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FAILURE OF WELLS ALONG THE LOWER HURON RIVER, MICHIGAN IN 1904*

BY MYRON L. FULLER

OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN, FEB. 8, 1905.

To the Honorable the Board of Geological Survey of the State of Michigan:

HON. FRED M. WARNER, PRESIDENT.
HON. L. L. WRIGHT.
HON. PATRICK H. KELLEY, SECRETARY.

Gentlemen:—I herewith transmit, with the request that it be published as part of the annual report of the Board for 1904, a paper by Myron L. Fuller of the U. S. Geological Survey on "Failure of Wells Along the Lower Huron River, Michigan, in 1904." Mr. Fuller is connected with the U. S. Geological Survey and was formerly an employe of this Survey. He is now in charge of the hydrology of the eastern United States. He kindly consented to examine this problem which has occasioned local embarrassment and newspaper comment, and the report is published with the permission of the Director of the U. S. Geological Survey. I asked the especially prompt publication of this report because it has a bearing on proposed legislation.

With great respect I am your obedient servant,

ALFRED C. LANE,
State Geologist.

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INTRODUCTION.

General statement.—In the late spring and early summer of 1904 the shallow wells throughout the region adjacent to the lower portion of the Huron river in southeastern Michigan, which up to that time had yielded abundant supplies of water, showed signs of failing. As the summer progressed the shortage became more severe, making it necessary in many cases to materially deepen the wells in order to secure the water necessary for ordinary domestic and farm purposes. Wide attention was attracted to the failure of the wells in the region because the shortage was supposed to have been brought about through under-drainage by a powerful flowing well on Grosse Isle a few miles to the east. Careful field investigations showed the improbability of such influence, the evidence indicating on the contrary the failure to be due to certain general causes of rather widespread application.

The explanation of the failure of wells in the region in question is similar to that in like districts at many points throughout the country, and it is with the object of calling attention to certain general factors, both temporary and permanent, which tend to induce a shortage of the ground water supplies over large areas that the present paper has been prepared.

Field work and acknowledgments.—The first study of the conditions of the district as made in July, 1904, by Mr. Frank Leverett, geologist, at the suggestion of the State geologist, who made a reconnaissance in the vicinity of Carleton, Flat Rock, Willow and Waltz, determining the general conditions as regards shortage. In August, the shortage still continuing, the writer visited the field and made a more detailed study of the conditions of the wells and of the cause of their failure, the results of which are presented herewith. Acknowledgments for certain geologic and well data are made to Mr. Frank Leverett, and Messrs. A. C. Lane and W. H. Sherzer of the State Geological Survey. Thanks are also due to Mr. James Swan, owner of the Grosse Isle well, and to Mr. Edward Ready and Jacob J. Lucke of Carleton for courtesies rendered.

WATER SUPPLIES OF THE LOWER HURON RIVER REGION.

GENERAL CONDITIONS.

Location of area.—The region in which the shortage of water in 1904 was earliest felt, and in which it was severest, is a belt perhaps 10 miles wide extending in a northwest-southeast direction parallel with and including the Huron river from a point near New Boston, about 20 miles in a straight line above its mouth, to its juncture with the Detroit river, 28 miles from Detroit city. The greater part of the affected belt lies south of the river, only a strip a mile or two in width falling on the north side. To the south the affected area is not only much broader, reaching a width of 7 or 8 miles, but the shortage was more pronounced, reaching a maximum along Swan Creek which parallels Huron river at a distance of from 3 to 5 miles on the south. South of Swan Creek the wells are affected only for a short distance, usually not over 2 or 3 miles.

The belt showing shortage lies in two counties, the relatively narrow strip north of the Huron river being in Wayne county and the wider one south of the river in Monroe county. The villages principally affected are Willow, Waltz, Carleton, Flat Rock and Rockwood. In the portion of the belt east of Rockwood and Newport and between these towns and the lake no shortage was reported up to August, 1904.

Character of country.—The entire region is characteristically flat, and, except in the vicinity of the streams which have cut shallow channels for themselves, almost no inequalities recognizable by the eye are to be seen over large areas. The surface materials are generally clayey, although locally the clay may be overlain by thin sheets of sand, which in places take the shape of low flat northeast-southwest ridges or terraces, representing old beach lines of the lake which formerly covered the region. Although excessively flat the country has a gentle slope southeastward towards Lake Erie, usually not exceeding 5 feet to the mile. The main streams, the Huron river and Swan Creek, flow in the direction of greatest slope to the southeast, while the smaller streams, including the tributaries of the larger streams named, flow either along similar southeast lines or converge slightly towards the main drainage lines.

The region is a populous one. Roads follow nearly every section line and houses are abundant, there being frequently from 10 to 20 to a section. The farms are

correspondingly small, but are under careful cultivation and the owners appear to be prosperous. Three steam railroads and a trolley line give frequent communication with Detroit and afford abundant opportunity for the shipping of produce.

Climate.—The climate of the region is tempered to a certain extent by the proximity to Lake Erie, being, with the exception of the southwest corner of Michigan, the warmest in the State. The average minimum temperature is 39 degrees, the average maximum 57degrees, and the average mean 48 degrees. The rainfall, which is about 30 inches, is low as compared with certain other portions of the state where it may reach to from 35 and 40 inches. (See fig. 1.)

There are, however, considerable areas in which the precipitation does not exceed 30 inches. Normally the rainfall is lowest in January, when it is under 2 inches, and highest in May and June, when it is over 3½ inches per month. About the head of Huron river the rainfall is greater than along the lower part of its course and serves to keep the stream somewhat higher than would otherwise be the case.

GEOLOGY.

SURFACE MATERIALS.

Character.—The materials overlying the rock in the region consist largely of what is locally called clay, but which is more properly a clay with an admixture of sand and pebbles. The materials are not usually arranged in definite layers as in stratified deposits, but commonly exist rather as heterogeneous mixtures, although occasional beds of quicksand or gravel, or even scattered bowlders may occur. In consistency the material is tough and clay-like, and is of a grayish blue color when fresh, but becoming yellowish through oxydation of the iron on exposure to the weather at the surface. Some bowlders occur in the part of the area nearest the Detroit river.

Thickness.—Although the superficial materials have a flat surface, their thickness varies from place to place because of differences in elevation of the buried rock surface which reaches much nearer to the top of the ground in some places than in others. The clayey deposits are from 15 to 40 feet in thickness, 25 to 30 feet being a fair average in the regions back from the streams. The streams, however, have cut their channels into the clay to some depth and may even have cut entirely through it into the rock. Occasionally the rock reaches nearly or quite to the ordinary surface as at the large quarries at Newport.

In a broad way the thickness of the clays may be said to increase as Detroit river and Lake Erie are approached. West of Carleton the thickness, as shown by wells, is commonly about 30 feet. East of that town the depth, though variable, is sometimes as much as 35 feet, while near Rockwood the thickness may be as high as 40 feet.

Origin.—The surficial materials are of somewhat diverse origin. The bowlders and the unstratified materials were derived from the glacial ice which once covered the region, the accumulation taking place under the ice, or very close to its margin during halts in its retreat. The waters at that time stood higher than at present, covering the entire area under discussion, reaching back as far as the base of the hills near Ypsilanti, and in them a portion of the clays and the sand locally covering the surface were deposited as the ice retreated. Ice and water deposition were simultaneous and without sharp lines of demarcation, making it difficult to differentiate one from the other. After the retreat of the ice from the region the waters finally sank, with several halts at different levels, to their present position. During these halts the deposits were subjected to more or less washing by the waves, with the result that beaches were cut in the clay or constructed of sandy materials derived from it. These are the so-called terraces, ridges or beaches extending in a northeast-southwest direction across the region northwest of the area under discussion and between it and Ypsilanti.

ROCKS.

Character of rock surface.—As was pointed out in the paragraph in which the thickness of the surface deposits was discussed, the rock surface is irregular as compared with that of the overlying clays, rising at points until it is within a few feet of the surface and again sinking 20, 30 or 40 feet below it. There are no great inequalities, however, and even if the soil were removed the surface would still be very regular, with elevations rarely rising more than 20 feet above the surrounding level. The irregularities are entirely independent of the present streams, which in the main have been determined in location entirely by the surface deposits.

Nature of rocks.—The rocks underlying the clays in the lower Huron river region consist of limestones, sandstones, shales, etc., arranged in belts extending in a northeast-southwest direction, or at right angles to the course of the Huron river. They are reached by all but the shallow dug wells, and afford the greater part of the ground water found in the region.

Dundee limestone.—In the northwestern portion of the area, or beyond a point a couple of miles northwest of Carleton, the rock is the Dundee limestone, a fairly pure, light colored, flint bearing Devonian limestone of perhaps 100 feet in thickness and dipping northwestward at a rate of 20 to 25 feet to a mile. It is characterized by waters more or less charged with sulphur in the form of hydrogen sulphide.

Upper Monroe beds.—These are drab magnesian limestones or dolomites, sometimes carrying sand, and gypsum and other minerals. The dip is similar to that of

the Dundee limestone. The waters are hard, but are not characterized by much sulphur.

Figure 1. Rainfall map of Michigan.

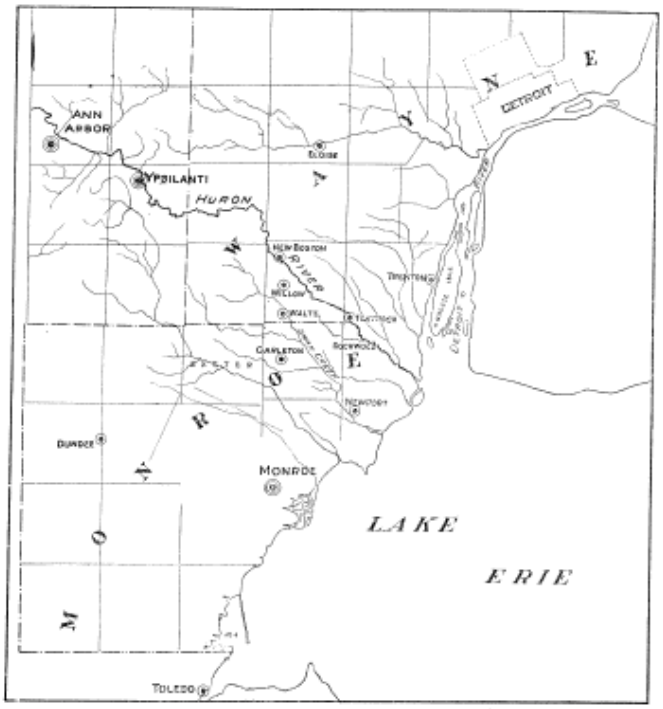

Figure 2. Sketch map of the lower Huron region and vicinity.

Sylvania sandstone.—This is a white sandstone outcropping beneath the clay in the region at a point about a mile east of Carleton nearly to the mouth of the Huron river. The dip is somewhat flatter than either of the preceding and is more to the north than to the northwest. It yields water of a good quality.

Lower Monroe beds.—These are generally similar to the limestones and dolomites constituting the upper part of the Monroe beds already described, but are often more silicious than the latter. They outcrop parallel to the Sylvania sandstone in a narrow belt along Lake Erie and Detroit river. Their waters carry some sulphur.

WATER SUPPLIES.

The conditions as regards water supplies vary considerably throughout the region under consideration, the variations being marked by differences in composition, head, volume, and in the amount of shortage shown in the time of drought. Each of the individual areas will be separately considered.

WILLOW-EXETER REGION.

General conditions.—The term Willow-Exeter region is applied to the area, now or formerly furnishing flowing wells, which extends from the vicinity of Willow southwestward past Waltz into Exeter township, Monroe county, at its northeast corner. The area in this township is mainly included in sections 1, 11, 12, 13 and 14, with parts in sections 2, 10 and 15. The belt lies transverse to the drainage of the region and is located mainly over the outcrop of the Dundee limestone.

Character of wells and water.—There are several types of wells in the district, including dug wells obtaining a very limited supply of non-sulphur water from the clays, the drilled wells passing through the clay and penetrating the rock obtaining strong sulphur waters which will frequently flow at the surface, and a combination of the dug and drilled types uniting the characters of both of the preceding types. Such wells are usually dug about 15 feet, a small drilled hole being continued from the bottom down to the rock, which is usually penetrated for a foot or two. Such wells are particularly adapted to those cases where the water will rise nearly, but not quite, to the surface. They furnish, under such conditions, admirable opportunities for storage and will ordinarily yield much more water than the simple pipe wells, which often show a strong tendency to become clogged when water is most needed.

The depth of the wells varies from about 15 to 35 feet, of which all but a foot or two is usually through the clay. The depth is least at the eastern limits and greatest at the western border of the district. The area has been spoken of as one of flowing wells, but it is generally only at the lower points near the streams, or in sags of the surface, that good flows are obtained.

Condition of wells in 1904.—The portion of the district near Willow was visited on July 18, 1904, by Mr. Frank Leverett, who furnishes the data in the following paragraph:

Extending a mile or more both to the east and west of Willow is a line of flowing wells averaging 60 feet in depth and obtaining sulphur water. They all draw from the same horizon and have always interfered more or

less with one another. The flowing well of Henry Ludwig, on the west side of the N. W. ¼ of section 28, which penetrated 50 feet of clay, etc., with a crust at its base before entering the rock, had a marked effect on the other wells, reducing the head or even, in cases, stopping the flow altogether. The flow of the Ludwig well was as strong as usual in July, however.

The data for the other portions of the district was collected by the writer and are presented in the accompanying table.

CONDITION OF WELLS IN WILLOW-EXETER REGION IN AUGUST, 1904.

Owner	Location.				Depth.	Head		Shortage noted.	Remarks.
	T	R	S	Q		Max.	Pres.		
R. Woodward	5	9	17	sw	16	.....	−8	.....	Type of well in clay. No shortage.
J. J. Locke	5	9	18	se	45	−20	−20	.....	Type of sandstone well. Good water. No shortage.
J. S. Ankerbrandt	5	9	20	nw	21	−10	−17	June	Tiled well. Rody before storm.
Frank Woodward	5	9	20	e	.....	.....	.....	.....	Two wells, type unknown, both dry.
George Burgess	5	9	19	ne	18	−6	−10	not n't'd	Sandstone well. Plenty water left.
Frank Durbeck	5	9	18	sw	33	+0	−12	.....	Plenty of water by pumping.
John Wenzel	5	8	13	se	41	−6	−6	.....	No shortage. Sandstone water.
Jas. Dana	5	8	13	ne	.....	−1	−3	July	Plenty sulphur water. A surface well goes dry every season.
J. Crimins	5	8	13	sw	.....	−3	−3	.....	Sulphur water. Went dry in spring but water returned on cleaning well.
Henry Kingsley	5	8	13	nw	28	+0	−2	July	Sulphur water. Another well still flows.
Edw Navarre	5	8	13	e	.....	.....	.....	.....	Lowered but still plenty.
Frank Oehs	5	8	14	ne	28	±0	±0	1902	Plenty sulphur water but less than before 1902. No recent shortage.
John Theisen	5	9	24	.....	.....	.....	.....	.....	Good flow just struck.
D. Livernois	5	8	14	e	20	.....	.....	.....	No sulphur. Plenty.
F. Mayres	5	8	14	e	30	+3	+½	.....	Sulphur water. No recent decline.
Phillip Zink	5	8	14	e	30	−4	−4	.....	Sulphur water. As much as usual.
F. Mayres (field)	5	8	14	nw	33	.....	+0	.....	New sulphur well.
J. W. Zink	5	8	10	se	37	−8	−8	.....	Always improved by cleaning.
John Murphy	5	8	11	sw	35	+0	−8	.....	Sulphur. Failed once before but flowed again on cleaning.
C. S. Davis	5	8	2	sw	.....	.....	.....	.....	Fresh and sulphur wells. No unusual shortage.
A. W. Dexter	5	8	11	nw	.....	.....	.....	.....	Fresh and sulphur wells. No unusual shortage.
A. Fay	5	8	2	s	.....	.....	.....	.....	Fresh and sulphur wells. No unusual shortage.
M. Vosber	5	8	1	se	32	+4	+3	.....	Sulphur water. Weakened but supply returned on cleaning.
F. Livernois	5	8	1	sw	.....	.....	.....	.....	Stopped at first and permanently weakened by Vosber well. Well of Dan. Fay also weakened.
Wm. Gauss	5	8	12	sw	40	−9	−9	.....	No change. Sulphur water.
Sam Gauss	5	8	12	sw	44	−3	−3	.....	No change. Sulphur water. Surface wells dry.
Jos. Discher	5	9	7	sw	.....	−8	−8	.....	No shortage. Surface wells full.
C. Heinzerling	5	9	18	nw	28	−14	−16	.....	No unusual shortage. Sulphur water.
J. J. Locke	5	9	7	se	22	−3	−18	1903	Sulphur well improved by cleaning Surface wells all right.
J. H. Jewell	5	9	7	ne	.....	+0	−3	spring	Flowed up to May. Sulphur water.

Summary.—An examination of the above table will show the conditions are not uniform. As to the surface wells, several are reported dry, while others report the supply to be the same as usual. No decrease is noted in the wells in the sandstone, and most of the limestone wells (yielding sulphur water) show little if any material shortage, although a few report losses which, in several instances, were returned wholly or in part after cleaning. Some interference exists.

No evidence is afforded by the wells to show that there is any shortage, except such as would always accompany an unusually dry season. The moderate decrease due to drought has not been uniform, but was felt first by the shallower wells, or by those yielding small supplies, and last by the deeper and stronger wells. The difference is naturally generally most noticeable in the flowing wells, in which a difference of a foot or two in head may determine whether it will flow or not. Shortage in previous years is reported.

The head of the water in relation to altitude declines from 622 feet above sea level in the western part of section 14, T. 5, R. 8, to 600 feet near the east line of section 19 of the next township east, or a little over 7 feet to the mile. It would indicate that the source of the supply was to the west, probably in the glacial hills near Ypsilanti.

CARLETON REGION.

The Carleton region is one of non-flowing wells, lying between the Willow-Exeter and the Swan Creek flowing well districts. The wells are commonly about 30-35 feet deep and probably enter the Sylvania sandstone for a few feet from which they get supplies of nearly or quite sulphur-free water by pumping. In general no material shortage was reported in August although the wells were somewhat lower than usual.

SWAN CREEK REGION.

General conditions.—This is a region of flowing wells extending along the valley of Swan Creek from near the Detroit Southern railroad 1½ miles northeast of Carleton southeast to a point about the same distance from the Lake Shore station at Newport. At the north the district opens out and merges with the Huron river and Rockwood districts of flowing wells. The area is mainly over the outcrop of the Sylvania sandstone.

CONDITION OF WELLS IN SWAN CREEK REGION IN AUGUST, 1904.

Owner	Location				Depth	Head.		Shortage noted	Remarks
	T	R	S	Q		Max.	Pres.		
John Coquin	5	9	17	se	33	.....	.....	.....	No decrease. Suggests ditching as cause of shortage in other wells.
Henry Spiser	5	9	20	ne	35	.....	.....	.....	No decrease.
Albert Spiser	5	9	21	sw	30	.....	.....	.....	No decrease in rock well, surface well failed.
Wm. Sillmore	5	9	20	se	30	.....	.....	June	Just to rock (surface well). Failed.
L. Graves	5	9	20	se	37	.....	.....	March	Low, cleaned without result.
J. Lentenschlager	5	9	21	sw	32	.....	.....	.....	18 feet, dug. Water only in pipe.
Sam McLaughlin	5	9	28	ne	.....	.....	.....	June	To rock only Three wells went dry. Little better after cleaning.
Benj. McLaughlin	5	9	28	ne	26	±0	−0	spring	Flowed 30 years ago. Dug 8 feet. Water in pipe only
Frank Bergmoser	5	9	22	sw	22	+0	−0	May	Nearly dry. Always plenty before.
Frank Bergmoser	5	9	22	sw	28	.....	.....	April	Dry. Has failed before.
Frank Bergmoser	5	9	22	sw	27	.....	.....	May	Dug 13 feet. Water in pipe only.
Henry Hood	5	9	21	se	28	−10	−16	Aug	Deepened with success. Another lower well stopped flowing.
Mrs P. Kelly	5	9	28	se	.....	.....	.....	.....	Nearly enough.
Ed. McCormick	5	9	28	se	30	−5	−11	June	Assigns loss to frozen ground and Newport quarry. Well improved by cleaning. No trouble with wells.
B. McLaughlin	5	9	28	se	.....	.....	.....	.....	
Jos. Espir	5	9	32	ne	20	−3	−15	June	Surface well. Ascribes loss to frozen ground.
J. Funerstalk	5	9	27	s	35	−10	.....	spring	Dug 12 feet. Water in boring only.
La Ranger	5	9	35	nw	.....	−4	−4	.....	No change. Large supply
C. Muth	5	9	33	nw	21	−6	−10	.....	Low but still plenty of water.
Geo. Calkins	5	9	35	ne	21	−5	−10	.....	Enters slowly but plenty of water. Ascribes shortage to frost.
Nicholas Noel	5	9	25	sw	14	−12	−13	.....	Surface well. A little less than usual. Two other similar wells in vicinity get plenty of water.
E. H. Van Tassel	5	9	25	se	.....	.....	.....	.....	To rock, no decrease noted.
W. M. Swype	5	9	25	sw	30	−10	−19	July	At bars. Never dry before Drilled wells at house as much as usual.
Wm. Southworth	5	9	25	nw	33	−6	−6	.....	No trouble. One well used to flow.
S. Uden	5	9	.....	.....	.....	.....	.....	.....	On line between secs 24 and 25 Two wells out of three failed.
Peter Bitting	5	9	26	ne	27	−8	−10	.....	Plenty. Another well the same.
B. Parish	5	9	23	s	27	+4	+½	June	In field. Has been low in August of other years.
B. Parish	5	9	23	s	30	−4	−8	June	At house. Has been low in August of other years.
Ed. Parish	5	9	23	s	22	+2	−15	July	Failed suddenly. Three similar wells.
School house	5	9	23	sw	25	+0	−0	May	Run during summer of 1903.
J. McCollum	5	9	25	sw	20	−8	−13	June	Still getting some.
J. McCollum	5	9	25	sw	15	+0	+0	.....	New well near creek.
G. A. Harpet	5	9	22	ne	20	−4	−14	Aug	Very low. Ascribes loss to Grosse Isle well.
Earl Baker	5	9	22	ne	28	−5	.....	.....	Water in pipe only
Tony Kohn	5	9	?	?	.....	.....	.....	.....	Still gets some water.
Chas. Kraemer	5	9	?	?	.....	.....	.....	.....	Still gets some water.
J. Hedger	5	9	22	se	.....	+0	−0	June	Still gets some water.
A. Beardet	5	9	22	se	.....	+0	−0	.....	Lowered pipe. Water now stands just at top.
Eli Barrow	5	9	15	e	.....	+0	−0	.....	Near creek. Well at house also failed
Edw. Whipple	5	9	14	w	.....	+0	−18	June	Plenty by pumping Ascribes loss to Grosse Isle well.
Mark Baker	5	9	15	e	.....	+0	+0	.....	Slight decrease Ascribes loss to Grosse Isle well.
G. Schweitzer	5	9	15	ne	18	−0	−3	.....	Near creek. Well at house also lowered but improved by going deeper.
F. Baker	5	9	14	sw	.....	+0	−0	1902	Less than usual but plenty
D. Reed	5	9	23	n	.....	.....	.....	.....	Dry but got plenty by going 2 feet deeper.
H. Gretchy	5	9	23	n	32	−3	−11	July	Another well at house failed. Plenty on cleaning.
Barnard Parish	5	9	23	ne	33	−7	−12	May	Supply sufficient. Similar well across road.
C. M. Hood	5	9	13	sw	35	−6	−12	.....	More water by deepening. Another well dry
F. Reinhart	5	9	13	nw	35	.....	−12	.....	New well. Old well failed. Ascribes loss to Grosse Isle well.
A Vizard	5	9	13	nw	35	−6	−11	.....	Another similar well. Supply sufficient. A dug well also has water.
J. F. Smith	5	9	12	sw	.....	.....	.....	.....	Enough for cattle.
Henry Geers	5	9	11	se	30	−4	.....	June	Dug 8 feet. Water in pipe only. Very low.
Irwin Barnum	5	9	11	se	28	−5	.....	May	Dug 8 feet. Water in pipe only. Very low.
W. Baker	5	9	14	ne	.....	−8	.....	.....	Surface well. Water by going 7 feet deeper.
Emily Clark	5	9	14	nw	30	−8	.....	spring	Scanty supply.
Fred Reeves	5	9	11	sw	37	−5	−13	June	Got more water by going 8 feet deeper.
C. Shumpmeyer	5	9	11	sw	.....	−6	−13	May	Three wells 32, 33 and 35 feet deep. Nearly dry. Cleaned without success. No previous trouble.
G. W. Reeves	5	9	10	se	.....	+0	−0	1902	Another well just to rock has plenty for ordinary use.
M. Reeves	5	9	10	sw	.....	.....	.....	.....	Near creek. Failed. Always plenty before.
J. E. Brown	5	9	10	sw	22	+0	−0	1902	Failed temporarily in August, 1903, and again in spring of 1904
Floyd Barnum	5	9	16	.....	.....	−5	−15	.....	Cleaned with little effect.
Alex Todd	5	9	9	....	20	+0	−0	spring	Plenty of water by pump.

Character of wells and water.—The wells are of the dug, drilled, or dug and drilled types. Except those of the first type, they all obtain their water on entering the rock after passing through the stiff impervious clays. The wells have hitherto always yielded good flows of

non-sulphurous water. Their depth commonly varies from 20 to 35 feet, according to location, the shallower ones being near the creek in the southern part of the district.

Conditions of wells in 1904.—The data relating to the condition of the wells is most conveniently presented in the form of the table which is given below. Besides the wells of the district proper, or the flowing well area, a number located within a mile or so outside the limits are included.

Nature of shortage.—As in the Willow-Exeter region the behavior of the wells is not uniform. In the Swan Creek region, however, nearly every well shows shortage, the amount varying from a barely noticeable decrease to a complete failure. The surface wells are very uniformly dry, although even here there are exceptions. Some of the artesian wells have stopped flowing, while others, though still running, rise to only a part of their former height. In the non-flowing drilled wells the loss of head is often but a few feet, but some of the drilled wells have entirely failed. In the combination dug and drilled wells the water has generally sunk so low that it no longer enters the dug part. The natural springs which formerly issued in some of the valleys have nearly all ceased to flow.

Suggestions of shortage have appeared several times in past years, a number of wells having previously ceased to flow or gone dry temporarily. The beginning of the present shortage was felt in 1903, but during the fall the supply returned in part, although it was low during the winter, and fell off rapidly again in the spring of 1904. Just what time the failure began can not be determined. No one was looking for a shortage, and it was only when wells began to go dry that attention was paid to their condition, and it was found that an almost universal shortage prevailed.

Supposed causes of shortage.—Nothing could be more variable than the opinions presented as to the cause of shortage. The most general of the explanations attributed the loss of water to subterranean drainage by a deep rock well located at the southern extremity of Grosse Isle and flowing at the rate of a barrel a second. Credit was given to this supposed cause by many who would not otherwise have thought of it because of the fact that one or two of the wells near Rockwood ceased to flow temporarily in the fall of 1903, only to begin again a short time after and to continue until the spring of 1904, when they again ceased. These changes are said to have coincided respectively with the striking of the water vein, insertion of casing, and finally with the withdrawing of the pipe from the Grosse Isle well.

Others, however, see no connection with the Grosse Isle well, attributing the shortage to lack of rainfall, the frozen condition of the ground when the rains of the previous autumn fell, the extensive ditching of the land in recent years and the consequent increase of runoff as compared with absorption, and to drainage by the quarry at Newport. All are possible causes and were investigated with the view of finding the determining factor in the shortage.

Steps taken to increase supplies.—Several methods of remedying the shortage were tried, the first being the cleaning of the wells. In a few of the less serious cases this was effective and the supply returned, at least for a time, but in other cases the cause of failure was more deep-seated and independent of imperfections of the well. In such cases cleaning did but little good and deepening of the well was resorted to. In some cases the dug part was carried a few feet deeper, and, by giving more storage space for the water, afforded temporary relief, but the amount of water was seldom materially increased. The most effective results were obtained by deepening the portion of the well in the rock. Where this was done more water was almost always obtained, although of course it had to be pumped to the surface.

HURON RIVER REGION.

General conditions.—This district extends along the Huron river from a point a mile or two southeast of New Boston, down stream to a point beyond Flat Rock, where it merges with the Rockwood and Swan Creek areas. The rock is largely Sylvania sandstone, except at the northern end of the district. The wells, as in the previous districts, are of the dug, drilled, or dug and drilled types, and range from about 25 to 60 feet in depth. A large portion of the wells flow, or did flow before the present shortage. At the northern end of the district the wells yield sulphur water, but in most of the remaining portions they yield water which is non-sulphur-bearing.

Condition of wells in 1904.—No special investigation was made in the New Boston part of the area this season, but the conditions are reported to be similar to those in the Willow-Exeter field, there being relatively little shortage. Some of the wells have, however, stopped flowing, but this is not characteristic of the present season alone. The well of Gus Miesner in S. W. ¼ of section 9 formerly yielded a flow from a depth of between 60 and 70 feet, but it has now ceased flowing. Near the school house, on the west side of section 15, a well, opened by Mr. Blum, flowed a 4 inch stream of sulphur water when first sunk in 1887, but now flows less than one gallon a minute. The well is 65 feet deep. South of the school house Julius Kahm sank a well in 1891 to a depth of 65 feet. This flowed at the start, but soon after ceased.[1]

In the region between the bridge, 2 miles east of Willow, and Flat Rock, most of the wells are still flowing, although some have ceased. North of the river the Horace Thompson well in the southeast part of Huron township is still flowing sulphur water after a lapse of thirty years, though at a level 1½ feet lower than usual. The depth of the well is 26 feet. In section 26 Mrs. Lawrence has a very weak flowing well of black sulphur water. In the N. W. ¼ of the same section Mr. Stoefflet

sank a well in June, 1904, to a depth of 96 feet, obtaining a full 2 inch stream of water. The well drained others for a quarter of a mile west and north and had to be plugged. South of the river the conditions are very similar, some wells having ceased flowing, while others still continue, though with diminished head.[2]

Summary.—In a broad way it may be said there is a general shortage of water in the region, but not so severe as in the Swan Creek district, for along the Huron many wells still furnish good supplies or even flow, while in the latter region the failure is almost universal. The causes ascribed for the shortage are similar to those of the Swan Creek area, but with less weight given to the supposed influence of the Grosse Isle well. Cleaning, and more especially deepening the wells generally resulted in an improvement of conditions.

[1]Information furnished by W. M. Gregory, August 2, 1904.

[2]Information furnished by Frank Leverett, July, 1904.

ROCKWOOD REGION.

General conditions.—The Rockwood area includes the region west and southwest of that town and between it and the Swan Creek area, together with the region near the town on the north side of the Huron river. It can be considered as merging into the flowing well areas of Swan Creek and Huron river on the west and with the Detroit river region on the east. The area is mainly over the outcrop of the Sylvania sandstone and yields waters generally free of sulphur. The wells are generally from 20 to 40 feet in depth and are non-flowing, except near the Huron river.

Condition of wells in 1904.—In the following table are given data relating to the condition of the wells as determined by the writer in August, 1904.

CONDITION OF WELLS IN THE ROCKWOOD REGION IN AUGUST, 1904.

Owner.	Location.				Depth.	Head.		Shortage noted.	Remarks.
	T	R	S	Q		Max.	Pres.		
D. Valrance	5	8	17	ne	28	—1	—7	May	Has been dry before. Ascribes loss to Grosse Isle well.
H. D. Valrance	5	8	17	ne	30	+3	—30	.....	Pump gave relief temporarily. Ascribes loss to Grosse Isle well.
V. Holmes	5	8	17	ne	.....	+0	—0	May	Water in pipe only.
John Strong	5	8	17	se	.....	+0	+0	.....	Diminished somewhat.
Royal French	5	8	17	nw	30	+0	—30	.....	Plenty by pumping.
Geo. Case	5	8	18	ne	.....	+0	—0	.....	Nothing done.
Jas. Todd	5	8	7	se	36	+2	—36	.....	Failed suddenly after 32 years. No water by pumping. Lays loss to Grosse Isle well. Two other wells have also ceased flowing.
John Antio	5	8	18	nw	30	—2	—8	spring	One fourth ordinary supply
S. Peters	5	8	7	nw	30	—6	—12	spring	Flowing well also stopped.
Chas. Bancroft	5	8	18	nw	31	+0	—8	1903	Two other wells also failed. Came on again during winter. One stopped temporarily during winter. Stopped again in spring of 1904.
Benj. Bancroft	5	8	18	nw	29	—5	—25	.....	Two wells. Not very low in 1903.
G. Van Riper	5	8	18	nw	36	—5	—14	July	Another similar well. No previous trouble. Lays loss to salt and oil wells.
H. Chamberlin	5	9	13	se	36	—5	.....	.....	Water in bore only.
Philip Bally	5	8	18	nw	40	—5	—12	June	Decreased gradually.
Peter Pilkey	5	8	19	nw	40	—2	.....	early	Low all winter. Water in pipe only.
Mattison	5	8	20	nw	.....	—9	—18	.....	Low all winter.
Mattison	5	8	20	nw	.....	—5	—10	.....	Low all winter
P. Donnelly	5	8	19	ne	.....	—4	—17	.....	Lays loss to Grosse Isle well.
Albert Rood	5	8	19	se	22	—10	—14	July	Usually plenty in summer.
John Sigler	5	8	29	nw	22	—3	—12	July	Usually plenty in summer.

Nature of shortage.—The facts set forth show a marked shortage of supplies with many complete failures. Most of the artesian wells had flowed uninterruptedly for many years until they ceased in the summer of 1904, but a few stopped flowing in 1903 when the present shortage first began to be felt. During the winter of 1903-1904 there was a slight increase over the preceding fall, but a considerable number of wells are known to have remained low all winter and one or two stopped flowing. While the flows of the individual wells stopped suddenly, the stoppage was not simultaneous in different wells, but extended over a considerable period of time. The wells in the region have always been somewhat sensitive, as if flowing at or near their maximum head, hence a slight decrease of the head would cause them to stop flowing rather abruptly. Several of the wells have always flowed roily water before storms and some ceased flowing during prolonged periods of westerly winds. The shortage is greatest to the west of Rockwood, becoming less near town as the Detroit river is approached. Many of the wells that have ceased to flow still yield water by pumping, while cleaning and deepening often add materially to the supplies.

Supposed causes of shortage.—The explanations of the shortage are the same as in the Swan Creek area, with special emphasis on the Grosse Isle well and the Newport quarry. On both of these supposed causes, however, opinions are divided, those not believing in their influence being as positive as those favoring such, interference. It was noticeable, however, that the belief in both the quarry and deep well became less firm the nearer they were approached, being held rather by the owners of more distant wells than by those of the nearer ones.

DETROIT RIVER REGION.

This region includes the area between the Rockwood district and the shores of Detroit river. The region is low, being only a few feet above the river and lake level, and along the shore and creeks is often decidedly marshy. The region is, however, quite thickly settled and wells are abundant, but probably averaging under 20 feet in depth. In general there has been no trouble with shortage of water, although in a few instances the water was thought to be a little below its maximum summer level. No particular cause of shortage was advanced other than a general belief that the numerous salt and other wells might have had some effect. It is probable that in reality the water was as high or higher than is ordinarily the case, as Lake Erie, which controls the groundwater level adjacent to its shores, stood about 15 inches above the normal in the summer of 1904.

WATER SUPPLIES OF GROSSE ISLE.

General conditions.—Grosse Isle is a north-south island about 9 miles long and 2 miles wide lying on the American side of the international boundary in the Detroit river, its center being opposite the town of Trenton, 16 miles south of Detroit. The population is mainly located along the shores of the island, only one or two houses being situated in the interior, notwithstanding the entire island is under cultivation. The surface is mainly clay or clayey silts, but rock is

commonly found not far from river level and in one point, where it rises slightly higher is quarried.

Very few wells have been sunk on the island, the main supply being from pipes extending out beneath the surface to deep water in the river. The water is pumped directly from these pipes by means of wind mills, no provision being made for filtering. There is some typhoid on the island. The few wells that have been sunk in the interior penetrate clay to the rock, which is entered at about 20 feet. The water of the dug wells is from the clay, but the drilled wells enter the rock and obtain an iron-bearing water carrying some sulphur. No shortage was reported in 1904, and no one had observed the slightest effect due to the big well at the southern end of the island.

The "Grosse Isle" or "James Swan well."—This well is located on the property of James Swan opposite Snake Island, about three-quarters of a mile from the extreme southern point of Grosse Isle, and was 2 or 3 feet above the level of the river in 1904.

The well, which was sunk in search of oil or gas, was begun in 1903 and completed in May, 1904, having reached a depth of 2,375 feet without obtaining anything of value. The diameter at top is 10 inches, decreasing to 6 inches at the bottom. A 13-inch casing extends from the surface to the rock at 17 feet.

The first considerable flow of water was encountered at 420 feet but at 450 feet a bigger flow was obtained. Both were fresh, but as the well was drilled deeper flows of sulphur water were encountered, which, although relatively small, were sufficient to impart a considerable amount of sulphur to the water as it issues from the pipe, which is recognizable by taste and sulphur deposit on the grass and stones about the well.[1] The water is said to have been cased off during the progress of the drilling from August, 1903, to May, 1904, when the casing was finally pulled. At present the water issues in a jet 11 inches high from the 13-inch pipe, forming a fountain of considerable size. (See plate I.) The flow is calculated at about 50 gallons per second and forms two sizable streams as it flows away from the well. The water was tested to a maximum height of 22 feet above the surface. It is stated that the owner contemplates using the water for a public supply for the island.

[1]In the analysis as given all the sulphur is reckoned as SO^3. There are soluble sulphides as well as H^2S present, but so far it has proved impracticable to separate them. L.

REPORT OF ANALYSIS

MADE AT THE CHEMICAL LABORATORY, UNIVERSITY OF MICHIGAN FOR THE STATE GEOLOGICAL SURVEY JANUARY 17, 1905.

Samples marked Grosse Isle water, James Swan's well.
Sampled and analyzed by F. K. Ovitz.

ANALYSIS

Constituents.	Grams per litre.
Silica	0.188
Calcium oxide	7.616
Strontium oxide	0.376
Magnesium oxide	1.212
Sodium oxide	0.292
Potassium oxide	0.112
Sulphuric anhydride	11.871
Chlorine	0.248
Carbon di-oxide	1.550
Iron and alumina	0.014
Loss on ignition	2.006
Total solids	23.972

DECLINE OF THE WATER SUPPLIES OF THE WELLS OF THE LOWER HURON RIVER REGION.

PRESENT CONDITIONS.

The conditions of the walls at the present time have been described in detail in the preceding pages. With the exception of the narrow belt along the shore of the Detroit river, where the supply is largely governed by the height of the river, the loss of supply has everywhere been felt in varying degrees. In the Willow-Exeter and Carleton regions the shortage is very slight, while along the Huron river it is only moderate. In the Swan Creek and Rockwood regions, on the contrary, the shortage is excessive, a large prorportion of the wells going dry and entailing much inconvenience.

BEGINNING OF THE DECLINE.

The present season does not mark the beginning of the decline, but rather its culmination. Investigations made by Prof. W. H. Sherzer previous to 1900 showed that even then shrinkage of supplies had been in progress for many years. In his report on Monroe county* he states that while continued drought makes no impression on many of the wells, the flow of others is reduced, or almost or quite stopped. The opening of new wells was found to affect the flow of others in the neighborhood, and the areas over which artesian waters could be secured was found to be becoming constantly more contracted. Wells in the southern part of Erie township back 3 miles from the lake, which formerly flowed, had then ceased.

The decline noted by Professor Sherzer as having already progressed for some time has continued to the present time. The areas of flowing wells outlined by him on his maps at that time are more extensive than those at the beginning of 1904, while by the close of the summer of that year very few flowing wells remained in some of the regions, as in the valley of Swan Creek and near Rockwood.

Not only have the artesian wells ceased to flow, but the water in the non-flowing wells is lower than formerly. In fact, the level of the groundwater in the clayey portions of southeastern Michigan is distinctly lower than it was ten years ago, and much lower than it was twenty years ago. It is only in a limited district that the pronounced falling off occurred during 1904.

The general decline which has been going on for many years is probably due to a gradual and far reaching change of conditions, the nature of which will be considered on subsequent pages, but the rapid decline of the last two seasons is doubtless due to local causes acting with special force in the region in question.

*Geol. Surv., Mich., Vol. VII., Pt. I., pp. 194.

SUPPOSED CAUSES OF THE DECLINE.

THE GROSSE ISLE WELL.

It is this well which has most frequently been assumed as a cause of the shortage of water in the region under discussion. That it can not be the sole cause is readily shown by the fact that the decline had been going on for many years before its sinking in 1903. That it might be the cause of the special decline in that and the following year did not, however, appear unlikely at first, a special argument being afforded by the behavior of the wells of J. E. Brown of the Swan Creek and of Chas. Bancroft and others of the Rockwood district, which went dry when the big flow of the Grosse Isle well first began in 1903, but returned coincident with the insertion of the casing, only to cease again after its withdrawal in May, 1904. There are, however, many facts which seem to show that the shortage has no connection with the Grosse Isle well.

DISTRICTS AFFECTED.—The investigation made by the writer showed, as has been described, that while wells in the Swan Creek and Rockwood districts ceased flowing or failed to yield their usual supplies, other wells much nearer Grosse Isle maintained nearly their usual flow, those nearest, even those on Grosse Isle itself, showing no decrease whatever. The conditions of underground drainage would need to be very exceptional, which would leave a nearby district unharmed, while seriously affecting more remote districts.

SLOPE OF WATER TABLE.—With a view of determining the source of the water of the Swan Creek-Rockwood area, the head, or height to which the water would rise, was plotted for each well in the region. It was found that this head showed an increase going west at a rate averaging about 3 feet per mile, indicating a source in the hilly region to the northwest. The increase of head to the west or decrease to the east was regular, there being no local lowering with a reversed slope downward towards the rock, such as would be present if water was being drawn down into the latter through a fissure connecting with the stratum furnishing water to the Grosse Isle well. (See Fig. 3.)

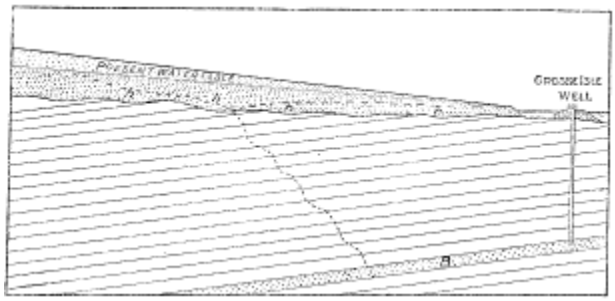

Figure 3. Ideal section across Grosse Isle and the mainland.

B is the previous water bearing bed from which the Grosse Isle well draws, and the line *h h h* shows the sort of form the water table should take were the surface strata connected therewith by the fisure shown by the dotted line leading down to *B*.

GEOLOGIC STRUCTURE.—The precise point where the main water-bearing bed of the Grosse Isle well outcrops and where its supply of water is derived can not be stated. The rocks incline regularly to the northwest (or rise to the southeast) at a rate of perhaps 20 feet to the mile. On the basis of this dip it would seem probable that the water bed, which has a depth of 450 feet at the well, would come to the surface somewhere west of Leamington, Ontario. In the Huron river region, however, it would be even deeper than at the well, probably in the vicinity of Carleton, being nearly 800 feet below the surface. The chance of there being any fissure through all this thickness of strata, by means of which connection between the deep water beds and the surface wells might exist, is very improbable. On the other hand water can pass downward along the bedding planes with the greatest ease. Such is probably the case, the water being derived from the Ontario region rather than on the American side of the river.

VOLUME.—A strong impression is left on the mind of one visiting the Grosse Isle well by the immense volume of its flow, which is calculated to be between 45 and 50 gallons or over a barrel a second. When, however, it is recalled that the region in which the failure of the wells has been attributed to the Grosse Isle hole has an area of over 100 square miles, it will be seen that the amount which could be taken each second per square mile is not over half a gallon, or less than a thousandth part of a gallon per acre. The amount ordinarily taken from a square mile by the flowing wells of the Swan Creek and Rockwood districts was much more than this, in fact the taking of a thousandth part of a gallon per acre each second would probably not have a noticeable effect on the flows.

HEAD.—The most convincing reason why the Grosse Isle well can not have affected the Swan Creek-Rockwood wells lies in a comparison of the heads of the water in the two localities. The head of the Grosse Isle well is 25 feet above lake level, or approximately 597 feet above sea level, while that of a considerable number of the Swan Creek and Rockwood flows is less than this amount. In other words, the head of the Grosse Isle well is greater than many of the wells under discussion, and the water, if any connection existed

between the two, would not be drawn from the shallow wells, but rather forced up into them.

SUMMARY.—The evidence at hand gives no indication of any connection between the shortage of the shallow wells and the flow of the big Grosse Isle well, but affords on the other hand many indications that such is not the case. The supposed connection with the Grosse Isle well of the loss of water in the Brown and Bancroft wells in 1903 is the result of mere coincidence, the failure simply happening to take place at the height of the dry season of that year. That they should have failed in the still dryer season of 1904 was to be expected. The conditions were almost ceratinly local, as other wells in the vicinity were not similarly affected at the same time.

NEWPORT QUARRY.

The under-drainage caused by the quarry was, next to the Grosse Isle well, most commonly advanced as a cause of the shortage along Swan Creek. A visit was accordingly paid to the locality and the conditions investigated.

The quarry is located just east of the tracks of the Lake Shore and Michigan Southern railroad at Newport and a few feet north of Swan Creek. The quarry is 200 to 300 feet across and is excavated to a depth of 18 feet in the limestone, which is reached after 10 or 15 feet of stripping. The creek flows on top of the rock surface, 18 feet above the bottom of the quarry, and is separated from the excavation by a small dike. Water enters at various points in small amounts, but is easily removed by pumping at a rate of about one-half a gallon a second.[1] A part of the wells near at hand have been affected, but the decrease in the water supply is not universal even within a few hundred feet of the quarry. A quarter of a mile back no effect has been noted.

The small amount of water entering the quarry is in itself an indication that no extensive area is being drained, while the fact that only a part of the adjacent wells are effected while those a short distance away are unaffected, shows that even in its vicinity, the quarry may be neglected as a factor in the shortage of the water supply.

[1]Four inch pipe, one-half full, but ejected with slight force.

DEFORESTING THE LAND.

The existence of forests in a region, while not affecting the amount of water falling on the ground, tends to prevent its escape into the streams with the rapidity with which it runs off of non-timbered lands. By holding it back, even for a few hours, considerable greater quantities are allowed to soak into the ground than would otherwise be the case. Evaporation from the surface is also retarded, the ground remaining wet for much longer periods in wooded than in unwooded lands. The cutting of the timber must, therefore, be accepted as a factor in the general decrease of the supplies of the region, but was effective only in the earlier days. It can not be considered as one of the immediate causes of the sudden shortage of 1903-4.

DRAINAGE BY DITCHES.

The region under discussion is exceedingly flat, and because of its clayey soil and poorly developed stream systems was originally poorly drained, the low sags often holding water or remaining wet for long periods. All this has been gradually changed through drainage by ditches, with the result that much land has been reclaimed. The process, however, has not been without its drawbacks, for the ditches rapidly carry off much of the water which had previously soaked into the ground to become a part of the groundwater body. The result has been a gradual depletion of the groundwater especially within the past few years, so that the beginning of the present drought found an inadequate reserve supply in the ground.

DRAINAGE BY STREAMS.

The level of streams generally determines that of the groundwater in their vicinity, the latter subsiding as the streams fall. During 1904 both Huron river and Swan Creek were unusually low and thus drew unusual quantities from the surrounding water table, which was thereby naturally lowered. The Huron river, being a longer stream, and one having its source in a region of greater rainfall, was not so low as Swan Creek, the entire course of which falls within an area of low rainfall. Moreover, the latter, flowing over clay nearly destitute of water, receives in considerable portions of its course only slight additions by percolation. It is probably for these reasons that the shortage is most marked along its course rather than in any other part of the region.

EARLY FROST OF 1903.

This appears to have been an important factor in bringing on the present acute shortage. According to the official records the permanent freezing of the ground took place on November 17th, which was before the heavy autumn rains had fallen. There was, therefore, little chance for the rainfall to soak into the ground during the winter and spring months. This was made manifest by the low water in many of the wells during the winter, the result being that when spring opened the groundwater was at an unusual low stage.

DEFICIENCY OF RAINFALL IN 1904.

Because of the fact that the ground was frozen during the autumn and winter the ground was in much the same condition at the opening of the spring of 1904 as it was at the end of the preceding summer, and as month after month during the present summer went by with deficient ranifall the shortage began to be severe.

The shortage of rainfall is brought out by the following table which gives the precipitation by months for 1904. Detroit lies about 25 miles northeast of the area, Dundee about 20 miles southwest, Eloise less than 15 miles north, and Ypsilanti 20 miles northwest.

The low rainfall, which in the spring of 1904 varied from half to somewhat more than half of the usual amounts at the stations in the table was, on the whole, even less in

the lower Huron river region itself. The deficiency of rainfall following as it did an autumn and winter during which little water was absorbed, owing to the frozen condition of the ground, and back of that the dry season of 1903, is ample to explain much if not all of the observed shortage.

RAINFALL IN THE VICINITY OF THE LOWER HURON RIVER REGION IN 1904.

Month.	Detroit.		Ekise.		Dundee.	Ypsilanti.	
	Actual.	Normal.	Actual.	Normal	Actual.	Actual.	Normal.
	In.	In.	In.	In.	In.	In.	In.
January	3.34	1.94	3.98	1.69	5.37	4.54	1.90
February	2.55	2.33	00	2.16	4.06	2.98	2.46
March	4.09	2.20	00	3.01	5.45	4.92	2.45
April	1.65	2.24	1.01	1.32	2.36	1.66	2.24
May	2.36	3.51	1.19	3.27	3.06	2.58	4.09
June	1.08	3.09	.79	3.26	1.30	.56	4.25
July	2.94	3.36	2.32	4.16	2.84	3.03	3.33
August	3.20	2.71	3.69	1.65	4.73	3.92	2.14
September	4.23	2.47	3.83	2.61	4.20	6.21	2.86
October	.86	2.53	00	2.61	.82	1.09	2.64
November	.19	2.60	00	2.38	.05	.09	3.23
December	1.83	2.57	1.88	2.23	2.53	1.96	2.38

Although considerable rain fell in July, and even more than the normal in August, it came largely as short heavy showers, and the water instead of soaking into the ground, as in more gentle rains, formed streams and ran off rapidly. The part that soaked into the ground was entirely insufficient to compensate for the many dry months which had preceded, especially as the relatively wet months of August and September were followed by several months when almost no rain fell.

SHORTAGE IN OTHER REGIONS.

While the shortage was made manifest in the lower Huron region much sooner than elsewhere, later in the summer the drought became severe throughout all the states bordering the Ohio and eastward to New England, and much trouble and inconvenience were the result. In the other regions the failure was due simply to the shortage of rainfall, the complicating conditions that were present in the Huron region and served to make the scarcity of water more severe being absent.

CONCLUSIONS REGARDING SHORTAGE.

No evidence was found to show that the Grosse Isle well had affected any of the wells whatever, nor that the Newport quarry was a factor in the failure of wells other than those situated within a few hundred feet of it. The deforesting of the region has been a factor in the general decrease of supplies in the past, but had no immediate connection with the present shortage. The ditching of the region was a prominent factor in the gradual depletion of the groundwater body so that when the usual fall rains were prevented by frost from being absorbed and the winter was followed by a summer of exceptional drought, the conditions were ripe for the failure of water which followed.

FUTURE PROSPECTS.

The failure of the wells being due largely to the severe drought of 1903-1904 it is probable that the return to the normal rainfall will result in an increase in the water supply, although, because of the excessive dryness of the ground, the increase in the available water may not be immediately noted. The full supply may not return until a wet year, or perhaps a succession of wet years occur.

In some cases the return of the water may not bring restoration to the wells, for water passages in clayey materials when dried out may, to a certain extent, crumble and become more or less clogged, so that their capacity for carrying water is lessened or destroyed even when the ground again becomes soaked. The return in any case will probably not be complete, as the thorough ditching which the region has undergone will result in a permanent lessening of the water supply of the region.

REMEDIES.

The wells in the lower Huron river region obtain their supplies in the upper few feet of the rock. The water, judging from its head, is derived from glacial deposits overlying the rock in the region northwest of the area under discussion. It probably traverses the upper more or less jointed and open portion of the rock because there is less resistance to its flow through such crevices and openings in the rock itself than through the compact clayey deposits which generally overlie the rocks of the region. In its passage the water takes up sulphur and other mineral matter contained in the rock, its quality thus being changed from its relatively pure condition when it left the drift.

It has been shown in the discussion of the wells of the region that deepening has almost invariably met with at least partial success, especially where the wells have been sunk deeper into the rock. Throughout the entire region, however, the wells are unusually shallow, even for the surface type, a depth of 50 feet being exceptional. In many other regions in Michigan nothing is thought of going 50 to 100, or 150 feet in search of water. It is almost certain that wells of such a depth would in the lower Huron river region yield permanent supplies. Until such wells, or at least wells entering some distance into the rock, are sunk a supply adequate to the demands in times of drought cannot be expected.

DESIRABILITY OF LAWS REGULATING DEEP OR ARTESIAN WELLS.

GENERAL STATEMENT.

The desirability of regulating the use of a commodity belonging in a sense to the public at large is very generally recognized. This has been especially true of petroleum and gas, many states having stringent laws against their waste. Regulations governing the casing of wells in use, the plugging of wells about to be abandoned, and forbidding the free flow of gas, are to be found among the enactments in most states in which such commodities are found and have been of much assistance in securing a more intelligent management of wells and the husbanding of their products.

Water, even to a greater extent than oil and gas, can be regarded as a public commodity, and although its value is less than either of the former, it is nevertheless an important factor in many businesses. Because of the excessive cost of the deep water wells, which is as great as those sunk for oil and gas, the obtaining of large amounts is, however, even more essential. The great importance of obtaining cheap supplies will be appreciated when it is recalled that among the competitors of almost every manufacturing establishment there will always be some who will be able to obtain abundant supplies of the best quality at almost no cost above that of pumping.

Moreover, the occurrence of groundwater can no longer as formerly be regarded even at law as anything mysterious, there being at the present time many geologists and engineers familiar with its occurrence and the character of its movements. For this reason it should be entirely possible to make intelligent regulations by legislative enactment for controlling its use and preventing its waste.

LIMITATIONS TO AMOUNT OF GROUND WATER.

Percentage of absorption.—The rainfall throughout the United States is said to average about 30 inches per annum, that of Michigan being from 30 to 35 inches. Of this, however, not all is absorbed by the ground, large portions being carried off by the streams, or removed by evaporation. The actual amount absorbed by the ground is probably but a very few inches.

Availability of groundwater.—Groundwater occurs under a great variety of conditions which have an intimate relation to its availability. It may occur in the pores of open sands or sandstones, in cavities in limestones, along bedding planes of slates, and in fissures in any of the consolidated rocks. In sands, or in sandstones and other similar rocks, the body of the material is saturated as a sponge, and a well penetrating it at almost any point will obtain a supply. In the case of cavities, bedding planes, or fissures, the water is likewise given up with ease when encountered, but, because of the fact that it occurs only in a limited number of openings, the position of which can not be predicted, failures frequently result, and the supplies when found are generally of less volume and permanency than in the sandy beds. Notwithstanding the density of clay much water is contained in it. This, however, because of the fine grain of the containing material, is held firmly instead of being given up readily to the wells as in the case of other materials. In fact a well may penetrate a clay containing a high percentage of water and yet be able to obtain hardly a drop. The same is true of certain of the finer quicksands, but for another reason, in the latter cases the material being so fine that it unites to form a mixture with the water which soon clogs the wells, and from which the water can not be separated. Much of the water which penetrates the rocks is carried to too great a depth to be reached by ordinary wells.

From the above it will be seen that even the small quantity absorbed by the soil or rocks is still further reduced by the amounts held in clay and similar material, by the amounts entering the deep lying rocks, and by the frequently localized nature of the occurrence of the water, as a result of which wells can be obtained only at certain favored spots.

Supply not inexhaustible.—When a single well penetrates a thick, porous water-bearing bed the supply may be equal to the maximum capacity of the well, but as other wells are sunk the demand rapidly increases and soon becomes greater than the supply, the wells showing the effect of shortage by a decrease in this volume or by a lowering of their head. This is well illustrated by the wells of the Chicago area. When the first wells were put down to the Potsdam sandstone the flows were large, the water rose as high as 80 feet above the surface, and the supplies appeared inexhaustible. As the wells multiplied, however, the amount obtainable by each became much less and the heads were so reduced that the wells rarely flowed. The same has been true of many other artesian districts; in fact, it may be laid down as a general law that no pool is inexhaustible. On the contrary each pool has a definite volume from which every well takes just so much, thereby diminishing the total available supply.

Replenishment of supplies.—The groundwater supplies are replenished from rainfall. When the wells drawing upon the underground supplies are few in number the water may be replenished as fast as it is removed by the wells, but when the number of wells is large the replenishment does not keep pace with the withdrawal. The replenishment is not altogether a question of rainfall, many other factors entering into the question, among which the conditions at the outcrop and the rate of water movement are the most important. The last is of great importance for if the rock be sufficiently

fine-grained the water will enter and move but slowly, even though the outcrop be constantly covered by water.

Danger from the free flow of wells.—The water in the rock represents the accumulation of years, and a well may draw off in a few hours water which it took months to get together. It is like pulling the plug out of the bottom of a barrel into which a stream of water is running, to allow a well to flow freely. Of course the only value of water lies in its availability for the use of man, and its employment for all legitimate purposes should be encouraged. It is only the useless waste of supplies that may soon become of great value that should be forbidden. Artesian water should no more be allowed to run to waste than should a young growth of timber be allowed to be burned simply because it does not at the present moment happen to be marketable.

Danger from improper casing.—In the same way that waste may take place from the free flow of a well at the surface, water from an underlying stratum may if the well is uncased rise and pass off laterally into an overlying non-saturated layer. In the same way the water from an upper stratum may pass downward and be absorbed by a lower stratum. In either case the loss is a real one, as real as if it had taken place at the surface, for the result is that the confined water, which from the very fact of its confinement furnishes the most ideal conditions of supply, becomes dissipated through a large amount of material, in no part of which is it probable will it be present in economic amounts.

SUMMARY.

Groundwater is properly a commodity belonging to the public at large, and is an asset of recognized value. The amount is not unlimited at any point, and any decrease in its volume means a reduction of assets and a permanent loss to the community. It is difficult to prove damages to surrounding wells caused by free flows, but when it is remembered that the underground supply is limited in amount, and that the available supply is being constantly decreased by such flow, it is readily seen that the loss is none the less real. A freely flowing well is in itself a proof of such loss, and should be forbidden, except where reasonable use is made of it.

RECOMMENDATIONS.

(1) An enactment should be passed making it unlawful to permit water to escape where no use is made of it regardless of the size of pipe or volume of flow, and a penalty should be fixed for its infraction.

(2) An enactment should be passed making it obligatory in case of abandoning a well over two inches in diameter to securely plug it above and below each water horizon, or to fill the hole with cement or other impervious material, with a penalty fixed for its infraction as before.

(3) An enactment should be passed requiring that wells when not in use shall be closed down until not more than an inch stream is flowing, a penalty to be attached for infraction as before.

(4) Provision should be made for restraint of flows by injunction on application of parties presenting evidence of waste.

(5) The power of entering private property for the purpose of determining questions relating to waste should be given to the proper officials.

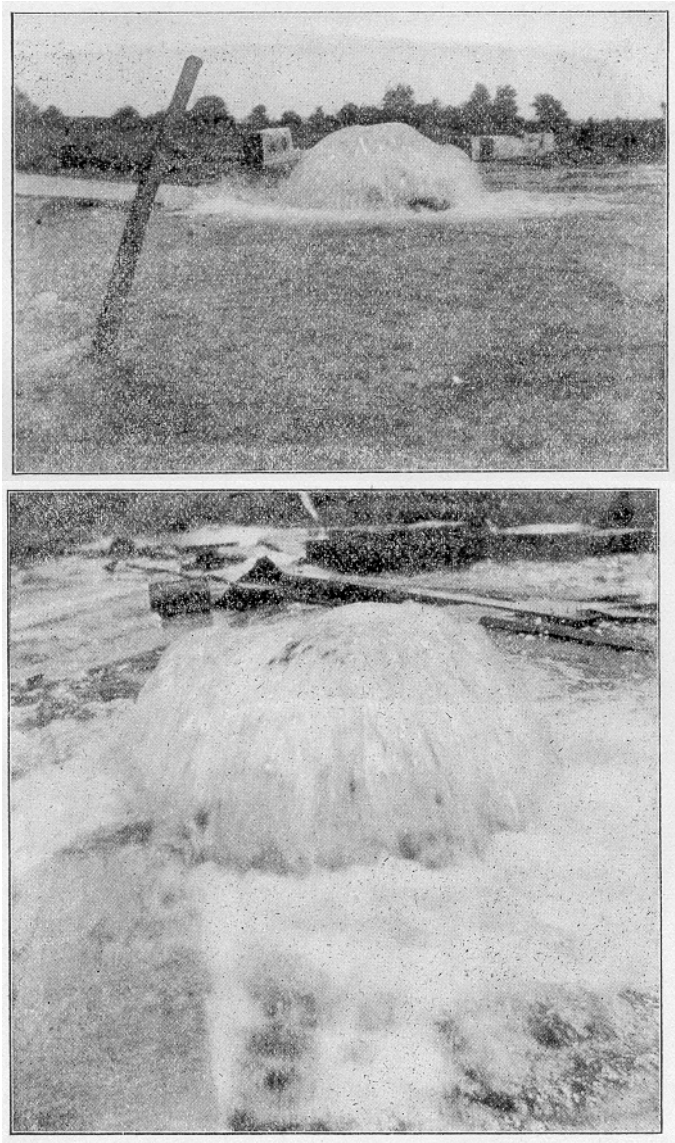

Plate I. Views of the flowing well at Grosse Isle.

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