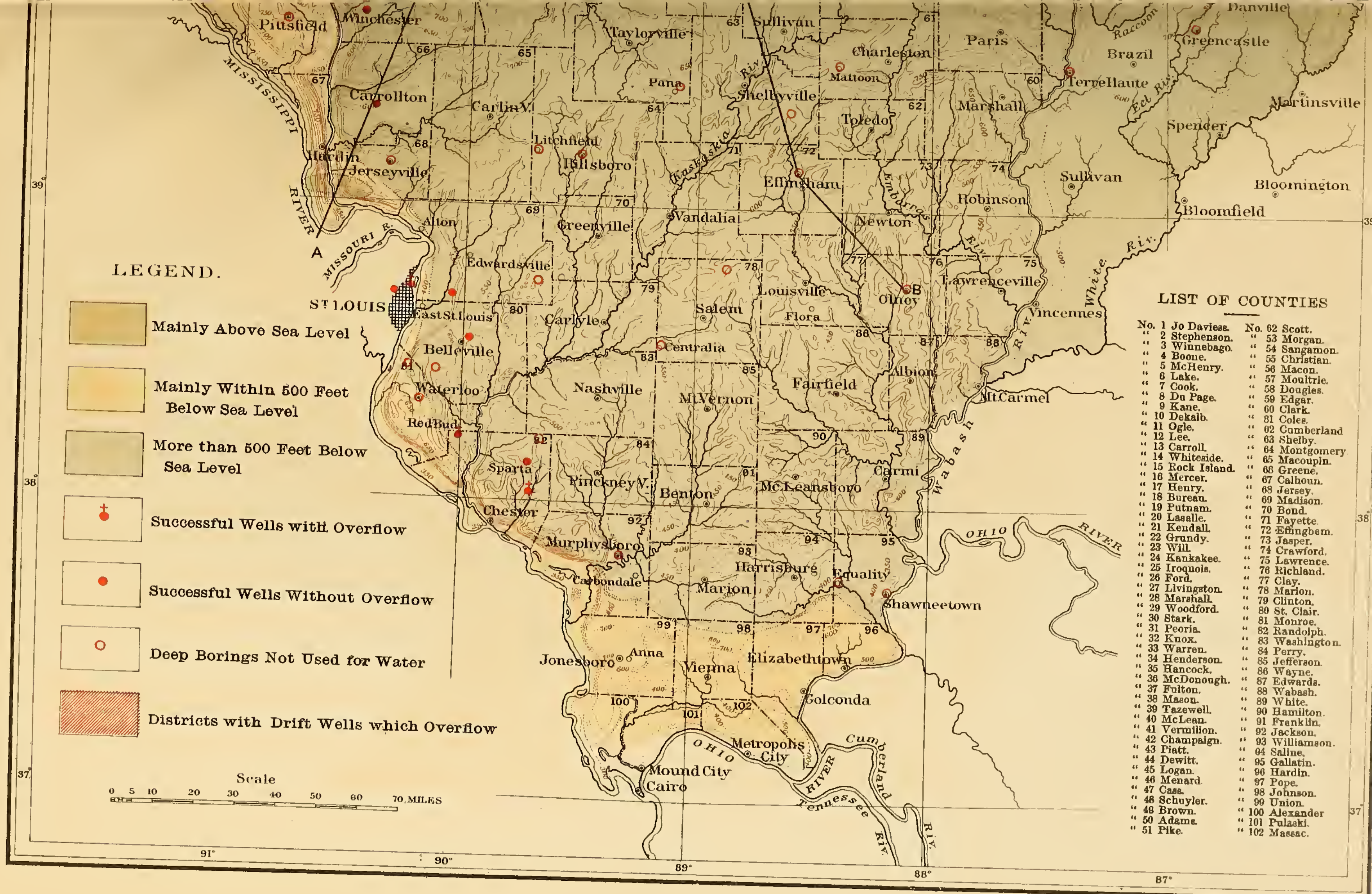
ALTITUDE OF ST. PETER SANDSTONE IN ILLINOIS.

For the northern portion of the State, where the Coal Measures are absent, the variations in altitude of formations may perhaps be best shown by a hypsographic map of the St. Peter (Pl. CXIII), which is supplemented by the following table of altitudes of the St. Peter sandstone. This formation in western Illinois lies 1,000 to 1,300 feet below the base of the Coal Measures. In eastern Illinois, near the northern border of the coal field, it is only 300 to 600 feet below that base, because of the absence of Devonian and Lower Carboniferous formations. These formations soon appear, however, in passing southward, and the interval becomes as great as in western Illinois. At Danville it appears to be nearly 1,300 feet. It is probable that in southern Illinois the average interval between the base of the Coal Measures and this formation is not less than 1,200 feet, but there are no borings to test the matter.

Altitudes of top of St. Peter sandstone in Illinois.

Location.	Altitude.		Thickness.	Situation.
	Above tide.	Below tide.		
	Feet.	*Feet.*	*Feet.*	
Aurora		20	236	On eastern block.
Beardstown		605	(?)	On western block.
Braidwood	57		210	On eastern block.
Canton		753	273	On western block.


HYPSOGRAPHIC MAP
OF THE
ST. PETER SANDSTONE
OF
ILLINOIS AND WESTERN INDIANA
SHOWING DISTRIBUTION OF
ARTESIAN WELLS AND
DEEP BORINGS
BY FRANK LEVERETT
1896
LAKE MICHIGAN
MISSISSIPPI RIVER
CHICAGO
Racine
Kenosha
Waukegan
Lake Forest
Highland Park
Evanston
South Haven
St. Joseph
Berrien Springs
Niles
Michigan City
South Bend
La Porte
Valparaiso
Hammond
Crown Point
Knox
Winamac
Rensselaer
Monticello
Logansport
Delphi
Kentland
Fowler
La Fayette
Williamsport
Frankfort
Covington
Crawfordsville
Lebanon
Newport
Danville
Galena
Freeport
Rockford
Harvard
Woodstock
Belvidere
Algonquin
Elgin
Sycamore
De Kalb
Geneva
Wheaton
Aurora
Yorkville
Joliet
Savanna
Mt. Carroll
Oregon
Polo
Clinton
Fulton
Morrison
Dixon
Sterling
Amboy
Rock Island
Muscatine
Geneseo
Princeton
Mendota
Lasalle
Utica
Ottawa
Morris
Braidwood
Kankakee
Cambridge
Kewanee
Hennepin
Aledo
Toulon
Streator
Dwight
Wenona
Lacon
Oquawka
Galesburg
Monmouth
Minonk
Metamora
Pontiac
Burlington
Peoria
Fairbury
Watseka
Ft. Madison
Canton
Pekin
Bloomington
Gibson
Paxton
Keokuk
Carthage
Warsaw
Macomb
Lewiston
Havana
Rushville
Clinton
Farmer City
Champaign
Urbana
Beardstown
Petersburg
Quincy
Mt. Sterling
Virginia
Monticello
Decatur
Rock
Illinois
Vermilion
Kankakee
Calumet
Wabash Riv.
Tippecanoe
Sugar Cr.
91°
90°
89°
88°
87°
42°
41°
40°


LEGEND.
Mainly Above Sea Level
Mainly Within 500 Feet Below Sea Level
More than 500 Feet Below Sea Level
Successful Wells with Overflow
Successful Wells Without Overflow
Deep Borings Not Used for Water
Districts with Drift Wells which Overflow
Scale
0 5 10 20 30 40 50 60 70 MILES
LIST OF COUNTIES
No. 1 Jo Daviess.
" 2 Stephenson.
" 3 Winnebago.
" 4 Boone.
" 5 McHenry.
" 6 Lake.
" 7 Cook.
" 8 Du Page.
" 9 Kane.
" 10 Dekalb.
" 11 Ogle.
" 12 Lee.
" 13 Carroll.
" 14 Whiteside.
" 15 Rock Island.
" 16 Mercer.
" 17 Henry.
" 18 Bureau.
" 19 Putnam.
" 20 Lasalle.
" 21 Kendall.
" 22 Grundy.
" 23 Will.
" 24 Kankakee.
" 25 Iroquois.
" 26 Ford.
" 27 Livingston.
" 28 Marshall.
" 29 Woodford.
" 30 Stark.
" 31 Peoria.
" 32 Knox.
" 33 Warren.
" 34 Henderson.
" 35 Hancock.
" 36 McDonough.
" 37 Fulton.
" 38 Mason.
" 39 Tazewell.
" 40 McLean.
" 41 Vermilion.
" 42 Champaign.
" 43 Piatt.
" 44 Dewitt.
" 45 Logan.
" 46 Menard.
" 47 Cass.
" 48 Schuyler.
" 49 Brown.
" 50 Adams.
" 51 Pike.
No. 52 Scott.
" 53 Morgan.
" 54 Sangamon.
" 55 Christian.
" 56 Macon.
" 57 Moultrie.
" 58 Douglas.
" 59 Edgar.
" 60 Clark.
" 61 Coles.
" 62 Cumberland
" 63 Shelby.
" 64 Montgomery.
" 65 Macoupin.
" 66 Greene.
" 67 Calhoun.
" 68 Jersey.
" 69 Madison.
" 70 Bond.
" 71 Fayette.
" 72 Effingham.
" 73 Jasper.
" 74 Crawford.
" 75 Lawrence.
" 76 Richland.
" 77 Clay.
" 78 Marion.
" 79 Clinton.
" 80 St. Clair.
" 81 Monroe.
" 82 Randolph.
" 83 Washington.
" 84 Perry.
" 85 Jefferson.
" 86 Wayne.
" 87 Edwards.
" 88 Wabash.
" 89 White.
" 90 Hamilton.
" 91 Franklin.
" 92 Jackson.
" 93 Williamson.
" 94 Saline.
" 95 Gallatin.
" 96 Hardin.
" 97 Pope.
" 98 Johnson.
" 99 Union.
" 100 Alexander
" 101 Pulaski.
" 102 Massac.
Pittsfield
Winchester
Taylorville
Sullivan
Paris
Charleston
Mattoon
Pana
Shelbyville
Danville
Greencastle
Brazil
Terrehaute
Martinsville
Carrollton
Carlinv.
Marshall
Toledo
Spencer
Litchfield
Hillsboro
Hardin
Jerseyville
Effingham
Sullivan
Bloomington
Robinson
Bloomfield
Alton
Greenville
Vandalia
Newton
Olney
Lawrenceville
Edwardsville
Louisville
Vincennes
St. LOUIS
East St. Louis
Carlyle
Salem
Flora
Belleville
Centralia
Albion
Waterloo
Nashville
Mt. Vernon
Fairfield
Mt. Carmel
Red Bud
Sparta
Pinckney V.
Benton
McLeansboro
Carmi
Chester
Murphysboro
Carbondale
Harrisburg
Marion
Equality
Shawneetown
Jonesboro
Anna
Vienna
Elizabethtown
Golconda
Metropolis City
Mound City
Cairo
MISSISSIPPI RIVER
MISSOURI R.
OHIO RIVER
Wabash
White Riv.
Embarras Riv.
Kaskaskia Riv.
Cumberland RIVER
Tennessee Riv.
Raccoon
Eel Riv.
A
B
91°
90°
89°
88°
87°
39°
38°
37°
JULIUS BIEN & CO. N.Y.

Altitudes of top of St. Peter sandstone in Illinois—Continued.

Location.	Altitude.		Thickness.	Situation.
	Above title.	Below tide.		
	Feet.	*Feet.*	*Feet.*	
Cap au Grès	550	....	(?)	Uplift in southwestern Illinois.
Carthage	....	297	(?)	On western block.
Carrollton	....	590	(?)	Do.
Chicago	....	225±	200±	On eastern block.
Danville	....	1,090	35	Do.
Davenport, Iowa	....	370	130	On western block.
Elgin	61±	....	110	On eastern block.
Elkhorn Creek	850	....	50+	On axis of upheaval.
Evanston	....	222	420?	On eastern block.
Galena	445	....	145	On western block.
Geneseo	....	428	220	Do.
Hammond, Ind	....	460	190	On eastern block.
Harvard	295	....	210	Do.
Highland Park	....	320	200	Do.
Ipava	....	630	290	On western block.
Jacksonville	....	900	319	Do.
Jerseyville	....	738	200	Do.
Joliet	....	91	210	On eastern block.
Kankakee	....	280	(?)	Do.
Keokuk, Iowa	....	318	110	On western block.
Lake Bluff	....	258	167	On eastern block.
Lasalle	....	907	175	In trough near axis.
Macomb	....	435	225	On western block.
Mendota	415	....	(?)	Near axis of upheaval.
Milan	....	364	195	On western block.
Millington	600	....	(?)	Small anticline.
Moline	....	371	216	On western block.
Monmouth	....	336	(?)	Do.
Morgan Park	....	405	(?)	On eastern block.
Morris	180	....	(?)	Do.
Morrison	....	100	200	On western block.
Near Oregon (est.)	850	....	185	On axis of upheaval.
Ottawa	483	....	138	On eastern block.
Princeton	....	900	160	In trough.
Rock Island	....	364	272	On western block.
Rockford	558	....	225	On eastern block.
Seneca	250	....	220	Do.
Sterling	....	33	300	On western block.
Winnetka	....	281	212	On eastern block.

THICKNESS OF THE PALEOZOIC FORMATIONS.

In the northern part of Illinois the thickness of the Paleozoic rocks is probably much less than in the central and southern portions, since in places only the Lower Silurian and Cambrian are present. No borings have reached the base of these formations, though there are several in the northern part of the State which exceed 2,500 feet in depth. From what is known of the thickness of the Lower Silurian and Cambrian in adjacent parts of Wisconsin, it seems scarcely probable that the thickness in the northern part of Illinois greatly exceeds the depth of the borings. Probably 3,000 feet at the State line would be a liberal estimate.

Concerning the thickness in southern Illinois, nothing definite is known further than the fact that Coal Measures there have a thickness of 1,200 to 1,500 feet, and that at St. Louis, Mo., a well passes through about 3,680 feet of Paleozoic strata below the Coal Measures before entering granite or pre-Cambrian rocks. The St. Louis well probably shows no greater thickness of rocks between the Coal Measures and the pre-Cambrian than will be found beneath much of southern Illinois. On the contrary, it seems probable that because of Devonian and Chester formations, which are present in considerable thickness beneath portions of southern Illinois and are not present in the St. Louis well, the thickness of the Paleozoic rocks of such portions of southern Illinois may exceed by several hundred feet the combined thickness of the Coal Measures and of the rocks penetrated in the St. Louis well. As this combined thickness is about 5,000 feet, it seems probable that the maximum thickness of the Paleozoic rocks in southern Illinois will be found to reach nearly 6,000 feet, or about double the amount thought to be present in northern Illinois.

STRUCTURE OF THE ROCK FORMATIONS.

The writer's knowledge of the formations aside from outcrops has been obtained mainly from the records of wells or other borings which have been made either by drillers or by persons who were present during the drilling of a well. Only a few samples of rock drillings have been personally examined. Some of the records appear to have been kept with care, and much discrimination has been used in classifying the rocks; but the majority indicate only in a partial or crude manner the features of the formations. For example, in the best records the several classes of limestone or shale or sandstone are clearly recognized, but in most records there is no attempt at separation beyond that of the general groups—sandstone, shale, and limestone. In cases where limestones are sandy and sandstones are somewhat calcareous there is often a doubt as to the correctness of the interpretation, even of the general groups. Such being the condition of knowledge of the structure, it seems unwise to publish the majority of the records which have been examined. Fortunately, Prof. J. A. Udden has had opportunity to carefully examine drillings from several of the wells in the vicinity of Rock Island, and his report upon this study is presented herewith. (See Chapter X.) This report, with the sections which accompany it, serves to indicate the character of the formations from the Devonian to the Potsdam in that part of Illinois.

From records in the writer's possession, together with those which have already appeared in print, sections have been made which set forth the structure along several lines traversing the State in various directions. One of these sections passes through Rock Island in a north-to-south course and indicates the changes in thickness and structure of the formations which occur in that direction (see fig. 67). Another leads eastward from near Rock Island to Joliet, showing the changes in dip, structure, and thickness in that direction (see fig. 69). A third section leads from Galena southeastward beneath the Coal Measures basin (see fig. 68). A section across southern Wisconsin from Prairie du Chien to Milwaukee, obtained from Professor Chamberlin's geological map of Wisconsin (see fig. 70), is also given.

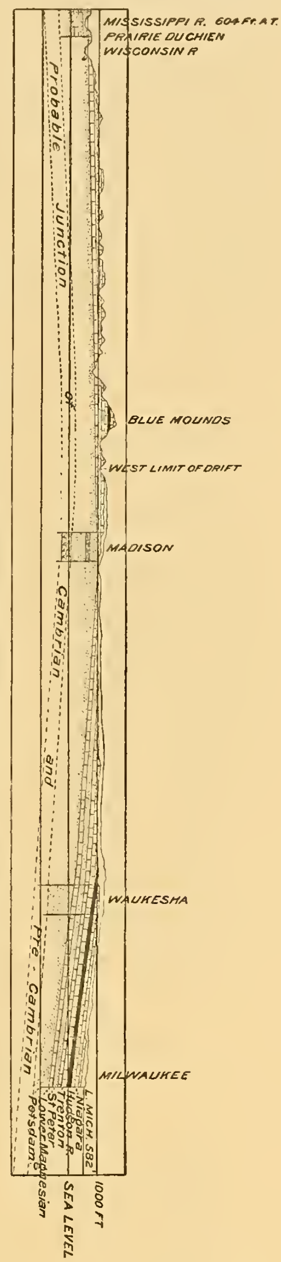


FIG. 70.—Section D-D, across southern Wisconsin from Prairie du Chien to Milwaukee. This section is reduced from Professor Chamberlin's section accompanying his geological map of Wisconsin, published by the Wisconsin Survey. The St. Peter and Potsdam are here separated by only a thin limestone formation. Vertical scale is 25 times the horizontal.

It will be observed that shale constitutes but a small part of the sections outside the Coal Measures area, the greater part of the section being limestone. The sandstones from which flowing wells are obtained apparently have found in the limestone cover as complete a check to the escape of water as would have been made by shale. The district to the west and north of the Coal Measures area is fully as productive in artesian flows as that within the limits of this formation.

The border line between the Lower Magnesian and Potsdam strata has not been satisfactorily determined. Professor Udden has found difficulty, even with the drillings before him, in deciding upon its place. His recognition of the close similarity between the Wisconsin Potsdam and certain beds in the wells at Rock Island and Davenport, however, makes it seem probable that the Lower Magnesian beds there have a thickness of about 800 feet.[1] As is well known, this formation has in southern Wisconsin and northern Illinois a thickness of only 200 feet. Whether this rapid southward increase in thickness prevails over the entire width of Illinois is not determined, though it seems probable that such is the case. A few carefully kept records of wells which penetrate these beds are herewith presented, since they may aid in future interpretations. The records of wells at Ottawa and Joliet were furnished by the driller, A. K. Wallen, of Morris. The record at Streator was kept by the late Dr. E. Evans, of that city.

Record of artesian-well boring at Streator, Ill.

[Altitude of well mouth, about 618 feet above tide.]

	Feet.
Drift	30
Coal Measures	211
Trenton limestone	203
St. Peter sandstone	225
Calciferous limestone	90
Calciferous sandstone	133
White limestone	211
White sandstone	37
Gray limestone	50
Red sandstone	15
Gray limestone	32
White sandstone	168
Blue shale	100
Dark limestone	73
Variable sandstone	187
Soft, white limestone	60
Variable clay shales	158
Red sandstone	80
Blue clay shale	50
Bluish limestone	50
Potsdam sandstone	333
Total	2,496

Record of well boring at Ottawa, Ill., foot of bluff at north end of Lasalle street.

[Altitude of well mouth, 73 feet above Illinois River, or 520 feet above tide.]

	Feet.
Alluvium, etc	35
St. Peter sandstone	130
Mainly limestone	145
Mainly sandstone	110
Fine limestone	175
Hard limestone, with thin sandstone beds and iron pyrites	260
Blue, sandy shale	120

[1] See discussion by Professor Udden in Chapter X.

	Feet.
Hard sandstone	100
Soft, white sandstone	360
Hard, dark-colored rock	90
Potsdam sandstone, with much water	200
Total	1,840

Record of well boring at Joliet steel mill.

[Altitude of well mouth, about 550 feet above tide.]

	Feet.
Drift	7
Niagara limestone	230
Dark-colored shale (Hudson River)	68
Trenton limestone	334
St. Peter sandstone	217
Red marl	40
Limestone	450
Sharp sandstone	175
Blue shale	50
Shaly limestone	125
Shale	230
Potsdam sandstone, with much water	150
Total	2,076

In the following table are arranged a few of the records of wells in the vicinity of Chicago. They show remarkable variations in the thickness of certain formations within short distances. The most remarkable is the St. Peter, which, in this small district, apparently ranges from 89 feet to 420 feet. The general reliability of the various records seems beyond question, for those which are not given by the drillers were furnished by men who were interested in the geologic structure.

Records of several wells in and around Chicago, showing variation in thickness of formations and elevation of contacts, in feet.

Location.	Distance between adjacent wells.	Elevation of curb.	Top of Niagara.	Thickness of Niagara.	Contact between Niagara and Hudson River shales.	Thickness of Hudson River shales.	Contact between Hudson River shales and Trenton limestone.	Thickness of Trenton.	Contact between Trenton and St. Peter sandstone.	Thickness of St. Peter sandstone.	Contact between St. Peter sandstone and marl or shale.	Thickness of marl or shale.	Contact between shale and Lower Magnesian limestone.	Thickness of limestone, sandstone, etc., below St. Peter sandstone.	Authority.
	Miles.														
Lake Bluff	0	682	475	320	155	198	*43*	216	*259*	167	*426*	32	*458*	46+	Drillers, Gray Bros.
Highland Park	8	695	520	400	120	200	*80*	240	*320*	200	*520*	50	*570*	935+	Driller, John Peterson.
Winnetka	6	658	474	316	158	192	*34*	247	*281*	212	*493*	45	*538*	470+	Drillers, Gray Bros.
South Evanston	7	612	540	260	280	230	50	270	*220*	420	*640*	14	*654*	336+	Dr. Oliver Marcy.
Chicago and Western avenues.	10	612	612	395	217	148	69	157+	......	.....	.....	....	....	....	W. T. B. Read.
Union Stock Yards	5	595	500±	254	246±	250	*4±*	325	*329±*	155	*484*	0	*484±*	70+	Dr. H. M. Bannister.
Morgan Park	10	640	477	.....	......	.....	......	......	*405*	.....	.....	....	....	....	W. S. Gamble, C. E.
Hammond	10	600	490	.....	......	.....	......	......	*460*	190	*650*	0	*650*	650+	W. F. Bridge, C. E.
Crown Point[1]	15	736	484	433	51	*234*	*183*	342	*525*	89	*614*	0	*650*	15+	Dr. A. J. Phinney.
Average	......	.....	......	.....	......	207	......	273	......	205	.....	....	....	....	

[1] At Crown Point the shales above the Trenton are separated into two beds, between which is a bed of limestone 57 feet thick, thought by Dr. Phinney to be Clinton limestone. This section also includes Devonian shales, and possibly Devonian limestone. The thickness of the Niagara may, therefore, be less than indicated above.

NOTE.—Italic numerals represent altitudes below sea level.

THE TERTIARY DEPOSITS.

These deposits are found in great thickness in the southern end of the State, and are probably present in many places beneath the drift at points farther north. Prof. R. D. Salisbury has found numerous exposures of beds of gravel and sand of pre-Glacial age on the border of the Mississippi between Alton and Warsaw, thus corroborating Professor Worthen's suspicion of the occurrence of such beds in the vicinity of Warsaw and Quincy, though he has not settled their exact date of deposition, compared with the Tertiary of southern Illinois. The deposits in southern Illinois are thought by Worthen to be of Eocene age.

These deposits consist of a variety of material, a large part of which is sand or gravel, but there are also beds of compact clay. The contained water is found in many places to be strongly chalybeate, and is, on the whole, less agreeable to the taste than water from drift gravel and sand. So far as known to the writer, artesian wells have not been found in these deposits within the State of Illinois. Whether or not the conditions are favorable for their development has not been ascertained.

GEOGRAPHIC DISTRIBUTION OF WELLS.

The artesian wells of Illinois are found mainly in the northern third of the State, on the north and west of the Illinois River. They are somewhat irregularly distributed. In a few sections, such as the city of Chicago, the head-water portions of the Illinois Valley, and the Mississippi Valley, the wells are very abundant, being, indeed, so numerous that the amount of flow is affected. Throughout the greater part of the area, however, they occur only at intervals of several miles. They are found mainly in the large towns of the district, but a few are located in villages, and rarely one has been made on a farm. Attention has already been called to the large use of these wells as sources of city water supply, and they are also used in various manufacturing industries.

The accompanying map (Pl. CXIII) shows the position of the wells, both flowing and nonflowing. It will be observed that the flowing wells are confined largely to the valleys, though a few occur on the lower parts of the upland.

In the central and southern portion of Illinois the occurrence of artesian waters of good quality has not been thoroughly tested. That region being underlain largely by Coal Measures shales, which contain sulphur and various mineral ingredients unpleasant to the taste, it can scarcely be expected that the water will be generally of good quality, suitable for drinking purposes. It has been found, however, that in some places wells with good quality of water may be obtained if certain horizons are selected which are free from these objectionable minerals. It should not, therefore, be understood that these portions of the State are entirely unfavorable for the development of artesian wells. But much discretion will be necessary in separating waters and selecting the proper horizon. In the district outlined as the main artesian-well district no such separation is called for, since the waters are generally wholesome and of agreeable taste.

STRATIGRAPHIC DISTRIBUTION OF WELLS.

Artesian wells have been found in nearly all of the main geological formations, excepting the Hudson River shales and Kinderhook shales. The best horizon is that of the Potsdam sandstone, which occurs at the base of the Paleozoic series. This is a very thick formation, and is usually sufficiently porous to readily transmit water. Mr. Mead estimates that in its most porous portions in Wisconsin it has the capacity to absorb water to an extent of 20 to 40 per cent of its volume. Such porosity is, however, not general, though a large part of the deposit will probably have a capacity equal to several per cent of its volume.

The next in order of importance, and the leading formation in order of development, is the St. Peter sandstone, which is also a very porous rock, well adapted for transmitting water. This deposit is, however, a thin one, averaging scarcely 200 feet, and is in places subject to changes to a shaly condition. Such being the case, wells in northern Illinois have often passed through it into the underlying Potsdam for their supply. As it lies much nearer to the surface than the Potsdam, it is over much of northern and all of western Illinois a more common source of supply for wells than the latter. Probably as many wells are obtained from this one formation as from the Potsdam and all others combined.

Next in order of importance is the portion of the Trenton formation known as the Galena limestone. In its lower portion the Galena limestone frequently becomes a porous, somewhat sandy formation, with a capacity for transmitting water nearly as great as the regular sandstone. It is this porous portion of the Trenton which in Indiana and Ohio is a gas-yielding rock, and where this porous rock is at too low a level to contain gas or oil it is filled with water. It is therefore an extensive water-bearing rock. Unfortunately, it is in Indiana and Ohio a salt water, but in Illinois it is usually suitable for domestic use. Well drillers in Illinois are in the habit of confounding this formation with the St. Peter sandstone, since it lies but a short distance above the latter. It appears not to have a very definite water horizon, for wells in neighboring villages often find the water in it at widely different depths. Though apparently subject to changes in texture at all the water levels, there is probably some connection by which the water may be transmitted readily.

The next formation in order of importance is the somewhat complex series of limestones and sandstones found between the St. Peter and the Potsdam, and called by the rather indefinite name Lower Magnesian limestone. The large amount of sandstone makes this an especially unfortunate name. As already shown, this formation is difficult to separate from the Potsdam, and in many cases it is difficult to say where the border line lies. The decision whether any given well is in the Potsdam or Lower Magnesian sandstones will depend upon the settlement of this border line. In the table of artesian-well data, which appears herewith, wells which have obtained their supply from this part of the rock series are provisionally referred to the Lower Magnesian. The wells are usually found in the sandstone beds, some of which are nearly as porous as the undoubted Potsdam.

The next formation in order of importance is the Niagara limestone. This appears, like the Galena, to be subject in limited areas to a change to a sandy constitution, in which case it often transmits water readily. This limestone also transmits much water through crevices or fissures, and wells are frequently obtained where no change to a sandy constitution has occurred. This formation lies so far above the level of the St. Peter that it should not be confounded with the latter, yet instances have occurred where such seems to have been the case. The water from the Niagara probably has access to many of the deep wells of northeastern Illinois, which are generally supposed to be supplied from lower horizons.

A few wells have been obtained from formations above the Niagara, but such wells are usually of much less strength than those from the main horizons. As already noted, it will be necessary, in the case of the Coal Measures, to separate the waters which are strongly impregnated with objectionable minerals from those having agreeable taste, before successful wells can be obtained.

Reviewing the above statements, it appears that the three main horizons for artesian wells are the Potsdam, the St. Peter, and the Galena. The other horizons are of minor importance, being more or less uncertain sources for wells.

DEPTH OF WELLS.

The artesian wells have a known range in depth of from about 40 feet to 3,115 feet. The shallowest wells are found along the Illinois River Valley, where the St. Peter and the Lower Magnesian strata lie at slight depth. Several hundred wells have been obtained in this valley at depths of 150 to 400 feet. It is estimated that in the city of Ottawa alone there are 200 such wells, and there are nearly as many in the city of Marseilles. Aside from this limited district along the Illinois, it is rare to find strong artesian wells at less than 500 feet, and the depth usually much exceeds that amount. The average depth for the 168 wells given below in the tabulated artesian-well data is 1,377 feet. The expense of sinking a well to a depth of 1,000 or 1,500 feet is usually not more than $3,000, and in the majority of cases the supply of water is such as to abundantly repay the outlay. Wells which have penetrated to a depth of 2,500 or 3,000 feet usually cost $6,000 to $12,000, and unless very strong flows of water of good quality are obtained there is not an adequate return for the investment. It is found, however, that in the city of Chicago, where large quantities of water are in demand, wells may profitably be sunk to a depth of 2,000 feet or more. Wells at various points in the northern part of the State exceed 2,000 feet in depth. On the whole, it may be considered safe to make sufficient outlay in that portion of the State to reach a depth of 2,000 to 2,500 feet, as the wells are generally strong and of good quality. The following list embraces the wells with a depth of 2,000 feet or more in which the returns seem to justify the outlay:

Profitable wells 2,000 feet in depth.

Location.	No.	Depth.
		Feet.
Amboy	1	2,000
Aurora	2	2,270 and 2,255
Chicago	[1] 30	2,000 to 2,700
Davenport	3	2,100
Elgin	2	2,026 and 2,230
Harvey	1	2,075
Joliet Steel Mill	1	2,076
Mount Carroll	1	2,502
Oak Park	1	2,200
Polo	1	2,098
Princeton	2	2,092 and 2,500
Riverside	1	2,200
Rock Island	1	2,282

[1] Estimated.

A longer list might be prepared of wells in which it was found not necessary to penetrate to this great depth, because the demand was abundantly supplied at less depth.

TABULATION OF ARTESIAN-WELL DATA.

In the following table the principal facts concerning the wells are presented. These facts were obtained largely by correspondence with the well owners or superintendents, for the writer has not had opportunity to examine many of the wells. Where not obtained directly or in this manner, a considerable part of the information has been gathered from Mr. Daniel W. Mead's tables in his paper on the hydrography of Illinois. The records for wells at Davenport, Rock Island, Moline, and Geneseo were furnished by Prof. J. A. Udden. A few records have been obtained from the Illinois Geological Reports, and a few from other publications.

In most cases the tables indicate precise altitudes and depths. The depth of well and of casing is nearly always based upon careful measurements.

Altitude.—The altitude of the well mouth is in some cases liable to an error of a few feet. This liability to error comes from assuming the well to have the same altitude as the railway station nearest it. In most cases it is known that the error is very slight. When there is a liability to an error of some consequence the sign (±) is affixed.

Capacity.—The capacity of the wells is not satisfactorily determined. In some cases the natural flow has been given, and in others the amount which can be pumped. As the supply can be greatly increased by pumping, the relative natural strength is not shown. The table is of value in showing actual use made of the wells.

Casing.—The water beds indicated in this table are in some instances all used by the well, and in other instances all except the lower are shut off by casing. The amount of casing used will serve to indicate what veins are left available for the wells.

Head.—The head, or rise of water in the wells, is affected by both natural and artificial influences. Neither of these are, as a rule, fully understood; consequently theoretical calculations are very liable to prove incorrect.

Determinations of head which appear in the following table are in some cases precise, while in others they are only approximate. The most precise are those made by Professor Udden from Rock Island and vicinity. Much care was exercised by Professor Udden in determining the elevation of the well mouth, the variations of head in the different wells, and the decrease of head in certain wells. Since these data are very reliable, the variations in head displayed by neighboring wells are of much interest and significance. It is probable that the wells of that district show no greater variation than is liable to appear in any artesian field. They serve to show that neighboring wells may vary a score or more of feet when from the same water horizon, and demonstrate the futility of predicting to a precise foot the height to which water will rise. Similar variations in head are reported by Mr. Mead to occur at Clinton, Iowa.

The head from the different water horizons seems to differ but little in northern and western Illinois, though a slightly greater head is generally found in the Potsdam than in the veins of higher horizons. Under the most favorable conditions the head from the St. Peter and the Galena appears to reach about 675 feet, as is the case at Monmouth, while from the Potsdam it appears to rise slightly above 700 feet, as shown by several wells in western Illinois. Qualifying conditions come in, however, which reduce the available head to the amount of 50 to 75 feet below the levels just given. Few wells in northern Illinois can be depended upon to maintain a head much exceeding 600 feet.

In the portion of the Illinois Valley near the point where the St.

Peter outcrops, the head from that formation is much lower than in surrounding districts, and it is thought that the outcrop of the water-bearing rock has led to this reduction. Data concerning this interesting region are meager, and hence the extent of the influence of this outcrop can not be confidently stated. The formation appears to have much greater extent to the south and east than toward the west. The lowest head is between Utica and Seneca, where it is but about 525 feet above tide. Eastward it reaches only 588 feet at Braidwood; southward, it reaches only 580 feet at Streator; but westward at Princeton, no farther than the points just named, the head is found to be 638 feet, or about as great as in the majority of wells in western Illinois.

In many cases there has been a marked loss of head since a well was made. For this reason it has been found necessary to arrange two columns, one showing the original, the other the present head. There are probably several causes for this loss of head. Among the most prominent, perhaps, is the clogging of the water-bearing stratum at the point where it issues into the well. This, however, has not been tested, so far as the writer is aware. Wells clogged in this way may often have their head restored by the discharge of some explosive, which causes a loosening of the bed at the point of entrance to the well. When a new well is made in the vicinity of one which has lost head and is found to have a head as great as the original head of that well, there is very strong probability that the loss of head is due to the clogging of the water bed or of the pipe. In some cases wells have lost head because of defective casing, there being strata about the well which absorbed water that would otherwise rise above the surface.

In certain districts loss of head has resulted from the overtaxing of the water bed. When several wells are sunk within a small area, as is sometimes the case in the most favorable localities for wells, the head is found to be greatly reduced. One of the best illustrations is afforded by the city of Chicago; and the Chicago district, when thoroughly examined, will probably throw much light upon the effect of overdrawing the natural flow of a well. The original head for the Galena and St. Peter water in the vicinity of Chicago is about 690 feet. At present water can scarcely be made to rise above 600 feet at any point near the city. The great drafts made in Chicago, which amount to several million gallons per day, appear to have reduced the head for several miles to the west and south from the limits of the city—as far west, it is thought, as the Des Plaines River, a distance of 10 miles from the part of the city where the wells are most numerous. Toward the south the head appears to have been lowered to an even greater distance. Another locality where the head appears to have been lowered by heavy pumping is found at Joliet. Mr. F. W. Dewey, the superintendent of waterworks of that city, reports that heavy pumping of a single well has been found to lower the head several feet in wells nearly one-half mile distant. It is probable that the Rock Island district has been affected to some extent by an overtaxing of head, though data are not available on that point.

The drawbacks, both natural and artificial, being so great, it is not at all remarkable that wells are seldom found to reach the theoretical head. Attention has already been called to the effect of an influx of surface water in raising the apparent head of wells which do not overflow. This is thought to be very great in the northeastern part of the State, where the drift beds are heavily charged with water.

Quality of water.—The chemical analyses which have been made, although few and from mixed water veins, are sufficient to throw some light upon the quality of water. They indicate an increasing amount of mineral matter in passing from north to south. This is a feature which is to be expected in passing away from the absorption area, for the strata through which the waters are transmitted contain soluble constituents, and wells which are remote from the absorption area must necessarily furnish waters which have been longer confined in these strata than those near the fountain head, and are in consequence more highly charged with the soluble minerals. The several strata which transmit water vary greatly in the amount of soluble constituents, and it is thought that a separation of the veins from each horizon would show marked variations in a given well. Indeed, certain properties of the water are usually recognized as characteristic of certain horizons. Unfortunately, such separation is rarely made in the waters which have been analyzed.

Of the wells located in the northern tier of counties, waters have been analyzed at Galena and Rockford. The former shows about 12.5 grains of mineral matter per gallon from Potsdam water. The latter shows 28.7 grains from St. Peter and 27.8 grains from Potsdam water. In the second tier of counties waters have been analyzed from several points, and show a range from 17.5 to 91.24 grains, as follows:

Location.	Geological source.	Grains per U. S. gallon.
Winnetka	Unknown	51.60
Evanston	Mainly St. Peter	71.30
Chicago, Munger's laundry	Unknown	23.23
Chicago, Leland Hotel	do	16.99
Chicago, Auditorium Hotel	do	91.24
Oakpark	Mainly Potsdam	56.90
Turner	do	18.20
Elgin	do	18.1
Dekalb	St. Peter, etc	17.5
Dixon waterworks	Potsdam	18.0
Dixon Condensing Co	do	28.39
Sterling	do	30.60

Analyses of waters in the vicinity of Rock Island show the following amounts of mineral matter:

Locality.	Geological source.	Grains per U. S. gallon.
Milan	Galena and St. Peter	68.4
Moline, paper mill	Galena, etc	71.9
East Moline	Galena and St. Peter	70.4
Rock Island, brewery	do	67.3
Davenport, glucose works	Galena and Potsdam	60.2

At Geneseo a well obtaining water from several horizons shows 157.4 grains; at Monmouth a well from St. Peter shows 73.9 grains; at Peru a well, probably from St. Peter, shows 50.9 grains; at Princeton only 28.5 grains are reported. Analyses farther south show a much larger amount than in any of the wells thus far mentioned. Thus, at Lagrange, Mo., 424 grains; at Hannibal, Mo., 987.64 grains; at Barry, Ill., 367 grains; and at St. Louis, Mo., 550.2 grains. At Jerseyville, however, only 141.5 grains are reported.

The most widely prevalent minerals of these waters which have been analyzed—and it is thought that the waters are fairly representative of the region—are calcium and magnesium carbonate and bicarbonate. These are generally present in all wells to such an extent as to render the water somewhat hard for laundry purposes. In many cases, also, wells drilled to supply water for boilers have found water too strongly impregnated by these minerals for satisfactory use.

Sodium chloride occurs only in small amount in the water of the northern part of the State, only a fraction of a grain per gallon being found in the wells at Galena, Rockford, Dekalb, Dixon, and Sterling, and less than 3 grains in the Chicago analyses. Less than 3 grains per gallon are found at Elgin, Aurora, Turner, and Winnetka, but at Oakpark 30.54 grains of potassium and sodium chlorides are reported. In the vicinity of Rock Island the wells are more salt than at Princeton and Monmouth, there being from 27 to 32 grains of sodium chloride found in the several waters analyzed, while at Princeton but 3.7 grains and at Monmouth but 9.61 grains are reported. Upon passing south to the wells containing large mineral residue, we find that sodium chloride greatly preponderates. Thus, at Lagrange, Mo., 320.6 grains; at Hannibal, Mo., 712.28 grains; at Barry, Ill., 277.7 grains, and at St. Louis, Mo., 401.5 grains are reported. At Jerseyville, where a smaller mineral residue occurs, there are 85.9 grains of sodium chloride. The salinity is such even at Rock Island as to be objectionable until a taste for the water has been acquired, while at points where the sodium chloride is greater the use of the water for drinking purposes can scarcely become popular.

In several cases wells are found to contain sulphates of various kinds in measurable amount, as may be seen by the analyses. Sodium sulphate is usually present with the sodium chloride in greater or less amount, and tends to render the water disagreeable.

Hydrogen sulphide is usually abundant in waters from the Niagara and from the Galena, but is less conspicuous in the St. Peter waters, and, so far as known, is not abundant at lower horizons.

Iron salts are not usually present in sufficient amount to greatly affect the water.

Where no analyses have been made statements concerning the quality of the water have been furnished by the well owners or superintendents. These are presented in the table, since they serve to show the popular idea of the quality of the water.

Tabulated artesian-well data.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost. Well.	Cost. Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Aledo, waterworks	1890	738	3,115	(?)	2,910	(?)	Drift, 41–60 ft.; St. Peter (?), 1,200 ft.; Potsdam, 2,300, 2,620, and 3,071 ft.	663	708	First veins fresh; brackish at 2,300 ft.		
Algonquin, Ill., Condensing Co.		760	2,527	(?)	(?)	(?)	Probably Potsdam	(?)	(?)	Rusts pipes; use discontinued.		
Amboy, waterworks		778	2,000	(?)	(?)	(?)	St. Peter (?), 390 ft.; Potsdam, 1,100 and 1,700 ft.	781		Pleasant and pure	$5,500	
Aurora, waterworks, No. 1		650±	1,388	8–6	(?)	350	St. Peter	(?)	(?)	See analysis	4,078	
Aurora, waterworks, No. 2		650±	2,270	(?)	(?)	(?)	Potsdam	710	740 ?	do		
Aurora, waterworks, No. 3		650±	2,255	(?)	(?)	(?)	do	710	(?)	do		
Aurora, C., B. & Q. R. R.		650	663	(?)	(?)	(?)	St. Peter	(?)	(?)	(?)		
Austin, town well		617	1,205	(?)	(?)	(?)	do	(?)	(?)			
Barry, waterworks	1880	760	2,510	6	60	100+	Fresh water at 60 ft.; St. Peter (?), 1,150 ft.	625	625	See analysis	6,000	$1,000
Beardstown, private well		445	1,100			175	Devonian, 350 ft.; flow with gas and oil, 500–600 ft.			do		
Belvidere, waterworks	1889	763	1,950	8–4	58	400	St. Peter and Potsdam	757		do	4,525	1,000
Belleville, brewery		540	503				Base of Coal Measures	460		Slightly saline		
Braidwood, test boring	1888	588	900	4	80		St. Peter, 655 ft.	588		Slightly sulphurous	3,000	
Canton, waterworks, No. 1	1882	661	2,500	4	90	125	Lower Magnesian (?), 2,050 ft.	630		Pure "magnesia" water.	8,000	3,000
Canton, waterworks, No. 2	1895	600	1,646½	14–6	797	260	Galena, 1,100–1,305 ft.; St. Peter, 1,405–1,646½ ft.	615		Pure and pleasant	4,271	4,733
Carrollton, waterworks		615±	1,330				St. Peter, 1,225–1,330 ft.	565				
Carbon Cliff, Argillo works	1890	592	915	5⅝	300	400	Galena, 850 ft.	642+	675	Brackish		
Carthage, No. 1		678	1,800	5–3			Niagara 750±; St. Peter, 1,000 ± ft.	662		do		
Carthage, No. 2	1892	678	1,000	10–8	223		Galena, 865 ft; St. Peter, 975 ft.	658		do	1,500	

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost.	
											Well.	Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Chicago, No. 1	1864	613	711	4½		400	Galena (?), 711 ft.	600 ±	690	Hard, but pleasant		
Chicago, No. 2	1865	613	694	5			Galena (?), 694 ft.	600 ±	690	do		
Chicago, stock yards, No. 1	1866	590 ±	1,200				St. Peter	590		do		
Chicago, Lehman well		595	2,604				Potsdam			Brackish		
Chicago, Swift & Co.		595	2,700				do					
Clinton, Iowa, waterworks		590	1,035	5				658		See analysis		
Do.		590	1,674	8–5		1,500	Potsdam	635				
Clinton, Iowa, Paper Co.		590	1,065	5½				625				
Collinsville, waterworks	1893	465	573				Sandstone, 509–573 ft.	445	445	"Like appollinaris"	1,300 ±	
Columbia, test boring	1886	528	1,010	5⅝			Sandstone, 1,000 ft.	518		Not pleasant	1,750	
Coulterville, test boring		545	1,117				Chester sandstone			Brackish		
Danville Junction, test boring.		610	2,008				Sandstone, 1,700–1,735 ft.			do		
Davenport, Iowa, Packing Co.	1893	564	1,180	5		250			609			
Davenport, Iowa, glucose factory, No. 1.	1880		1,500	5	8	200	St. Peter, 970–1,040 ft.		618	See analysis		
Davenport, Iowa, glucose factory, Nos. 2, 3, 4.	(?)		2,100	5	80	400						
	1888		2,100	5	80	400	St. Peter, 970–1,040 ft.					
	1892		2,100	5	80	400	Potsdam, 1,870–2,100 ft.		641			
Davenport, Iowa, Kimball House.	1890	579	1,080 ±	5	800	120	Galena, 740 ft.; St. Peter, 1,075 ft.	599	637	Sulphurous and salt at 740 ft.; less sulphurous and salt at 1,075 ft.		
Davenport, Iowa, ice factory.	1893	590	1,064	(?)	(?)	240	Galena, 775 ft.; St. Peter, at bottom.	600	(?)			
Davenport, Iowa, woolen mill.	1890	564	1,053	3½	700	300	Magnesian, 85 ft.; Galena, 700 ft; St. Peter, 1,050 ft.	599+	590	Sulphurous at 700 ft.		

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost.	
											Well.	Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Davenport, Iowa, malt and grain.	1892	592	1,076	5	1,050	300	Galena, 700 ft.; St. Peter, 1,050–1,076 ft.	605±	612+	Sulphurous at 700 ft.; pure at 1,050–1,076 ft.	....	....
Davenport, Iowa, Schmidt Building.	1892	576	1,200	4	1,200	73	Galena (?); St. Peter, near bottom.	(?)	600±	Not used........	....	....
Davenport, Iowa, Gas Co., Nos. 1, 2.	1891	564	1,200	5–4	1,200	400?	St. Peter, near bottom	611	611	....	....	....
Davenport, Iowa, bottling works.	1891	575	780	(?)	(?)	300±	Galena, 750 ± ft........	634	657	Used for carbonated waters.	....	....
Dekalb, public square........	1882	897	800	8–6	200	(?)	St. Peter and drift........	772	772	See analysis........	$4,000	$7,070
Dekalb, in city........	1880	887	981	6–4	190	(?)	.....do........	827	827	Pure........	....	....
Do........	1891	883	700	(?)	(?)	(?)	.....do........	843	843	....	....	....
DeKalb, block 18........	1892	899	880	10–8	(?)	(?)	.....do........	844	844	....	....	....
DeKalb, waterworks........	1895	855	890	14–6	(?)	300	Drift, 125–161 ft.; St. Peter, 595–890 ft.	790	790	Pure and pleasant....	....	....
Near Denver, Hancock County.	....	700	1,030	....	....	....	St. Peter........	660	660	.....do........	....	....
Dixon, Nos. 1, 2, 3 (waterworks).	....	675±	{1,640 1,730 1,810}	....	....	....	Potsdam........	(?)	(?)	See analysis........	....	....
East Dubuque, town well....	....	612	940	5	....	420	.....do........	707?	....	Pleasant........	....	....
East Peoria, test boring......	....	450±	734	....	....	....	317 and 734 ft........	....	....	Brackish........	....	....
Elgin, watch factory........	....	715	2,026	6	52	....	St. Peter, 650–700 ft; Potsdam, 2,024 ft.	....	742	Sulphurous at 650–700 ft.; soft at 2024 ft.	....	....
Elgin, Insane Hospital......	....	735	2,230	....	....	....	St. Peter, 650–700 ft.; Potsdam, 2,000 ± ft.	731	....	St. Peter, sulphurous; see analysis.	....	....
Elgin, Creamery Co........	1894	722	1,400	....	....	....	Galena, 487–514 ft.; sandstone at 972, 1,208, and 1,398 ft.	716	....	Sulphurous, 650–700 ft	....	....
Elgin, Condensing Co........	1876	712	1,876	....	....	....	St. Peter, 650–700 ft........	714	740	.....do........	....	....

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost. Well.	Cost. Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Equality, salt well	1	375 ±	1,800	6–3½	400		Probably Chester, 900 ft.			Very salt		
Evanston, city well		612	1,602				Limestone, 562-832 ft	617		See analysis		
Fairbury, waterworks	1892	708	2,002	8	2,002		First water at 60 ft.; deeper veins struck.	648		Soft and pleasant	$4,500	$2,000
Forreston, waterworks	1894	927	300	8	40			907			400	1,000
Fort Madison, Iowa, paper mill.		522	687				Probably Niagara at 610–687 ft.		648	Sulphurous		
Fulton, waterworks		594	1,246	5		300	First flow at 475 ft.; Potsdam at 940–1,050 ft.	655		Sulphurous at 475 ft.		
Galena, waterworks		605 ±	1,209	8		166	Potsdam	690		See analysis		
Galesburg, waterworks	1896	737	1,226	14–6	1,060	120	St. Peter, 1,060–1,226 ft.		635	Pleasant and pure	4,000	
Geneseo, waterworks		645 ±	2,250	6		190	Devonian or Niagara at 140–160 ft.; Galena at 950–975 ft.; Lower Magnesian at 1,350, 1,450, and 1,590 ft.; Potsdam, 2,040–2,160 ft.		676	do		
Hamilton, sanitarium		600 ±	680			36	Niagara	663		Sulphurous		
Harvey, waterworks		603	{ 1,300 / 2,075 }			250	St. Peter and Potsdam	593				
Harvard, railroad well	1892	935	900	12–7	102	90		894		Hard, with magnesia	7,000	2,000
Hennepin, town well	1875	495	800	4	800	80		545		Slightly saline		
Henry, town well		490	1,355	3½		32				White sulphur		
Highland Park, city well	1887	685	2,200	8–5	160	150	Galena, 900 ft.; Lower Magnesian, 1,300 ft.; Potsdam, 1,700–2,200 ft.		694+	Slightly saline and hard.	3,200	
Hinsdale, waterworks		691	864									
Ipava, waterworks		650	1,570	4		60	Galena (?), 1,010 ft.; St. Peter, depth (?).			Salt and sulphur at 1,010 ft.; lower vein pleasant.		

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost.	
											Well.	Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Jacksonville, J. Clapp & Sons	1887	570	2,408	5⅝	....	85	Lower Magnesian (?), 2,100 ft.	580	......	Brackish	....	....
Jacksonville, city well	1888	570	2,343	6–4⅝	1,950	30	Lower Magnesian (?), 2,340 ft.	555	......	....do	....	....
Jacksonville, waterworks	1895	570	3,028	6⅝–5⅝	1,800	500	St. Peter (?), 1,800 ft.; Potsdam, 3,000 ft.	540	540	Slightly saline	$12,500	....
Jerseyville, waterworks	....	662	2,003	12–3	(?)	200	St. Peter, 1,400–1,600 ft	562	......	See analysis	....	....
Joliet, steel mill	....	550	2,076	....	....	(?)	Potsdam	560	......	(?)	....	....
Joliet, waterworks, No. 1	....	535	1,200	....	....	500	St. Peter	......	......	(?)	....	....
Joliet, waterworks, No. 2	....	535	1,700	....	....	500	Lower Magnesian (?)	545	575	See analysis	....	....
Kankakee, private well	....	620	1,000	4	(?)	(?)	St. Peter, 900 ft	605	......	(?)	....	....
Keokuk, Iowa, Rand Park	....	637	1,987	6–4	1,975	(?)	Niagara at 600 ft.; Galena or Trenton at 900 ft.; flow near bottom Lower Magnesian (?).	637	......	Upper flows sulphurous; lower flows saline.	4,500	Siphon, $25.
Kewanee, No. 1	....	847	1,480	9–6	(?)	130	Probably St. Peter, 1,000 ft.	......	697	Soft and pleasant	....	....
Kewanee, No. 2	....	847	1,050	7–4	(?)	80	....do	......	......	....do	....	....
Kewanee, No. 3	....	847	1,050	6–4	(?)	52	....do	......	......	....do	....	....
Knoxville, waterworks	1896	770	1,350	8	1,180	80	St. Peter, 1,180–1,350 ft	......	......	Pleasant and pure	....	....
Lagrange, Mo., Wyaconda well.	....	490	840	....	....	60	Probably St. Peter	......	(?)	Brackish; see analysis.	....	....
Lake Forest, C. B. Farwell	....	650±	960	(?)	(?)	60	....do	......	700	(?)	....	....
Lasalle, waterworks, No. 1	1895	460	332	6	(?)	150	Coal Measures at 250 ft.	......	......	Moderately soft	581.00	....
Lasalle, waterworks, No. 2	1895		502	6		200					878.50	....
Lemont, waterworks	....	596±	1,366	....	....	(?)	Probably St. Peter	......	656	(?)	....	....
Lodi, Ind., artesian well	1865	510	1,155	....	....	35	Base of Devonian, 1,051 ft	......	(?)	Brackish; NaCl, 502 grains per United States gallon.	....	....
Macomb, waterworks	....	700	1,630	....	1,135	(?)	St. Peter, 1,135–1,360 ft	......	......	See analysis	....	....

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost.	
											Well.	Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Marseilles, private wells		480 ±	100–200	3–2		12	St. Peter	492	500 ±	Pleasant and pure		
Mendota, waterworks		747	400				St. Peter, 350–400 ft	700	700	....do		
Milan, town well	1894	566	1, 157	5	16	318	Galena, 800 ft.; St. Peter, 1,000 ft.	634	634	See analysis		
Millstadt, test boring	1895	625 ±	620	$7\frac{5}{8}$	200	4	Limestone	550		Hard	$1, 200	$800
Minonk, waterworks	1893	749	1, 755	10–6	700	100	Subcarboniferous limestone, 750 ft.; St. Peter (?), 1,700 ± ft.	600	600	Moderately hard	5, 000	1, 500
Minooka, test boring		614	2, 100				Potsdam, 1,985 ft		660			
Moline (East Moline)	1895	579	1, 340	6	28	240	Galena, about 750 ft.; St. Peter, 1,030–1,080 ft.	615	615	See analysis		
Moline, paper mill	1881	564	1, 628	5		350	Galena, about 700 ft.; lower veins; depth ?		646	....do		
Moline, Prospect Park	1891	611	1, 166		76	250 ±			636			
Monmouth, waterworks, No. 1.		735	1, 230	6–4	1, 074	200	St. Peter, 1,074–1,230 ft	675		See analysis		
Monmouth, waterworks, No. 2.		735	1, 227		935		Galena, 935 ft.; St. Peter, 1,074–1,227 ft.	675				
Montezuma, Ind	1891	500 ±	1, 675	4	128		Veins at 450 ft., and at 1,100–1,200 ft.		500 ±	See analysis		
Morgan Park, waterworks		640	1, 046				St. Peter, 1,040 ft.		595			
Morris, waterworks		510 ±	600				St. Peter			Moderately hard		
Mount Carroll, waterworks	1895	720	2, 502	5			Potsdam, strong, 1,200 ft.; Potsdam, weaker, 1,300–2,500 ft.					
Oakpark, waterworks, No. 1	1894	630	1, 568	$6\frac{1}{2}$	65	500	Lower Magnesian (?), 1,529 ft.	610 ±		See analysis	3, 000	1, 000
Oakpark, waterworks, No. 2	1894	630	2, 200				Lower Magnesian (?), 1,600 ft.; Potsdam, 2,200 ft.	610 ±				

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost. Well.	Cost. Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Olney		475	2,000				Does not flow			Not used; saline		
Ottawa, Lasalle street		528	1,840				Potsdam, 1,640–1,840 ft		705			
Ottawa, many wells		500 ±	400				Lower Magnesian, 290–400 ft			Variable; sulphurous		
Palatine, C. & NW. R. R.		748	1,656				Drift, 160 ft.; St. Peter, 800 ft.	750		Pleasant and pure		
Pana, test boring		695	2,507				Weak vein, depth (?)			Brackish		
Park Ridge, waterworks		660	1,500	6–3½				650				
Pedicord, near Marseilles		700 ±	2,189			8	Potsdam, 1,845–2,143 ft.		700 ±			
Pekin, City Park		525	850							Salt at 500 ft.		
Peru, waterworks		475 ±	1,250	6		450	Trenton, near bottom	560		See analysis		
Peru, zinc works		450	1,360	8	1,050	200	Niagara (?), 750 ft.; St. Peter, 1,350–1,360 ft.	570				
Polo, waterworks		841	2,098				Potsdam			Pleasant and pure		
Princeton, waterworks, No. 1.	1890	710	2,500				St. Peter and Lower Magnesian.	638		See analysis		
Princeton, waterworks, No. 2.	1894	710	2,092	9⅝–4⅝	1,000	320	St. Peter, 1,521–1,670 ft.; Lower Magnesian (?), 1,850–1,975 ft.	638		Hard; slightly saline.	$7,000	
Red Bud, glucose factory	1887	420	580	3		4	Chester, 200–260 ft.	427		Slightly alkaline	1,500	
Red Bud, test boring	1890	450 ±	1,350	4			Chester, 230–290 ft.	430 ±		do		
Riverside, waterworks		617	1,300 / 2,200	3½		1,000	St. Peter and Potsdam	597		More soda salts than lime.		
Rockford, waterworks, 5 wells.		711	1,300 to 1,996	8–6	400	116–260	St. Peter, 380–400 ft.; Potsdam, 1,200–1,300 ft.		719	See analysis	2,638 to 4,257 (Well and Pumps, etc.)	
Rock Island, Atlantic Brewery.	1890	577	1,150 ±	4½		400	Galena, 750 ft.; St. Peter, 980 ft.		647	Sulphurous at 750 ft.; less sulphurous at 980 ft.		

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Altitude.	Depth.	Diameter.	Amount of casing.	Capacity per minute.	Water bed and veins.	Present head.	Original head.	Quality of water.	Cost. Well.	Cost. Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Rock Island, Mitchell & Lynde Building.	1890, 1893	558	2, 282	8–4$\frac{5}{8}$	950 ±	....	Devonian weak, 40 ft.; Galena strong, 800 ft.; also from St. Peter, Lower Magnesian, and Potsdam strata.	608	644	Sulphurous at 800 ft.; less sulphurous in lower veins.	....	....
Rushville, waterworks	....	677	2, 500	....	....	....	(?)	....	....	Said to have an unpleasant taste.	....	....
Sabula, Iowa, waterworks ...	1895	592	973	....	6	720	Limestone vein at 870–973 ft.	670	670	Pleasant and pure	....	....
Savanna, waterworks	....	592	1, 432	....	....	500	Potsdam	675	....	.....do	....	....
Seneca, several wells	1885	510 ±	350, 680	4	....	....	St. Peter, 350 ± ft.; lower magnesian, 380 ft.	525	....	Hard and sulphurous.	$700 to 1, 400	....
Shawneetown, oil well	....	350	1, 513	....	....	....	Coal Measures, 730–780 ft.; Carboniferous conglomerates, 1,110–1,300, 1,325–1,370 ft.	....	....	Very salt	....	....
Sparta, town well	....	525	480	....	....	....	Chester, 480 ft	450	450	Soft, not pleasant.....	....	....
Steelville, Jenkins well	1887	449 ±	312	2	....	....	Coal Measures, depth (?)	....	450 +	Soft, pleasant	300	....
Sterling, waterworks	....	667 ±	1, 450	....	....	350	Potsdam	....	667 +	See analysis	....	....
Streator, city well	....	618	2, 496	....	....	....	St. Peter, 450 ft.; Lower Magnesian, depth (?); Potsdam, 2,170–2,496 ft.	....	578, 584, 663	....	....	....
Texas City, gas well	....	375	302	3½	....	....	Coal Measures, gas at 240 ft.	....	368	....	....	....
Tuscola, town well	....	660	792	....	....	....	Sub-Carboniferous limestone (?)	....	....	....	....	....
Utica, several wells	....	480	40–80	2	....	....	St. Peter or Lower Magnesian, 40–80 ft.	....	485	Pure and pleasant....	....	....
Utica, town well	....	480	290	....	....	140	Lower Magnesian (?), 150–290 ft.	525	525	.....do	....	....

Tabulated artesian-well data—Continued.

Locality and owner.	When made.	Alti-tude.	Depth.	Diame-ter.	Amount of casing.	Capac-ity per minute.	Water bed and veins.	Pres-ent head.	Origi-nal head.	Quality of water.	Cost. Well.	Cost. Pumps, etc.
		Feet.	*Feet.*	*Inches.*	*Feet.*	*Gallons.*						
Utica, James Clark		480	328			280	Lower Magnesian (?), 150–328 ft.	525	525	Pure and pleasant		
Utica, Jacob Norton		480	200 ±				Lower Magnesian (?), 260–300 ft.	525	525	do		
Vermillionville, oil boring			1,000				St. Peter, depth (?); Lower Magnesian, depth (?).			do		
Vermont, test boring		690	2,487				Potsdam (?)			Not in use		
Virginia, test boring		620	750				Sub-Carboniferous (?), 730–750 ft.			Unfit for drinking		
Warsaw, town well	1886	555	860	6	100	200	Galena or Trenton	617	653	Sulphurous	$2,150	
Warsaw, Colonel Marsh's well.	1888	600	800	4		95	do	(?)	650	do		
Warsaw, Negel well	1886	585	780	4		90	do	(?)	650	do	1,950	
Warsaw, William Hill's well	1887	585	790	4		100	do		650	do		
Warsaw, woolen mill	1891	495	750	6		90			650	do		
Waukegan, old waterworks		600	1,135 1,600 2,005				St. Peter and Lower Magnesian. (?)			Pure, with some iron; sulphurous (?). Not in use.		
Wenona, waterworks		690	1,854			100	Potsdam	565	565	Soft, pleasant		
Wilmington, private wells	1889	540 ±	635	4½	200		St. Peter, 400-635 ft		586	Sulphur and magnesia	1,500	
Winchester, at mill		545	412				Sub-Carboniferous (?), 350 ft.	470	470	Pleasant and pure		
Winnetka, Lloyd's well		658	1,570			150		650	676	See analysis		
Woodstock, waterworks		916	1,014			500	Probably St. Peter			Soft and pleasant		

CHAPTER IX.

WATER ANALYSES.

The State Board of Health, in 1888 and 1889, made sanitary analyses of the waters used by the State institutions, and also of waters from several cities. In most cases several analyses of a water were made, in order to determine its average condition. In the following table only the averages are presented.[1]

This table is followed by analyses of the polluted waters of the Des Plaines and Illinois rivers and of the canal waters near Chicago, also made by the State Board of Health in 1888 and 1889. With these analyses appear analyses of waters from Lake Michigan and Dupage and Kankakee rivers, which are comparatively unpolluted.

[1] The full report of analyses will be found in the Preliminary Report to the Illinois State Board of Health on Water Supplies of Illinois and the Pollution of its Streams, by J. H. Rauch, M. D., secretary. Published at Springfield, Ill., 1889.

Waters used by cities and State institutions.

[Analyses mainly by State Board of Health.]

Cities and State institutions.	Season.	Number of analyses.	Total solids. (1)	Suspended matter.	Nitrogen in nitrates.	Chlorine.	Hardness, $CaCO_3$.	Free ammonia.	Albuminoid ammonia.	Oxygen consumed.	Sulphates.
Alton, Mississippi River	Autumn	15	278.6	75.2		4.08	169.4	.16	.35	7.35	
Alton, hydrant	do	15	238.3	33.3		4.20	174.0	.06	.26	6.43	
Anna, Insane Asylum, storage reservoir	do	3	177.1	2.4		4.87	131.0	.16	.13	2.45	
Aurora, artesian well No. 1, 1,388 feet	(?)	1	380.0		.20	4.77		.81	.07	1.20	
Aurora, artesian well No. 2, 2,270 feet	(?)	1	500.8			124.0		.37	0	2.7	
Aurora, artesian well No. 3, 2,255 feet	(?)	1	445.8			85.0		.28	0	.40	
Aurora, Fox River	Autumn	4	302.5	3.4		2.44	261.0	.06	.18	3.98	
Belleville, Richland Creek, new reservoir	Oct. 10, 1888	1	136.0	19.4		4.24	80.0	.07	.51	7.60	
Bloomington, shallow drift well	Autumn	4	603.6	3.5		4.24	489.0	.93	.08	1.82	
Cairo, Ohio River	do	3	208.4	116.9		3.10	46.0	.08	.18	4.53	
Chandlerville, Sangamon River	Summer	8	317.8	70.7	.75	3.60	212.0	.05	.28	5.48	
Chester, State penitentiary, Mississippi River	Autumn	3	439.3	111.2		7.16	.29	.07	.23	5.52	
Chicago, Lake Michigan	Summer	27	149.9	13.5		2.11	125.3	.007	.08	1.42	
Dwight, drift well	do	1			.82			2.50	.13	5.80	
Decatur, Sangamon River (hydrant)	Autumn	1	364.3	5.0		6.01	320.0	.05	.19	3.04	
East St. Louis, Mississippi River (pump house)	do	8	616.4	67.7		4.45	.13	.05	.41	3.75	
Elgin, Insane Asylum, springs	do	3	351.4	4.9		3.46	300.0	.02	.05	.93	
Elgin, Fox River	do	3	266.5	2.0		3.23	282.0	.26	.27	4.0	
Freeport, drift wells	do	4	475.5	1.7	6.26	12.89	435.0	.03	.06	2.86	
Galesburg, drift well	do	4	399.3	11.3		1.18	370.0	.93	.11	2.40	
Galena, artesian well, 1,507 feet	do	4	286.1	2.6		.60	201.0	.07	.06	2.14	
Jacksonville, storage reservoir, city	Oct. 26, 1888	1	197.0	2.1		5.51	160.0	.12	.42	6.80	
Jacksonville, artesian well, 2,400 feet, city	Oct. 29, 1888	1	2,522.2	1.1		934.5	460.0	1.22	.01	2.80	
Jacksonville, abandoned coal shaft, 210 feet, city	Oct. 30, 1888	1	1,191.6	52.4		169.9	436.0	2.50	.29	6.56	
Jacksonville, Insane Asylum, city water	Autumn	3	197.1	12.1		3.10	158.0	.33	.36	5.02	

[1] The quantities given in this table indicate the number of grains in one United States gallon.

Waters used by cities and State institutions—Continued.

Cities and State institutions.	Season.	Number of analyses.	Total solids. (1)	Suspended matter.	Nitrogen in nitrates.	Chlorine.	Hardness $CaCO_3$.	Free ammonia.	Albuminoid ammonia.	Oyxgen consumed.	Sulphates.
Jacksonville, Deaf and Dumb Asylum, city water (filtered).	Autumn	2	206.4	27.5	....	3.54	147.0	.03	.38	5.80	....
Joliet, artesian well, 1,200 feet, city water	Summer	4	453.1	7.4	.54	8.33	326.6	.03	.08	2.37	....
Joliet, State Penitentiary, artesian wells {553 / 1,948 ft.}	Autumn	3	766.9	1.76	....	199.8	242.0	5.61	.52	2.56	....
Kankakee, Insane Asylum, filter gallery	do	5	256.1	15.2	....	2.06	223.0	.03	.26	7.68	....
Lasalle, Little Vermilion River	Summer	7	375.1	30.8	.36	5.66	210.2	.18	.41	7.15	....
Lincoln, Asylum for Feeble-Minded	Autumn	3	325.9	10.9	....	4.94	285.0	.01	.06	2.53	....
Morrison, storage reservoir	do	4	390.4	3.0	6.42	7.48	348.5	.009	.03	1.10	....
Normal, Soldiers' Orphans' Home	Winter	3	420.2	13.8	2.18	2.22	....	1.06	.11	2.61	....
Ottawa, Fox River	Summer	18	330.3	46.3	.02	4.97	242.1	.27	.46	7.06	....
Pekin, drift well	do	4	341.8	6.5	3.83	2.85	277.8	.009	.038	.59	....
Polo, artesian well	....	(?)	....	(?)	2.00	7.0	....	.025	.07	....	....
Pontiac, Reform School	Autumn	3	1,673.7	10.6	....	520.0	522.0	.25	.07	2.10	....
Quincy, Mississippi River	do	2	180.3	12.3	....	1.04	147.0	.07	.27	6.09	....
Rock Island, Mississippi River	do	4	192.2	26.2	....	1.31	151.0	.05	.25	6.06	....
Springfield, Sangamon River (pump house)	do	2	363.2	23.4	....	3.94	295.0	.408	.084	1.80	....
Streator (R. O. Graham, analyst)	(?)	....	424.5	....	.006	4.0	....	.025	.05	....	15.80
Wilmington, Kankakee River	Summer	19	251.4	35.6	.09	1.01	164.1	.11	.58	12.66	....

[1] The quantities given in this table indicate the number of grains in one United States gallon.

Waters of the Des Plaines and Illinois and tributaries.

[Analyses by State Board of Health in 1888 and 1889.]

Locality.	Season.	Number of analyses.	Total solids. (1)	Suspended matter.	Nitrogen in nitrates.	Chlorine.	Hardness, $CaCO_3$.	Free ammonia.	Albuminoid ammonia.	Oxygen consumed.
Chicago, Lake Michigan		27	149.9	13.5	0	2.11	125.3	.007	.089	1.42
Bridgeport, canal, Chicago sewerage	Summer	29	471.2	129.2	0	46.81	201.3	12.25	2.55	23.11
Do	Winter	9	376.6	27.2	0	62.93		8.92	2.80	26.50
Lockport, canal, Chicago sewerage	Summer	24	431.2	69.8	0	46.12	207.7	10.88	1.99	16.23
Do	Winter	8	408 6	24.6	0	56.08		8.14	2.48	22.82
Joliet, Dam 2, canal and Des Plaines water	Summer	26	442.7	107.9	0	43.65	216.8	8.93	1.68	14.30
Do	Winter	8	432.8	55.5	0	57.71		8.48	2.66	21.71
Channahon, Dupage River	Summer	21	294.7	14.1	.30	5.78	244.8	.41	.34	4.74
Wilmington, Kankakee River	do	19	251.4	35.6	.09	1.01	164.1	.11	.58	12.66
Morris, Illinois River	do	24	355.9	30.85	.36	32.14	214.8	4.10	.70	10.92
Do	Winter	8	325.2	29.1	0	28.74		4.71	1.58	10.69
Lasalle, Illinois River	Summer	23	345.7	50.3	1.03	19.71	211.7	.62	.52	8.55
Do	Winter	9	417.6	93.8	.94	13.10		1.45	.63	8.58
Henry, Illinois River	Summer	19	306	27.5	.68	17.66	204.4	.46	.48	8.65
Do	Winter	5	316	30.9	.96	11.69		1.05	.40	8.63
Peoria, Illinois River at inlet to pumps	Summer	19	329.75	54.27	.89	12.35	199.7	.21	.52	9.76
Peoria, from hydrant	do	14	327.7	27.4	.89	28.33	206.6	.08	.39	8.18
Pekin, Illinois River	do	16	353	84.3	.79	16.15	204.6	.64	.65	9.41
Do	Winter	6	352	43.5	1.25	11.79		1.59	1.01	13.35
Havana, Illinois River	Summer	24	301.78	45.4	.73	11.58	204.2	.34	.43	8.14
Do	Winter	9	352.4	80.8	.41	9.27		1.07	.58	9.23
Beardstown, Illinois River	Summer	24	390	84.7	.62	7.52	204.9	.20	.38	7.35
Do	Winter	6	317.8	56.3	.96	6.93		.76	.35	5.50
Chicago and Alton Railroad Bridge, Illinois River	Summer	16	402.5	172.5	.71	8.71	213.4	.06	.42	7.65
Grafton, mouth of Illinois	do	12	301.6	50.3	.58	9.20	242.4	.09	.48	7.30
Do	Winter	9	410.8	44.6	.08	23.64		.87	.72	9.81

[1] The quantities given in this table indicate the number of grains in one United States gallon.

The following table of chemical analyses of springs, shallow wells, etc., has been taken in the main from Mr. Mead's report. The additional analyses were obtained through schedules for city water supply. The analyses vary quite widely in the determinations made, some being less complete than may be shown in this table, while a few embrace several not included in the table. Mention of the additional substances is therefore made at this point. In the Bushnell well there is in the analysis a statement that 3.50 grains of alkali occur. In four instances determinations of magnesium sulphate were made, as follows: Dwight, 13.61; Nashville Spring, 103.7; Spring Valley (spring No. 1), 9.12; and Waukesha Hygeia Spring, 4.35 grains. The iron and alumina are not separated in the Lincoln and the Hygeia analyses. At Oregon a small amount (6.90 gr) of potassium carbonate is reported. At the Perry Iron Spring a large amount of ferrous sulphate (69.96 gr.) is reported. At Spring Valley calcium and magnesium chlorides appear in greater amount than in most waters of the region, there being 33.72 grains. At the Hygeia Spring several additional determinations were made, viz: Free carbonic acid, 1.43 grains; magnesium sulphate, 4.35 grains; magnesium chloride, 0.21 grain; magnesium nitrate, 1.62 grains; iron phosphate, 0.008 grain; iron carbonate with alumina, 3.039 grains.

Chemical analyses of springs, shallow wells, etc.

[Grains per United States gallon.]

Locality.	Calcium carbonate.	Calcium bicarbonate.	Calcium sulphate.	Ferrous carbonate and bicarbonate.	Magnesium carbonate.	Magnesium bicarbonate.	Potassium chloride.	Potassium sulphate.	Silica.	Sodium carbonate.	Sodium bicarbonate.	Sodium chloride.	Sodium sulphate.	Alumina.	Total.	Analyst.
Alcyone Spring (Cook County)	......	18.69	......	......	......	13.79	......	4.86	.68	......	......	......	3.39	1.99	48.08	J. V. Z. Blaney.
Bluemound, waterworks well	{+Mg. 6.76}	......	{+Mg. 15.66}	......	......	......	......	......	......	......	......	13.21	......	......	50.90	W. J. Williams.
Bushnell railroad well, alkali not separated.	7.04	......	.24	......	2.71	......	......	......	.43	......	......	......	......	.13	15.30	George H. Ellis.
Dekalb, Corkin's well in drift	16.66	......	7.39	.12	6.29	12.25	2.33	......	.87	......	......	......	{+K_2SO_4 4.68}	......	47.59	G. M. Davidson.
Dwight, waterworks well in drift.	15.65	......	3.83	......	......	......	......	......	.02	......	......	4.41	23.9	{+Fe. .36}	64.40	Arthur Palmer.
Elgin, Zonian Spring	9.56	......	......	.49	2.49	......	......	......	......	......	.45	.70	1.74	{+SiO_2 .26}	15.74	J. E. Siebel.
Galesburg, old waterworks well.	9.69	......	.33	3.79	5.06	......	.43	......	1.12	......	1.50	.12	......	......	22.06	J. H. Long.
Glen Flora Spring (Cook County).	......	15.57	......	.11	......	11.09	......	......	.91	......	6.45	.18	1.85	.15	36.41	J. V. Z. Blaney.
Lake Michigan	4.46	......	.31	.02	2.20	......	......	.28	.30	......	......	......	.22	Trace.	7.82	J. H. Long.
Lincoln, filter gallery	7.30	......	6.76	......	4.73	......	.73	1.02	.71	......	......	2.31	......	......	16.07	Do.
Nashville Spring	......	......	65.8	......	......	......	......	......	......	24.0	......	10.0	53.0	......	265.5	W. F. Hillebrand.
Oregon, Ganymede Spring	9.20	......	......	.08+	8.56	......	......	.15	9.62	......	......	.10	......	......	20.0	E. W. Hall.
Perry, iron spring	......	15.89	73.94	......	......	17.0	......	......	1.31	......	......	......	.44	......	156.0	Henry Egbren.
Rockford, drift well	......	16.03	......	.39	......	11.43	......	.15	1.04	......	4.66	.11	.21	.08	29.94	E. G. Smith.
Spring Valley, spring No. 1	8.96	......	3.84	......	3.40	......	......	......	.24	......	......	34.80	35.16	......	129.24	J. V. Z. Blaney.
Versailles, magnesium spring	14.60	......	Trace.	.06	8.95	......	......	......	1.40	{+K 1.32}	......	Trace.	......	......	26.33	G. A. Marnier.
Waukesha, Bethesda Spring	17.02	......	......	.04	......	12.39	......	.46	.74	......	1.26	1.16	.54	.12	35.71	C. F. Chandler.
Waukesha, Hygeia Spring	......	......	......	......	19.22	4.63	......	.69	.70	......	......	1.89	......	......	37.53	A. W. Palmer.
Waukesha, Silurian Spring	9.93	......	......	.13	......	6.83	......	......	.70	......	.03	.19	.29	.59	18.69	W. S. Haines.
Woodstock, drift well	16.59	......	......	.39	......	5.19	......	.30	1.04	......	5.29	5.06	4.44	.08	29.94	Do.

In the following table are arranged the best analyses of artesian waters that are available. The water in the majority of the wells is not from a single vein or water horizon, there being few wells in which casing is carried far into the rock. It is probable, however, that the water in the following wells is mainly from the St. Peter: Dekalb waterworks, Monmouth waterworks, Rockford 400-foot well, and Rock Island brewery. The water in the following is probably mainly from Potsdam: Clinton (Iowa) waterworks, Galena waterworks, Rockford waterworks, St. Louis (Mo.) Insane Hospital, Sterling waterworks, and Turner Junction railroad well.

In addition to the substances classified in the table, a few wells show measurable amounts of other substances. Thus, organic matter is reported as follows: Dekalb, 0.70 grain; Elgin Hospital, 0.99 grain; Moline Paper Mill, a trace. Magnesium chloride is reported as follows: Montezuma, Ind., 9.97 grains; St. Louis, Mo., 46.08 grains; Winnetka, Ill., 1.95 grains. Magnesium sulphate is reported as follows: Auditorium Hotel, Chicago, 11.90 grains; Hannibal, Mo., 72.21 grains; Milan, 0.75 grain. Potassium chloride is reported as follows: Barry, 8.57 grains; Montezuma, Ind., 2.68 grains; St. Louis, Mo., 0.86 grain. The Dekalb and Dixon wells show a trace. The Montezuma (Ind.) analysis reports several substances not mentioned in the other analyses, viz: strontium sulphate, lithium chloride, borax, and sodium bromide, each with "more than a trace;" sodium iodide, a trace; calcium phosphate, a trace; hydrogen sulphide, 3.728 grains. In the Oakpark and Turner wells potassium and sodium sulphates are not separated, and in the Oakpark well potassium and sodium chloride are not separated. In the Lagrange (Mo.) well 8.17 grains of potassium carbonate were found.

An analysis of the water from the Macomb artesian well has been made at the Survey office, by Mr. George Steiger, since the table was prepared. It is thought to represent fairly well the quality of water to be obtained from the St. Peter sandstone in western Illinois. The superintendent of waterworks, Mr. W. E. Thompson, states that an attempt was made to exclude water from the water-bearing beds above the St. Peter, there being a continuous iron casing with tight screw joints from the top of the well down to the St. Peter sandstone, packed at the bottom with rubber, which was expanded by screw pressure to completely fill up the space between the outside of the casing and the wall of the well. A similar packing was also put in at 145 feet, the beginning of the rock formation. It is scarcely probable, therefore, that water to any great amount enters the well from other horizons than the St. Peter sandstone. A comparison of the analysis of this water with the analysis of the unseparated waters from a neighboring well at Barry, Ill., reveals a great difference in the amount of sodium chloride, and raises the question whether the Barry well and all other wells in this part of the State may not be greatly improved by casing out the water above the St. Peter sandstone.

Analysis of St. Peter water, Macomb, Ill.

[Grams per 1,000 cubic centimeters.]

	Grams.
SiO_2	.0105
TiO_2	None.
SO_3	.8326
CO_2	.2899
Cl	.5418
P_2O_5	None.
O (basic)	.2732
Al	.0007
Fe	.0013
Ca	.1581
Mg	.0672
K	.0237
Na	.8086
Total	3.0076

Hypothetical combinations.

	Grams per 1,000 c. c.	Grains per U. S. gallon.
KCl	.0454	2.652
NaCl	.8570	50.063
Na_2SO_4	1.4555	85.025
$MgSO_4$	.0192	1.121
$MgCO_3$	.2218	12.956
$CaCO_3$	.3950	23.074
Al_2O_3	.0013	0.075
Fe_2O_3	.0019	0.111
TiO_2	None.	None.
SiO_2	.0105	0.613
P_2O_5	None.	None.
Total	3.0076	175.690

Analyses of artesian well waters.

[Grains per United States gallon.]

Locality.	Alumina.	Calcium carbonate.	Calcium bicarbonate.	Calcium sulphate.	Ferrous carbonate and bicarbonate.	Magnesium carbonate.	Magnesium bicarbonate.	Potassium sulphate.	Silica.	Sodium carbonate.	Sodium bicarbonate.	Sodium chloride.	Sodium sulphate.	Total.	Analyst.
Barry, waterworks				58.64	Trace.		16.89		84.0			217.7	62.6	367.0	(?)
Chicago, Auditorium	0.07		21.33	16.31	.13			1.58	.84			2.33	36.75	91.24	E. G. Smith.
Chicago, Leland Hotel		5.69			.304	0.24		.12	1.33	6.32		2.51		16.99	C. G. Wheeler.
Chicago, Munger's Laundry	.03		5.63		.04		7.45	Trace.	.49		7.03	1.82	.47	23.23	E. G. Smith.
Clinton, Iowa, waterworks	Trace.		11.22		Trace.		7.42		6.1		6.28	6.6	6.6	38.8	Do.
Davenport, Iowa, glucose factory.	.36		5.13	5.54			4.77		.2			28.1	16.1	60.2	E. Guteman.
Dekalb, waterworks	.69		8.39				6.47					Trace.	1.13	17.5	G. M. Davidson.
Dixon, waterworks	.12		9.03	.06			9.94		.28			.4	.7	18.0	E. G. Smith.
East Moline	Trace.			2.52	.08		8.82	1.90	.57			27.2	19.1	70.4	Do.
Elgin, Insane Hospital	Trace.		8.39				4.41		.24	.73		1.4	1.77	18.1	W. Haines.
Evanston			10.82	22.46			7.82	19.42	.48			5.36	4.81	71.3	W. L. Brown.
Galena, waterworks	.06		3.70		Trace.		8.50	Trace.	.06			.10			W. Simpson.
Geneseo, waterworks	8.55	24.10	4.50		{ 1.8 / 2.8 }	10.23						90 4	11.03	157.4	D. M. Stanner.
Hannibal, Mo., Oakwood well				125.89								712.28	77.26	987.64	R. Chauvent & Bros.
Jerseyville, waterworks	.06		6.84	16.9	.11		15.53	10.3	.78			85.9	5.05	141.5	E. G. Smith.
Lagrange, Mo., Wyaconda well.	.09		51.6				31.28		2.86		.20	320.6	9.22	424.05	(?)
Macomb, waterworks	.075	23.07				12.95			.61			50.06	85.02	175.69	George Steiger
Milan, town well	Trace.	6.26				1.50		7.43	.03	[1]42.19		[1]10.21		68.4	(?)
Moline, paper mill		8.76			.22	5.84			.35			27.85	28.84	71.9	W. Haines.
Monmouth, waterworks	.10		15.8	4.7	.23		14.07	4.86	1.04			9.61	23.4	73.9	E. G. Smith.

[1] Given as potassium in analysis, but probably sodium, and thus reported by J. A. Udden.

Analyses of artesian well waters—Continued.

Locality.	Alumina.	Calcium carbonate.	Calcium bicarbonate.	Calcium sulphate.	Ferrous carbonate and bicarbonate.	Magnesium carbonate.	Magnesium bicarbonate.	Potassium sulphate.	Silica.	Sodium carbonate.	Sodium bicarbonate.	Sodium chloride.	Sodium sulphate.	Total.	Analyst.
Montezuma, Ind	.07	....	11.18	10.66	....	....	17.88	....	.82	....	....	357.7	....	426.3	W. A. Noyes.
Oakpark, waterworks	....	8.16	....	Trace.	Trace.	2.33	....	....	.40	....	8.7	30.54	6.79	56.9	G. M. Davidson.
Peru, waterworks	.04	....	12.65	....	....	....	7.16	....	.79	....	7.02	16.0	7.25	50.9	E. G. Smith.
Princeton, waterworks	....	....	....	....	....	....	....	....	....	....	....	3.7	....	28.5	E. H. Bartley.
Rockford	.13	....	13.17	....	.07	....	12.79	.50	.58	....	.81	.27	.35	28.7	E. G. Smith. (?)
Rockford, waterworks	.06	....	13.83	.19	.15	....	12.28	.23	.54	....	....	.11	.34	27.8	Do.
Rock Island, brewery	....	10.0	....	....	....	6.3	....	....	....	4.0	....	32.00	15.00	67.3	Wall and Hennsock.
St. Louis, Mo., Insane Hospital.	....	....	47.49	50.18	.65	....	....	3.05	.93	....	....	401.5	....	550.2	P. S. Schwitzer.
Sterling	.05	....	14.85	....	.06	....	13.35	.46	.61	....	....	.69	.54	30.60	E. G. Smith.
Turner Railroad Co	Trace.	6.67	....	.11	.12	4.08	....	....	.56	....	....	1.48	4.49	18.20	(?)
Winnetka, Lloyd's well	....	....	12.79	20.46	.87	....	4.85	3.86	....	....	1.69	2.48	2.65	51.60	C. E. Clacius.

CHAPTER X.

AN ACCOUNT OF THE PALEOZOIC ROCKS EXPLORED BY DEEP BORINGS AT ROCK ISLAND, ILL., AND VICINITY.

BY J. A. UDDEN.

GENERAL STATEMENT.

Within a distance of 6 miles from the cities of Moline, Rock Island, and Davenport, 21 deep wells have been made, up to the present time (January, 1896), for the purpose of obtaining artesian water. The wells are scattered over an area extending 11 miles east and west and about 6 miles north and south. With the exception of the well in the

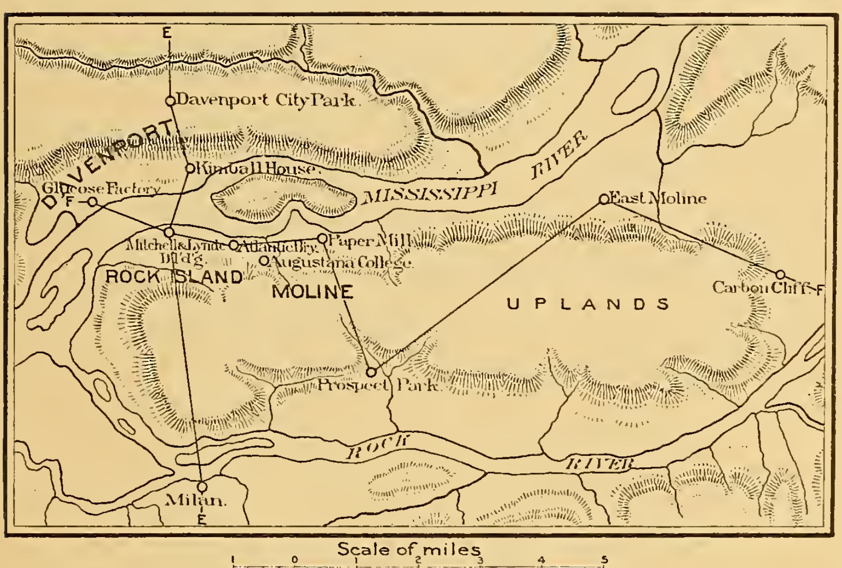


FIG. 71.—Map showing location of deep wells in Davenport, Moline, Rock Island, and suburbs, by J. A. Udden.

city park in Davenport, all are located on the bottom lands of the Mississippi and the Rock rivers, some of them just in the lower slope of the river bluffs. The well in the Davenport Park is the only one which has not furnished a flow of water.

Reports on the nature of the strata explored by these borings have been published in a few instances, but a comparative study of the obtainable data from this locality has not been made. At any rate, the results of such a study have not been placed on record.

The author has examined specimens of drillings from six wells, and

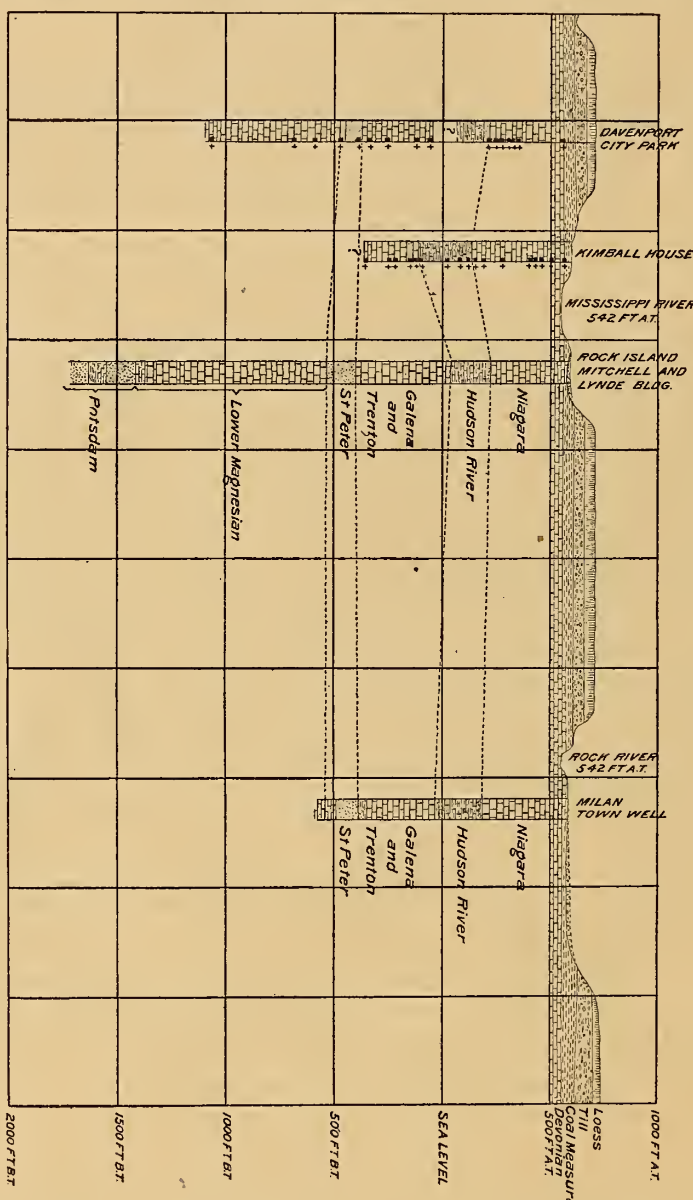


Fig. 72.—Geological section from Davenport, Iowa, to Milan, Ill.

drillers' "logs" have been obtained for two of these and for four others. It is believed that these data furnish a sufficient basis for estimating the thickness of the formations penetrated. They also throw considerable light on the lithological character of the rocks at different depths and on the geological structure of the area covered. (See figs. 72 and 73.)

The data which have been obtained may be found in condensed form at the close of this paper.

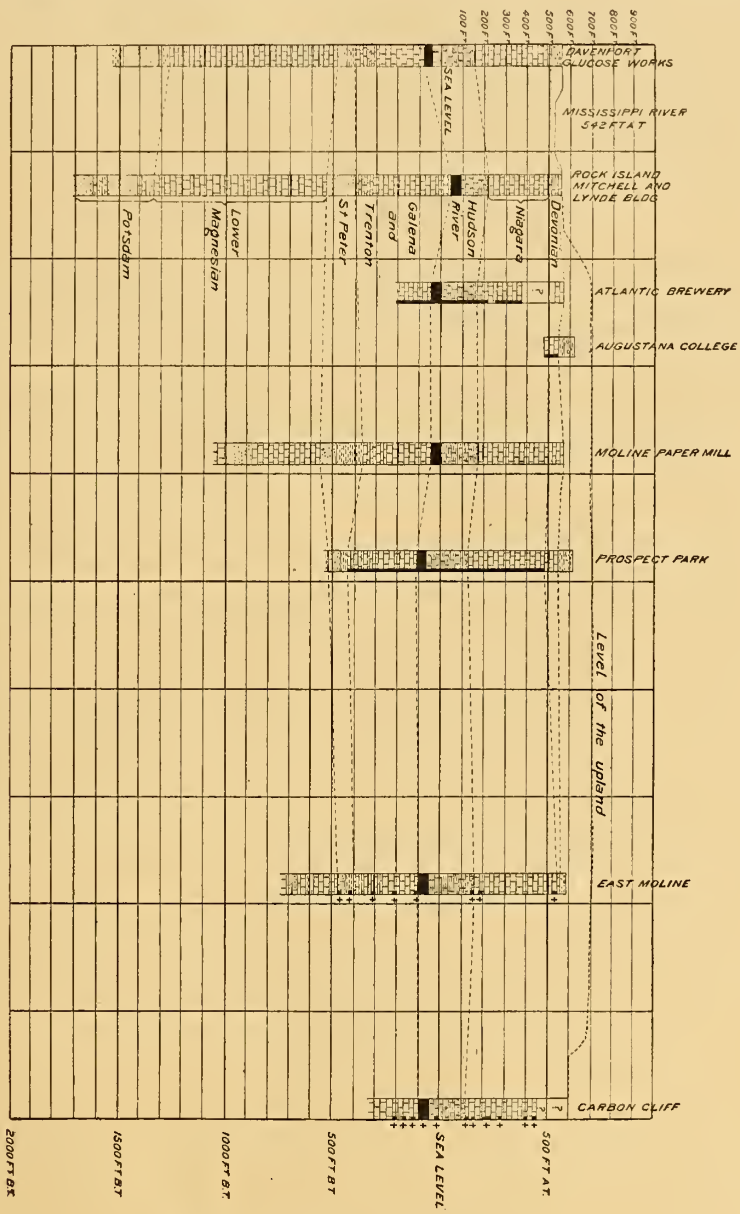


Fig. 73.—Geological section from Davenport, Iowa, to Carbon Cliff, Ill.

STRATIGRAPHIC FEATURES.

The territory where these wells are located lies near the north limit of the beds of the Coal Measures and of the Devonian shales and limestone. The Coal Measures have mostly been removed in the river valleys by recent eros on, and are now found only on either side of these valleys. The rocks immediately below consist of the feather-edge of the Devonian shales and limestone, which disappear a short distance to the north and east, and are succeeded in these directions and downward by the Silurian system. The drift and the Coal Measures are best studied in their natural exposures, but the Devonian rocks extend below the beds of the drainage valleys, and all the Silurian rocks are wholly concealed. In an account of the rocks explored by these wells the drift and the Coal Measures may therefore properly be omitted.

THE DEVONIAN LIMESTONE.

As known from exposures in this vicinity, the Devonian rocks consist of about 50 feet of shaly limestone, resting on a lower member of a pure white or dove-colored limestone, often brecciated, and variously estimated as being from 50 to 100 feet in thickness.

The thickness of the Devonian strata as exhibited in these wells varies from less than 10 feet to at least 100 feet, as may be seen from the following figures:

Table showing thickness of the Devonian rocks.

	Feet.
1. East Moline, from 551 to 541 feet above tide	10
2. Prospect Park, from 540 to 481 feet above tide	59
3. Augustana College, from 546 to 501 feet above tide	45
4. Mitchell & Lynde Building, from 558 to 498 feet above tide	60
5. Kimball House, from 567 to 467 feet above tide	100

These are all the wells in which the Devonian rocks have been separated from the Niagara limestone, which comes in below. In four of them the Devonian rock consists of the lower calcareous, massive, and brecciated ledges. At Augustana College, at the Mitchell & Lynde Building, and at Prospect Park there is nothing left of the upper argillaceous beds, which lie above the limestone, but in the Kimball House well, and possibly also in the Davenport City Park well, these beds were present.

The thickness of the lower limestone appears to be about 60 feet. It is underlain by dolomite. In the East Moline well this dolomite contained, near its upper limit, a joint of a crinoid stem, such as may be seen in the upper part of the Niagara limestone, where it comes up to the surface only a mile away.

In the drillings from the Kimball House well, now in the collections of the Davenport Academy of Science, fragments in every respect like the Devonian limestone are seen mixed with fragments of dolomitic Niagara limestone, and taken from a depth of 169 feet. The size of the fragments and their association with green clay make it probable that the Devonian rock, if really encountered at this level, was not in situ. It is possible that the fragments have dropped down from above in the hole, but there is some reason to think that blocks belonging to the upper rock may have come down in caverns. At any rate, Niagara limestone was taken out at a depth of 140 feet, and clay was found both above and below this depth in caverns.

Caverns may be seen in almost every quarry in the vicinity, and have been observed and described by several geologists who have examined the rocks of this region. Several if not all of the wells have given evidence of their existence. They appear to be particularly frequent near the contact of the Devonian and the Silurian systems. A shallow well on the river front in Davenport entered a cave at this level. In the Paper Mill well, at Moline, there was an empty cave 28 feet deep entered at 53 feet below the surface. In the well at Augustana College green cavern shale was noticed at a depth of 124 feet. The well at Carbon Cliff had to be curbed over 150 feet down to prevent the walls from caving. At this place the Devonian limestone comes up near by to within 10 feet of the surface. In the Milan well shale is reported as being found in the upper 300 feet of limestone. The top of this well starts in the lower solid ledges of the Devonian limestone, which is succeeded downward by the Niagara limestone.

The best evidence of caverns was seen in the drillings from the well at the Atlantic Brewery. This is only a few rods distant from the quarry where Professor Hall saw caverns in the limestone filled with clay in 1857,[1] and where such caverns may yet be seen, some filled with sandstone, some with clay, and one with a breccia containing large fragments of yellow chert. The uppermost sample from this well comes from a depth of 210 feet and consists of dolomitic Niagara limestone. The next sample was taken 10 feet deeper. Besides some pieces of a porous magnesian limestone and a fragment of a crinoid stem, evidently belonging to the same rock as the sample above, there are several lumps of shale like that in the caverns in the quarry, a piece of yellow chert, and several pieces of sandstone, also like that seen in the caves. Ten feet farther down there is a piece of limestone with a leached surface and a pebble of yellow chert. One-half of the sample is sandstone. Similar material, with green cavern clay, continues down to 270 feet, where the dolomite begins again. The almost invariable association of green clay with large leached and porous pieces of limestone in the borings is readily accounted for as being due to the existence of caverns partly or wholly filled with the clay. As long as the drill works in hard stone everything is pounded into fine fragments, and the harder the rock the finer the drillings will be, but when a cavern is entered the materials yield more readily and the borings accumulate in greater quantity before they are ground fine, and larger fragments are apt to come up in the bucket. Some of these are detached from the very walls of the caverns and show the roughness of surface and change in color due to erosion and leaching.

[1] Geology of Iowa, James Hall, Vol. I, p. 130.

THE NIAGARA LIMESTONE.

In the nearest exposures of the Niagara limestone it immediately succeeds the Devonian limestone downward. It is dolomitic, and the estimates of its thickness for the nearest territory where it comes into view range from 175 to 300 feet. In its upper part it often exhibits an oblique, irregular bedding, is porous, has a dull yellowish-gray color where weathered, and frequently contains casts of fossils, among which stems of crinoids, gasteropods, and brachiopods are most common. This is a source for many windmill wells in the district north and east from Rock Island.

The lower two thirds of the formation is composed of horizontal beds of a compact bluish-gray rock, in which fossils are not numerous. In the lowest 30 or 40 feet nodular layers of white chert occur.

As explored in the wells, this limestone varies in thickness from 276 to 392 feet, averaging 340 feet.

Table showing thickness of the Niagara limestone.

	Feet.
1. Kimball House, from 467 to 132 feet above tide	335
2. Mitchell & Lynde Building, from 498 to 222 feet above tide	276
3. Prospect Park, from 481 to 125 feet above tide	356
4. East Moline, from 541 to 149 feet above tide	392

While the upper irregularly bedded part of this formation generally has a buff color in natural exposures, the samples of drillings from this horizon in the wells are white or even bluish-white, except where there is evidence of the existence of caverns, near which a faint rusty tint appears. In the Prospect Park well this tint prevails, although there are no certain indications of caverns. The porous character of the rock is well exhibited by the drillings from all the places. A thin bed of very hard rock is, however, penetrated in the Kimball House and Prospect Park borings about 250 feet above the base. Traces of fossil mollusks were seen in two cases, and casts of crinoid stems were found in four wells.

In the lowest 200 feet the rock is compact, but not very hard. Dark blotches are seen on the larger fragments. Except in the City Park well at Davenport, no fossils have come up from this lower depth. Pieces of white chert are found in all of the wells, with one exception, in the drillings from the lower 40 feet, and in the Atlantic Brewery well this chert constitutes the greater part of the sample.

THE HUDSON RIVER SHALE.

The thickness of the Hudson River shale (also called Cincinnati shale and Maquoketa shale) has been estimated for different places in Iowa, Illinois, and Wisconsin as ranging from 40 to 240 feet. It is by all geologists described as very variable in composition in the States named, changing from limestone through shale to sandstone. It is sometimes bituminous, and often contains iron pyrites, gypsum, and other substances as accidental minerals. Sometimes it is destitute of fossils, and sometimes it contains them in profusion.

As it has been explored in the wells, the Hudson River shale ranges in thickness from 182 to 265 feet, averaging 223 feet in nine of the wells. It is easily distinguished from the beds above it and below it, and the figures given relative to the dimensions of this shale may be considered reliable.

Thickness of the Hudson River shales.

	Feet.
1. Glucose factory, from 152 feet above tide to 73 below sea level	225
2. Kimball House, from 132 feet above tide to 108 below sea level	240
3. Mitchell & Lynde Building, from 222 to 40 feet above tide	182
4. Atlantic Brewery, from 157 feet above tide to 48 below sea level	205
5. Milan, from 176 feet above tide to 39 below sea level	215
6. Paper mill, from 169 feet above tide to 51 below sea level	220
7. Prospect Park, from 125 feet above tide to 110 below sea level	235
8. East Moline, from 149 feet above tide to 116 below sea level	265
9. Carbon Cliff, from 112 feet above tide to 108 below sea level	220

The lithological characters of the formation seem to be quite constant for the territory explored. Certain features persist for certain horizons in different wells. The upper 120 or 150 feet consist of a light-green or grayish-green shale, which is not at all or but slightly calcareous above, but which becomes a little more calcareous farther down. In the highest 20 feet fine arenaceous material enters as an ingredient in the rock, and fragments of bryozoans and brachiopods occasionally appear in the drillings. For the next 60 feet no fossils have been noticed. A little below the middle of the formation the shale becomes more calcareous and the color turns to gray. At this horizon crinoid stems have been found in nearly every instance where drillings have been taken, and they are associated with bryozoa, which appear in profusion in a sample from the Kimball House well. From this lower fossiliferous bed down to about 20 or 30 feet from the base of the shale pyrites is present more often than either above or below. The lowest part of the shale, from 20 to 50 feet, consists of a dark, occasionally almost black, bituminous shale. Several analyses show that it contains from 5 to 10 per cent of combustible matter. Seen under the microscope, this dark clay exhibits some peculiar brownish-yellow flakes, with an irregular outline and with an uneven surface. These particles are possibly of an organic nature. There may also be seen irregular agglomerations of small spherical grains resembling sedimentary flocculi. These occur throughout the entire shale, but they appear most frequently in the dark shale. Here they are composed of a greater number of particles than in the upper part of the beds.

THE GALENA LIMESTONE.

In Illinois and Iowa the Galena limestone is generally described as a drab-colored, subcrystalline magnesian limestone, and it is estimated as ranging in thickness in these States and in Wisconsin from 209 to 275 feet.

By well drillers this limestone is generally not reported separately from the underlying Trenton limestone. In the Prospect Park well and in the well at the Mitchell & Lynde Building the two have been identified separately, the upper rock being magnesian and the lower a more pure limestone. In the Milan well a change in color of the rock was noticed at the depth where the dividing plane should come in, and this change may perhaps be taken as indicating the contact between the two limestones. In these three wells the Galena limestone ranges in thickness from 200 to 353 feet, averaging 262 feet.

Thickness of the Galena limestone.

	Feet.
1. Mitchell & Lynde Building, from 40 feet above tide to 313 feet below sea level.	353
2. Milan well, from 39 to 274 feet below sea level	235
3. Prospect Park, from 100 to 310 feet below sea level	200

For a depth of about 50 feet from its upper surface this rock appears as a light-gray, granular, dolomitic limestone. Fragments of bryozoa were seen in the drillings from the upper layers in the East Moline well. Below the upper 50 feet, or even a little higher up, the color changes to a shade of light drab or yellow, and this is the prevailing color all the way down to the Trenton rock. With this change there sometimes comes an admixture of fine sand, of grains of pure quartz, and of yellow, red, rose-colored, dark, and greenish quartz. At a distance of about 100 feet below the Hudson River shale some small spherical concretions of a brown color were observed in three wells. They somewhat resembled oolitic spherules. In the Carbon Cliff well a fragment of zinc-blende came from about the same depth. Quite a number of the samples from this limestone contain fragments of chert.

In the lower 200 feet a flow of water is invariably obtained, apparently at different depths in different wells, as indicated in the following table:

Levels of the upper artesian water, below top of the Galena limestone.

	Feet.
1. Glucose factory	165
2. Kimball House	50
3. Mitchell & Lynde Building	300
4. Atlantic Brewery	170
5. Moline Paper Mill	100?
6. Milan	200

The great range of the figures and the variable nature of the Galena limestone suggest that this water is not confined to any limited and well-defined horizon. Most probably it may be tapped at any level where the rock is sufficiently porous. It always smells more strongly of sulphurous gas than the deeper St. Peter water.

THE TRENTON LIMESTONE.

Within a distance of 130 feet upward from the top of the St. Peter shales and sandstone the drillings taken from the wells at East Moline, the Kimball House, Prospect Park, and the City Park in Davenport consist of limestone which promptly effervesces in cold dilute acid, and these samples are believed to belong to the Trenton limestone. The thickness, so far as known, ranges from 90 to 130 feet, averaging 103 feet.

Thickness of the Trenton limestone.

	Feet.
1. Mitchell & Lynde Building, from 313 to 403 feet below sea level	90
2. Milan (brownish limestone), from 274 to 364 feet below sea level	90
3. Prospect Park, from 310 to 440 feet below sea level	130

Chert is present in several of the samples. Grains of sand of various colors are to be seen. In one instance there was a fragment of a fossil. The rocks of this horizon appear to have a pronounced fissility in the direction of the bedding planes. The drillings consist largely of flat flakes, which may be ten times as long and wide as they are thick. The aspect of these flakes is quite unique, and they may be looked upon as characteristic of the rock at this level. It appears reasonable to suppose that these drillings come from such thin-bedded and laminated layers as have been observed in the outcrops of the Trenton limestone in other localities.

In four of the wells the Galena and the Trenton limestones have not been estimated separately, but their united thickness is known, viz: East Moline, 300 feet; Moline Paper Mill, 320 feet; glucose factory, 334 feet; Argillo Works, 358 feet. If the average of these wells, which is at least 328 feet, be averaged with the figures from the wells where the two limestones have been separated, we have 344 feet as the combined thickness of the Galena and the Trenton limestones.

THE ST. PETER SANDSTONE AND ASSOCIATED VARIABLE BEDS.

The accounts of this rock, as it is seen in the nearest outcrops, describe it as a siliceous sandstone, ranging from 10 to 250 feet in thickness. In some places a layer of green shale has been observed separating it from the limestone above.

In the wells here discussed it is found associated with beds of finer sediments above and below, together almost equaling the sandstone itself. In all the borings except one[1] a green shale overlies the sandstone and separates it from the Trenton limestone. Specimens have been examined from three wells, and in all cases it is a green, unctuous shale or clay, only slightly if at all affected by acid. It contains now and then good-sized rounded grains of quartz, a white, tough chert, exhibiting an irregularly reticulated structure on broken surfaces; also considerable pyrites, and lumps of more compact and darker shale. In the Paper Mill well, where the greatest development of this upper shale is reported, it was sandy, and contained "streaks of sandstone."

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[1] Mitchell & Lynde Building. Even in this well the shale may have been found, though not reported, as the record given by Professor Southwell merely gives his own determinations without any description of the nature of the rock.

Thickness of the variable beds above the St. Peter sandstone.

	Feet.
1. City Park, from 370 to 380 feet below sea level	10
2. Glucose factory, from 407 to 437 feet below sea level	30
3. Paper mill, from 371 to 511 feet below sea level	140
4. Milan, from 364 to 394 feet below sea level	30
5. Prospect Park, from 440 to 480 feet below sea level	40
6. East Moline, from 416 to 446 feet below sea level	30
Average	41

The St. Peter sandstone retains its usual character. In all the samples seen it consists of well-rounded grains of mostly clear quartz. In the East Moline well there was a notable admixture of opaque white grains and of reddish and greenish grains. It contains a never-failing supply of water, rising to a level of 650 feet above the sea level.

Thickness of the St. Peter sandstone.

	Feet.
1. City Park, from 380 to 470 feet below sea level	90
2. Glucose factory, from 437 to 479 feet below sea level	42
3. Mitchell & Lynde Building, from 401 to 546 feet below sea level	145?
4. Paper mill, from 511 to 576 feet below sea level	65
5. Milan, from 394 to 484 feet below sea level	90
6. Prospect Park, from 480 to 530 feet below sea level	50
7. East Moline, from 446 to 496 feet below sea level	50
Average	76

A bed of clay occurs again below the sand, but this is more variable than the clay above. In the Prospect Park well it is a green shale, which, as far as explored, is quite similar to the shale above the sandstone. In the City Park well at Davenport some of it is white, some green, and some purple-red. There are also some pyrites and some white and porous chert. Several of the pieces are gritty. In the Paper Mill well a "red marl" was found directly under the sand. In the East Moline well a "red marl" 35 feet thick was separated from the sandstone above by 105 feet of limestone. In this case both the limestone and the "red marl" may perhaps rather be regarded as belonging to the limestone below. But a somewhat similar succession was noticed in the Milan well, and here the resemblance is rather with the sandstone above. In this well 65 feet of "sandy limestone," "sand and limestone with shale and crevices," and "hard and sharp sandstone" follow under the St. Peter sandstone, and then there is a "red marl" 10 feet thick.

Thickness of the variable beds under the St. Peter sandstone.

	Feet.
1. City Park, from 470 to 500 feet below sea level	30
2. Milan, from 484 to 559 feet below sea level	75
3. Prospect Park, from 530 feet to well bottom	20+
4. East Moline, from 496 to 636 (?) feet below sea level	140?
Average	66

THE LOWER MAGNESIAN LIMESTONE.

In its nearest exposures to the north this rock is not known to much exceed 200 feet in thickness. It is described as a light-colored magnesian limestone, with chert and occasional intercalations of sandy and shaly material, especially in its upper part. From some deep wells in Iowa it is reported as being several hundred feet in thickness.[1]

Five of the wells are known to have entered this limestone, and two (really four, counting the several wells at the glucose factory separately) extend through it. Drillings from it have been examined by the writer from only one well, the one in the city park in Davenport. These consist of finely ground white magnesian limestone, with some admixture of sand, chert, and green shale. The records from the other wells describe it as "sandy limestone," "sandy magnesian limestone," or merely as "limestone." In the East Moline well there was a stratum of sand 3 feet thick 60 feet below the top of the limestone, and in the Paper Mill well alternations with shale are indicated for the upper part of the limestone. The rock below the St. Peter sandstone is there described as "red marl and limestone," extending down to 892 feet below the sea level. At this depth there was 121 feet of sandstone (called "Potsdam sandstone"), below which limestone again was encountered as far down as the well extended.

Thickness of the Lower Magnesian limestone.

	Feet.
1. City Park, from 500 feet below sea level to well bottom	503+
2. Glucose factory (one well), from 479 feet below sea level to well bottom	459+
3. Glucose factory (three wells), from 479 to 1,267 feet below sea level	788
4. Mitchell & Lynde Building, from 546 to 1,357 feet below sea level	811
5. Paper mill, from 587 feet below sea level to well bottom	487+
6. Milan, from 559 feet below sea level to well bottom	32+
7. East Moline, from 636 feet below sea level to well bottom	125+
Average (for four wells)	800

THE POTSDAM ROCKS.

The glucose factory wells and the well at the Mitchell & Lynde Building are the only ones which extend below the Lower Magnesian limestone. The writer has not seen any samples from either place. The drillings from the Mitchell & Lynde well were examined by Prof. J. H. Southwell, and he has reported these lowest formations in a more descriptive way than he reported the formations above. The data from the glucose factory wells were furnished by the drillers. This circumstance may perhaps explain some differences between the two accounts. Professor Southwell reports 30 feet of "compact sandstone" lying under the Lower Magnesian limestone. In the other wells there was 40 feet of "shale." The material may have been a somewhat indurated,

[1]See thickness of the Paleozoic strata of northeastern Iowa, by William H. Norton: Iowa Geological Survey, Vol. III, p. 184.

fine-grained, clastic rock, alike in both wells, and verging on the border between the descriptions given, or there may have been a slight change in the bed horizontally. Under this there was in both wells a calcareous rock, 35 feet of "limestone" in the well at Rock Island, and 20 feet of "sandy limestone" in the well at Davenport. Then follow 130 feet of "sandstone" in the former well and 160 feet of "sandy rock" in the latter. In the well at the Mitchell & Lynde Building this rests on 75 feet of "shaly limestone and shale," and in the glucose factory wells there is 51 feet or more of "shale." Below this, again, the former well penetrated 97 feet of "sandstone." The close resemblance of the strata reported from these wells with the Potsdam series in Wisconsin reported by Prof. T. C. Chamberlin may be presented in a table, viz:

Table showing close resemblance of the strata with the Potsdam series in Wisconsin.

	Mitchell & Lynde Building.	Glucose factory.	Wisconsin section.
	Feet.	*Feet.*	
Compact sandstone or shale.	30	40	30 feet Madison sandstone.
Limestone, arenaceous	35	20	35 feet Mendota shale and limestone.
Sandstone	130	160	150 feet sandstone.
Shaly limestone and shale...	75	50+	80 feet shale.
Sandstone	97+	....	300 feet sandstone.
Total penetrated	347	270	

Judging from the position and the succession of these beds, there seems to be good reason to believe that the sections are equivalent. Another circumstance of the same import is the fact that the sandstone is water-bearing, and that the head of its flow is slightly higher than that of the water from the St. Peter sandstone.

In the following table of "thickness of the formations and elevations of the contacts" the main results of the study are presented.

This table is followed by a generalized geological section for Rock Island and vicinity, based upon this study.

Table of thickness of the formations and elevations of the contacts.

	Elevation of the curb above sea level.	Top of the Devonian limestone.	Thickness of the Devonian limestone.	Contact between the Devonian and the Niagara limestones.	Thickness of the Niagara limestone.	Contact between the Niagara limestone and the Hudson River shale.	Thickness of the Hudson River shales.	Contact between the Hudson River shale and the Galena limestone.	Thickness of the Galena limestone.	Contact between the Galena and the Trenton limestones.	Thickness of the Trenton limestone.	Contact between the Trenton limestone and the St. Peter sandstone.	Thickness of the St. Peter sandstone and associated beds.	Contact between the St. Peter sandstone and Lower Magnesian limestone.	Thickness of Lower Magnesian limestone.	Probable contact between the Lower Magnesian limestone and the Potsdam (?) series.	Explored thickness of the Potsdam (?) series.	Average elevation of contacts in each well above (+) or below (—) the averages of each contact in the several wells.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Glucese factory	562					152	225	*73*			[1]334	*407*	72	*479*	788	[2]*1,267*	270+	+10
City Park, Davenport	704	574			[3]357	217						*370*	130	*500*				+45
Kimball House	580	567	100?	467?	350+?	132	240	*108*										—33
Mitchell & Lynde Building	558	556	58	498	276	222	182	*40*	353	*313*	90	*401*	145	*546*	811	[2]*1,357*	367	+26
Atlantic Brewery	577					157	205	*48*										+8
Augustana College	626	546	45	501														
Paper mill	564	557			[3]388	169	220	*51*			[1]320	*371*	216	*587*				+1
Milan	566	559			[3]390	176	215	*39*	235	*274*	90	*364*	195	*559*				+19
Prospect Park	611	540	59	481	356	125	235	*110*	200	*310*	130	*440*	120+					—29
East Moline	579	551	10	541	392	149	265	*116*			[1]300	*416*	220	*636*				—23
Carbon Cliff	592					112	220	*108*										—44
Average				498		161		*68*		*299*		*398*		*550*				

[1] Including the Galena limestone.
[2] Omitted in the averages.
[3] Including the Devonian limestone.

NOTE.—The elevations are all referred to sea level, except in the last column. The figures in italics indicate distance below sea level.

EXAMINATION OF WELL DRILLINGS.

DAVENPORT, IOWA; WELLS AT THE GLUCOSE FACTORY.

[Elevation of the curbs of the wells, 562 feet above tide.]

At the glucose factory in Davenport four wells have been drilled close together, no two wells being more than 250 feet apart. The logs

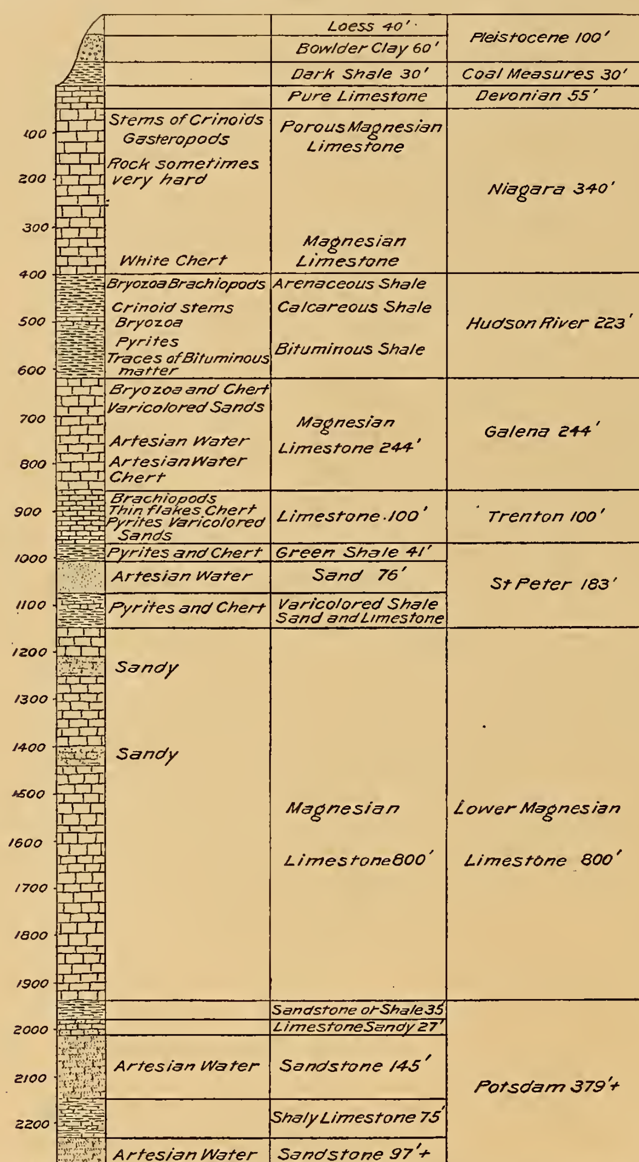

FIG. 74.—Generalized geological section for Rock Island and vicinity, by J. A. Udden.

are reported to have been quite similiar in all four wells. Mr. William Schoendeler, the engineer, has furnished the following record as representing the formations explored in one of the wells: Surface material, 52 feet; bluish limestone, 358 feet; shale, 225 feet; limestone, 334 feet; shale, 30 feet; sandstone, 42 feet; sandy limestone, 530 feet; no record, 258 feet (Mr. Schoendeler thinks the rock in this interval was sandy limestone like that immediately above); shale, 40 feet; sandy limestone, 20 feet; sandy rock, 160 feet; shale, 50 feet.

DAVENPORT, IOWA; WELL AT THE CITY PARK.

[Elevation of the curb, 704 feet above tide.]

Samples of drillings from this well were taken by Dr. A. S. Tiffany, who has published his determinations of the same in the American Geologist, Vol. III, p. 117. This set of drillings is the only one from this locality with samples from the Lower Magnesian limestone that the present writer has examined. It has been in the hands of several parties. The labels are extremely unsatisfactory, owing to the fact that they have been changed, erased, and rewritten in several instances. Uncertain depths are indicated thus (?). The following are the present writer's identifications:

1 (574 feet above tide): Compact calcareous limestone. Devonian.

2 (354[1] feet above tide): Yellowish magnesian limestone, some clay, and some eroded fragments, somewhat porous. Niagara.

3 (324 feet above tide): Large fragments of a porous, light, yellowish magnesian limestone, some fragments with apparently eroded surfaces. Niagara.

4 (304? feet above tide): Gray magnesian limestone, somewhat porous. Niagara.

5 (244? feet above tide): Almost pulverized magnesian limestone, cream-colored. Niagara.

6 (214? feet above tide): Fragments of a sandy gray shale, which have been washed out from the softer body of the shale or clay; a small brachiopod. Hudson River.

7 (54 feet above tide): Dark-gray magnesian limestone, with minute rounded dark and black grains. Galena.

8 (21 feet below sea level): Gray magnesian limestone. Galena.

9 (121? feet below sea level): Yellowish-gray magnesian limestone in fine fragments, and containing rounded minute nodules of pyrites. Galena.

10 (246 feet below sea level): Light-gray limestone, readily effervescing with acids, in fine fragments. Trenton.

11 (321 feet below sea level): Gray limestone, effervescing with acids, in thin, flaky fragments. Trenton.

12 (371 feet below sea level): Green clay, or shale, with some sand and pyrites. Shale associated with the St. Peter sandstone.

13 (376? feet below sea level): Somewhat coarse, well rounded, white sand, with a small admixture of grains of dark, green, and pinkish color. St. Peter sandstone.

14 (376+? feet below sea level): Like the above, slightly more yellowish. St. Peter sandstone.

15 (456 feet below sea level): White, purple, and green shale, in large lumps; some white chert and pyrites. Shale associated with the St. Peter sandstone.

16 (486 feet below sea level): Magnesian limestone in fine fragments, mixed with sand; a large number of fragments of a hard, green shale. The green fragments appear frequently to have been worn round. Lower magnesian limestone.

17 (546 feet below sea level): Like 16, but with a larger admixture of magnesian limestone. Lower magnesian limestone

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[1] Possibly 304 feet.

18 (596 feet below sea level): Same as 17, but finer and with less sand. Lower magnesian limestone.

19 (1,093 feet below sea level): Same as above. Lower magnesian limestone.

DAVENPORT, IOWA; WELL AT THE KIMBALL HOUSE.

[Elevation of the curb of the well, 580 feet.]

Two series of samples were taken from this well, one by Mr. A. S. Tiffany, and one by the curator of the Davenport Academy of Sciences. The samples in each series were taken at irregular intervals. The two sets complete each other. Workmen who were present when the well was made state that the depth of the well is 1,050 feet, the bottom being in sandstone. On a label on one of the samples taken by the curator of the Davenport Academy of Sciences is a note to the effect that a shale 240 feet in thickness began at a depth of 448 feet. Mr. Tiffany reports that the drift was 13 feet deep.

1 (567 feet above tide): Dove-colored calcareous limestone.

2 (500 feet above tide): White calcareous limestone, some few fragments of magnesian limestone.

3 (452 feet above tide): White magnesian limestone in rather large fragments, a few darker pieces, some shale and pyrites, casts of a gasteropod and of a crinoid stem.

4 (405 feet above tide): White magnesian limestone; some green shale.

5 (275 feet above tide): Grayish-white magnesian limestone.

6 (155 feet above tide): Same, in large fragments, with apparently eroded surfaces; also chips of white chert.

7 (132 feet above tide): Pieces of magnesian limestone, of dark shale and of gray arenaceous shale; also of concretions of pyrites, and a joint of a crinoid stem.

8 (15 feet above tide): Shaly limestone filled with Bryozoa; also some pyrites.

9 (*110* feet below sea level): Yellowish-gray magnesian limestone.

10 (150 feet below sea level): Yellowish-gray magnesian limestone, ground fine, a considerable admixture of sand of dark, black, yellow, and rose-colored grains.

11 and 12 (180?[1] and 220 feet below sea level): Yellowish-gray magnesian limestone, with some grains resembling white chert, fragments very fine.

13 (245 feet below sea level): Dull buff-gray magnesian limestone, ground up fine.

The samples taken by the curator at the Davenport Academy of Sciences are:

1 (567 feet above tide): Calcareous limestone.

2 (505 feet above tide): Green clay, with ground-up calcareous limestone.

3 and 4 (501 and 479? feet above tide): White calcareous limestone.

5 (470 feet above tide): Green clay.

6 (440 feet above tide): White magnesian limestone.

7 (411 feet above tide): Large lumps of white calcareous limestone (Devonian) and magnesian limestone (Silurian).

8 (411 feet above tide): White magnesian limestone, ground up fine, also some green clay. A note on the label says: "Hardest yet found."

9 (275 feet above tide): Green clay, with quartz sand.

10 (260 feet above tide): White magnesian limestone.

11 (220 feet above tide): Grayish magnesian limestone.

12 and 13 (180 and 155 feet above tide): White magnesian limestone.

14 to 16 (132, 80, and 40 feet above tide): Dark gray clay; calcareous at 40 feet.

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[1] Label obscure.

17 (90 feet below sea level): Almost black clay, distilling oil, and containing brown microscopic scales of irregular outline; also some rounded black grains.

18 (110 feet below sea level): Gray magnesian limestone, with a buff tinge.

19 and 20 (145 and 155 feet below sea level): Same, with some bluish fragments and some greenish grains.

21 (240 feet below sea level): Magnesian limestone of a faint buff color, with some darker fragments. A number of spherical concretions (?) were observed, ½ mm. in diameter and less, some single and some in groups of two and three. Their outer surface was reddish, and their form resembled that of oolitic spherules.

21a (240 feet below sea level): Magnesian limestone of a faint buff color.

22 (340 feet below sea level): Limestone, with some red and green grains of sand.

ROCK ISLAND, ILL.; WELL AT MITCHELL & LYNDE BUILDING.

[Elevation of the curb of the well, 558 feet above tide.]

Prof. J. H. Southwell was closely watching the progress of the drilling of this well in 1890 and 1893, and he has given to the proprietors of the well the following section of the rocks explored: Devonian limestone, 60 feet; Niagara limestone, 276 feet; Cincinnati shale, 180 feet; Galena limestone, 353 feet; Trenton limestone, 90 feet; St. Peter sandstone, 145 feet; Lower Magnesian limestone, 811 feet; Potsdam rocks: compact sandstone 30 feet, limestone 35 feet, sandstone 130 feet, shaly limestone and shale 75 feet, sandstone 97 feet.

ROCK ISLAND, ILL.; WELL AT ATLANTIC BREWERY.

[Elevation of the curb, 577 feet above tide.]

Specimens of borings were obtained from the proprietors three years after the well was made. The samples were mostly taken at intervals of 10 feet, but the set examined lacks the samples from the upper and from the lower part of the well. Prof. J. H. Southwell, who watched the work as it proceeded, has stated that the upper 150 feet of the hole was chiefly through sandstone. The Devonian limestone has been extensively quarried close by, and it exhibits several caverns, now filled with sand and clay of the Coal Measures. The total depth of the well is in the neighborhood of 1,100 feet.

1 (367 feet above tide): Grayish-white magnesian limestone, in large lumps.

2 (357 feet above tide): Same, porous; also a little shale, white sandstone, and some chert. A cast of a fragment of a crinoid stem was seen in the limestone.

3 (347 feet above tide): Eroded lumps of porous magnesian limestone; cast of a Murchisonia. A large part of the sample was sandstone. A good-sized pebble of yellow flint was observed. It resembled the yellow flint occurring in the basal conglomerate of the Coal Measures seen in the outcrops near by in old caverns.

4 (337 feet above tide): Chiefly sandstone; one dark pebble; some green clay.

5 (317 feet above tide): White sandstone and green clay.

6 (307 feet above tide): White magnesian limestone, sand, and flint pebbles.

7 (297 feet above tide): White magnesian limestone and some sandstone.

8 (287 feet above tide): White sandstone in large lumps.

9 (277 feet above tide): White magnesian limestone, sandstone, and a lump of pyrites.

10 to 12 (247, 217, and 197 feet above tide): White magnesian limestone; some sand.

13 (187 feet above tide): Mostly sand.

14 (177 feet above tide): Mostly white chert; large fragments of dolomite; a few fragments of sandstone.

15 (152 feet above tide): Greenish, slightly calcareous clay, with microscopic spherical grains of quartz. A joint of a crinoid stem was found.

16 (142 feet above tide): Greenish, slightly calcareous clay, with grains of quartz, as above.

17 (127 feet above tide): As above. Bryozoans and brachiopods in calcareous fragments.

18 (117 feet above tide): Greenish, slightly calcareous clay.

19 (97 feet above tide): Same, somewhat lighter in color.

20 (77 feet above tide): Gray shale, with fine sand and pyrites.

21 (67 feet above tide): Gray shale, with fragments of limestone, showing marks of fossils. One joint of a crinoid stem, apparently worn.

22 and 23 (57 and 47 feet above tide): Gray shale, with fragments of limestone and pyrites, traces of fossils. Bryozoan at 47 feet.

24 to 26 (37, 27, and 7 feet above tide): Gray calcareous clay or shale, with lumps of darker material.

27 to 29 (3, 13, and 23 feet below sea level): Gray calcareous clay or shale, with lumps of darker material. Pyrites at 13 feet.

30 (43 feet below sea level): Dark calcareous clay or shale, bituminous, with microscopic brown flakes of irregular shape, and with rounded agglomerations of minute dark particles.

31 and 32 (53 and 73 feet below sea level): Grayish-white magnesian limestone, with scattered fragments of chert.

33 to 45 (83, 93, 103, 113, 123, 133, 143, 153, 163, 173, 183, 193, and 213 feet below sea level): Yellowish-gray magnesian limestone. Green clay at 143 and 173 feet; chert at 153 feet.

ROCK ISLAND, ILL.; WELL AT AUGUSTANA COLLEGE.

A few rods to the southeast of the main building of Augustana College a well has been drilled to the depth of 150 feet. In this well the drift was nearly 50 feet in thickness. This rests on 30 feet of shales of the Coal Measures, a thin coal seam occurring at a depth of 70 feet. Under the Coal Measures there is 45 feet of compact calcareous limestone, identical with the rock in the Devonian outcrops near by. The lowest 25 feet of the well was in magnesian limestone, evidently belonging to the Niagara formation. The elevation of the curb of this well is about 626 feet above tide.

MILAN, ILL.; TOWN WELL.

[Elevation of the curb of the well, 566 feet above tide.]

The drillers of this well recorded the following data, published in the Milan News: Drift, 7 feet; white limestone with some shale, 383 feet; shale, 160 feet; shale with streaks of limestone, 55 feet; brown limestone, 95 feet; white limestone, 140 feet; brownish limestone, 90 feet; shale, 30 feet; sand, 90 feet; sandy limestone, 10 feet; sand and limestone with some shale and crevices, 35 feet; hard and sharp sandstone, 20 feet; red marl, 10 feet; white limestone, 32 feet.

MOLINE, ILL.; WELL IN PROSPECT PARK.

[Elevation of the curb, 611 feet above tide.]

Specimens of drillings have been examined from levels 10 feet apart for nearly the whole depth, as indicated below:

1 (540 feet above tide): Compact calcareous limestone, quartz, sand, and coal.

2 to 4 (510, 500, and 490 feet above tide): Compact calcareous limestone, some pyrites and sand.

5 (480 feet above tide): Compact calcareous limestone and some fragments of magnesian limestone, coal, and pyrites.

6 to 8 (470, 460, and 450 feet above tide): Whitish, straw-colored magnesian limestone, somewhat porous, fragments large. Crinoid stem at 450 feet.

9 and 10 (440 and 430 feet above tide): Grayish-white magnesian limestone, some fragments large and with eroded surfaces, cavern clay. Crinoid stem at 430 feet.

11 and 12 (420 and 410 feet above tide): White magnesian limestone. Cavern clay at 410 feet.

13 to 27 (400, 390, 380, 370, 360, 350, 340, 330, 320, 310, 300, 290, 280, 270, 260, and 250 feet above tide): White magnesian limestone with bluish tinge at 400; large fragments with eroded surfaces at 390; some blue clay at 370; pyrites at 360 feet.

28 and 29 (240 and 230 feet above tide): White magnesian limestone with a yellowish tinge, some large and porous fragments.

30 (220 feet above tide): Same, not porous, a cluster of small quartz crystals.

31 and 32 (210 and 200 feet above tide): Compact white magnesian limestone.

33 and 34 (190 and 180 feet above tide): Grayish-white magnesian limestone, in coarse and porous fragments, with crystals on some surfaces.

35 to 39 (170, 160, 150, 140, and 130 feet above tide): Grayish-white magnesian limestone, with fragments of white chert; green shale at 150; angular quartz grains at 130 feet.

40 and 41 (120 and 110 feet above tide): Buff-gray shale. Brachiopod fragments at 110 feet.

42 (100 feet above tide): Darker-gray shale.

43 to 47 (90, 80, 70, 60, and 50 feet above tide): Gray shale, with pyrites; a few fine sand grains. Color more greenish at 50 feet.

48 to 53 (40, 30, 20, and 10 feet above tide, at sea level, and 10 feet below sea level): Bluish-gray shale, microscopic spherical grains of sand. (?) Fragments of dark limestone at 30 and 10 feet.

54 (20 feet below sea level): Gray shale, octahedral and cubic crystals of pyrites; a fragment of a crinoid stem.

55 to 57 (30, 40, and 50 feet below sea level): Gray shale, microscopic spherules; latter in clusters at 50 feet.

58 to 61 (60, 70, 80, and 90 feet below sea level): Dark-gray shale, with brown microscopic flakes of irregular outline, possibly of organic origin. The shale is bituminous, distilling a brown oil and losing 9 per cent in weight on ignition.

62 (100 feet below sea level): Gray shale, microscopic spherules in clusters.

63 to 67 (110, 120, 130, 140, and 150 feet below sea level): Grayish dolomitic limestone, subgranular.

68 to 80 (160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, and 280 feet below sea level): Yellowish-gray dolomitic limestone. Chert at 210, 260, and 280; lumps of green clay at 270 feet.

81 to 90 (300, 310, 320, 330, 340, 350, 360, 370, 380, and 390 feet below sea level): Slightly straw-colored calcareous limestone, in quite coarse fragments; chert at 380; thin flat fragments at 390 feet.

91 to 94 (400, 410, 420, and 430 feet below sea level): Bluish-gray calcareous limestone.

95 to 98 (450, 460, 470, and 480 feet below sea level): Greenish clay, with rounded sand grains and white chert, occasionally with some pyrites; chert shows reticulated structure at 470 feet.

99 to 101 (490, 510, and 530 feet below sea level): Well rounded pure quartz sand.

102 and 103 (540 and 550 feet below sea level): Greenish clay, with pyrites and some harder rounded pieces.

MOLINE, ILL.; WELL AT THE PAPER MILL.

[Elevation of the curb of the well, 564 feet above tide.]

At the time this well was completed, Mr. W. H. Pratt published in the proceedings of the Davenport Academy of Sciences a record of the strata as given by the drillers. This record reads: Surface soil, 7 feet; Devonian limestone, 113 feet; Niagara limestone, 275 feet; Maquoketa shale, 220 feet; Galena and Trenton limestones, 320 feet; sandy shales and streaks of sandstone, 141 feet; St. Peter sandstone, 65 feet; red marl and limestone, 316 feet; Potsdam standstone (supposed), 121 feet; limestone, 50 feet. At a depth of 53 feet there was a cavern 28 feet deep, and a "strong sulphur water" was reported at a depth of 700 feet.

EAST MOLINE, ILL.

[Elevation of the curb, 579 feet above tide.]

Samples of drillings from this well were obtained from Mr. E. H. Pope, the president of the East Moline Company. These samples were taken at depths indicated below. A written record of the rocks explored was secured from the drillers just after the well was completed. It reads: Drift, 28 feet; limestone, from 28 to 430; shale, from 430 to 695; limestone, from 695 to 995; shale, from 995 to 1,025; sandstone, from 1,025 to 1,075; limestone, from 1,075 to 1,180; red marl, from 1,180 to 1,215; limestone, from 1,215 to 1,275; sand, from 1,275 to 1,278; limestone, from 1,278 to 1,340.

1 (549 feet above tide): Large fragments of compact calcareous limestone, with smaller fragments of the same and of magnesian limestone, all of white color. There was also some green clay and some reddish marly material. A crinoid stem.

2 (179 feet above tide): White magnesian limestone and some greenish clay.

3 (149 feet above tide): Grayish-white shale, with microscopic round grains in irregular agglomerations, one fragment of white chert, and a trace of a fossil. The chert is of the kind found in the base of the overlying limestone.

4 (56 feet below sea level); Dark shale, with bituminous material. It contained microscopic yellow flakes of irregular outline, some pieces of harder and darker material, and some pyrites of iron.

5 (116 feet below sea level): Rusty, gray, subgranular limestone, effervescing slowly with strong acid; Bryozoa.

6 (221 feet below sea level): White magnesian limestone in small fragments, with colorless, greenish, and pink-colored rounded sand grains, and with small, dark spherical concretions.

7 (321 feet below sea level): Dark and buff calcareous limestone, with brachiopods, pyrites, and crystalline calcite. The drillings split into thin flakes.

8 (421 feet below sea level): Green clay, with some darker lumps and pyrites.

9 (471 feet below sea level): Well-rounded quartz sand, with some opaque white, black, green, and rusty grains.

CARBON CLIFF, ILL.

[Elevation of the curb, 592 feet above tide.]

The specimens of drillings from this well were given to the writer by Mr. Milo Lee, proprietor of the Argillo works at Carbon Cliff. This gentleman stated that the well had to be cased 200 feet down from the top to keep the rock from caving in. The total depth of the well is in the neighborhood of 950 feet, and the driller stated that it stopped in limestone. The thirteenth sample was taken at a depth of 600 feet, and on the label of this sample was written the note: "The past 120 feet a dark shale."

1 (442 feet above tide): White magnesian limestone.

2 and 3 (432 and 422 feet above tide): Grayish-white magnesian limestone, with some darker fragments; pyrites at 422 feet.

4 to 6 (392, 292, and 252 feet above tide): White magnesian limestone in coarse fragments; dark fragments at 252 feet.

7 (232 feet above tide): White magnesian limestone, ground fine, and containing some sand.

8 (212 feet above tide): White magnesian limestone, with some gray shale.

9 to 12 (172, 152, 132, and 112 feet above tide): White magnesian limestone.

13 (8 feet below sea level): Green calcareous shale, with some darker fragments, some pyrites, and a joint of a crinoid stem.

14 (88 feet below sea level): Very dark, almost black, calcareous shale, with much pyrites and with thin microscopic yellow flakes of an irregular outline. In the closed tube the material distils a brown oil.

15 to 20 (128, 138, 158, 178, 218, and 223 feet below sea level:) Gray, somewhat granular, magnesian limestone; large fragments at 178 feet; some gray shale and a small fragment of zinc-blende at 223 feet.

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