TREASURY DEPARTMENT

Public Health and Marine-Hospital Service of the United States

HYGIENIC LABORATORY—BULLETIN No. 83

MARCH, 1912

SEWAGE POLLUTION OF INTERSTATE AND INTERNATIONAL WATERS

WITH SPECIAL REFERENCE TO THE SPREAD OF TYPHOID FEVER

II. LAKE SUPERIOR AND ST. MARYS RIVER
III. LAKE MICHIGAN AND THE STRAITS OF MACKINAC
IV. LAKE HURON, ST. CLAIR RIVER, LAKE ST. CLAIR, AND THE DETROIT RIVER
V. LAKE ONTARIO AND ST. LAWRENCE RIVER

By

ALLAN J. McLAUGHLIN

WASHINGTON
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The Surgeon General

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CHARTS.

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SEWAGE POLLUTION OF INTERSTATE AND INTERNATIONAL WATERS WITH SPECIAL REFERENCE TO THE SPREAD OF TYPHOID FEVER.[1]

INTRODUCTION.

The rather common use of sewage-polluted water supplies without filtration or treatment has been responsible in our cities for disaster in the shape of typhoid fever epidemics, with a frequency not pleasant to contemplate. Cities which neglect to filter or treat in a proper manner such polluted supplies would be exposed also to outbreaks of Asiatic cholera, should persons ill with cholera, or "carriers," gain access to the United States.

It is useless to expect that the dejecta of all persons ill with typhoid fever or cholera will be properly disinfected before reaching the sewers, especially if the contributor is a carrier who shows no signs of illness. It is evident that the surest and most prompt protection against water-borne disease can be afforded in each case by proper treatment or filtration of the public water supplies. With cholera, we have only the menacing possibility, but with typhoid fever, we have the actual existence of the disease in such a high rate of prevalence that the United States suffers seriously as compared with other civilized countries.

TYPHOID FEVER IN THE UNITED STATES.

The undue prevalence of typhoid fever in the United States has been characterized as a national disgrace, and this characterization is not unreasonable or unjust, in view of the fact that much of the typhoid fever is preventable by one simple measure—the installation of a safe water supply. Theoretically typhoid fever is a preventable disease to the point of complete eradication. We also know that if the human excreta of the entire population were properly cared for and if personal hygiene could be encouraged and enforced to the point where individuals would wash their hands thoroughly before leaving the toilet and before handling food or drink, typhoid fever would become a matter of history.

We know practically, however, that proper disposal of excreta of the entire population is an ideal to which we may aspire, but which is

[1] Manuscript submitted for publication Mar. 1, 1912.

still far from attainment. Instead of being able to destroy the infective agent at its source in feces and urine, we are compelled by expediency to attempt to prevent the entrance of the germs into the human body by making our water and milk supplies safe. We know also that much education in personal hygiene is necessary before the individual carrier will voluntarily protect others by disinfecting his hands at the proper time.

In drawing conclusions regarding the prevalence of typhoid fever in the United States, it must be remembered that the mortality statistics of the United States Census Bureau are made up from what is known as the registration area.

Eighteen States furnish mortality statistics complete enough to be included in the registration area. There is reason to believe that there is more typhoid fever per 100,000 population in the States outside the registration area than in the States included in that area. Even if this were not true, the typhoid fever rates from the registration cities and States themselves alarm, and demand concerted effort for their reduction. The average American citizen displays toward sanitary problems a very dangerous apathy. It is difficult to arouse his interest in anything so common as typhoid fever. Cholera or plague or any scourge which to him suggests a quick and mysterious death will awaken his instinct of self-preservation and arouse him to activity. Not so typhoid fever—it has been all about him always, excites no terror, and is viewed indifferently as an inevitable visitation which comes every year and takes its toll from the community. He rarely asks himself is this visitation inevitable, or may not typhoid fever be prevented or reduced?

Twenty deaths per 100,000 probably represent 200 cases of typhoid fever. Suppose 200 cases of Asiatic cholera occurred in any American city of 100,000 population, would not strenuous activity be displayed, and very properly so, for the eradication of the scourge? Although typhoid fever mortality is lower than that of cholera, yet it is more dangerous in its transmissibility, more expensive in its lingering course, and more disastrous in its sequelæ than Asiatic cholera. The mental attitude toward typhoid fever displayed by many physicians, and especially health officers, is scarcely more commendable. Their complacency in the face of typhoid fever rates of above 20 deaths per 100,000 population is difficult to explain. If the rate should be below 20, many municipal officials are inclined to boast of this low rate as compared with less fortunate cities.

What may be considered a low rate for typhoid fever?

Table 1 shows the death rates per 100,000 population in 10 large European cities. The average for 5 years is given in the first column. The other columns show the rate for the individual years

from 1906 to 1910, inclusive. The figures are given for 10 years to show that the low rates are consistent and not a mere coincidence. These 10 cities represent a population of about 15,000,000 persons, and the average death rate per 100,000 population for the 10 years was about 4.0. The rates are gradually becoming lower and the rate for these 10 cities combined with a population of 15,000,000 was only 3.1 in 1910.

TABLE 1.—*Deaths per 100,000 population, typhoid fever.*

	Average 5 years, 1901–1905	1906	1907	1908	1909 [1]	1910 [1]
Stockholm	3	2	2	1	0.5	4.0
Christiania	3	4	2	2	1.7	2.0
Munich	4	2	3	3	1.9	1.4
Edinburgh	8	3	3	2	1.2	2.0
Vienna	4	5	3	4	2.8	4.0
Hamburg	4	4	3	4	3.3	4.1
Berlin	4	4	4	4	4.2	4.0
Dresden	4	7	2	6	4.2	2.2
Copenhagen	8	4	2	7	2.7	3.6
London	8	6	4	5	2.2	4.0

[1] Compiled from Public Health Reports.

In comparing European cities with American cities in the basin of the Great Lakes, only cities of northern Europe have been mentioned, in order to make a fair comparison of sanitary results under climatic conditions not essentially different. For the same reason in comparing the Lake cities with other American cities no cities have been referred to outside of the States of Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin, and Minnesota. It would be manifestly unfair to compare Wisconsin with Mississippi or Cleveland with New Orleans.

Table 2 shows 15 other European cities which in 1909 and 1910 did not reach double figures in typhoid death rates per 100,000 population. These 15 cities represent a total population of over 9,000,000. The average rate for the total population was only 5.3 in 1909 and 4.5 in 1910.

Table 3 shows the remaining 8 cities in northern Europe with populations in excess of 300,000. These 8 cities have a population of about 7,500,000. Their total average rate for 1909 was 13.9 and for 1910, 15.6. These rates would be considered low in America, but the European officials consider the persistence of such rates to be a disgrace.

TABLE 2.[1]

Cities.	Typhoid fever deaths per 100,000—		Cities.	Typhoid fever deaths per 100,000—	
	1909	1910		1909	1910
Frankfort	1.5	0.9	Sheffield	9.4	3.0
Antwerp	1.0	2.3	Rotterdam	6.4	6.5
Bristol	2.8	2.1	Amsterdam	3.8	6.7
Nuremburg	2.6	....	Paris	8.4	5.6
Birmingham	5.0	3.9	Bradford	4.3	9.2
Belfast	5.2	3.9	Leipzig	8.3	7.5
Lyons	5.8	4.4			
Leeds	7.2	3.8	Total average rate	5.3	4.5
Liverpool	8.4	3.9			

TABLE 3.[1]—*Northern European cities with higher rates.*

Cities.	Typhoid fever deaths per 100,000—		Cities.	Typhoid fever deaths per 100,000—	
	1909	1910		1909	1910
Glasgow	12.5	6.4	Moscow	13.8	15.0
Budapest	9.4	13.6	Warsaw	13.5	17.4
Brussels	7.4	16.1	St. Petersburg	25.2	33.7
Dublin	15.7	12.2			
Manchester	13.9	10.3	Average	13.9	15.6

[1] Compiled from Public Health Reports.

To recapitulate, in northern Europe the 33 principal cities with an aggregate population of 31,500,000 had an average typhoid death rate per 100,000 population of 6.5 in 1909 and 1910. This includes such notorious typhoid centers as St. Petersburg, which had a rate of 33.7 in 1910. The rate in St. Petersburg is considered disgraceful in view of the fact that the water supply is responsible. This supply is partly filtered and partly raw Neva water. The bacterial examination of raw and filtered water showed little difference, and during the cholera epidemic cholera vibrios were recovered from both the filtered and unfiltered water. The filters only removed 60 per cent of the bacteria in the raw water.

It is clear that in cities which have had safe water supplies for a period of years the rate should not be above 5 per 100,000, unless some unusual condition exists, such as poor control of milk or lack of control over patients and carriers. Now let us compare typhoid fever rates in American cities.

Table 4 shows our honor roll for 1909 and 1910. These are the typhoid fever death rates among the 50 cities in the United States with more than 100,000 inhabitants. One city (Bridgeport, Conn.) has a rate below 5, three cities (Paterson, N. J., Cincinnati, Ohio, and Cambridge, Mass.) have rates below 10 per 100,000, 22 other cities have rates from 11 to 20 deaths per 100,000, and the remaining 24 cities have rates from 20 to 86.

TABLE 4.

Cities having a population of 100,000 or over.	Number of deaths from typhoid fever per 100,000 population.		Cities having a population of 100,000 or over.	Number of deaths from typhoid fever per 100,000 population.	
	1909	1910		1909	1910
Birmingham Ala	59.7	49.5	Omaha, Nebr	36.8	86.7
Los Angeles, Cal	16.1	14.2	Jersey City, N. J	8.8	11.5
Oakland, Cal	11.2	16.5	Newark, N. J	11.9	13.1
San Francisco, Cal	13.9	15.5	Paterson, N. J	9.7	7.1
Denver, Colo	24.1	27.5	Albany, N. Y	19.0	14.0
Bridgeport, Conn	9.0	4.9	Buffalo, N. Y	23.8	20.4
New Haven, Conn	20.5	17.9	New York, N. Y	12.1	11.6
Washington D. C	34.3	23.2	Rochester, N. Y	9.4	13.7
Atlanta, Ga	50.6	50.1	Syracuse, N. Y	11.2	28.2
Chicago, Ill	12.6	13.7	Cincinnati, Ohio	13.3	8.8
Indianapolis, Ind	22.3	28.5	Cleveland, Ohio	13.3	17.9
Louisville, Ky	45.0	31.7	Columbus, Ohio	19.6	18.1
New Orleans, La	28.4	31.5	Dayton, Ohio	26.9	21.4
Baltimore, Md	24.9	42.0	Toledo, Ohio	41.7	37.2
Boston, Mass	13.8	11.3	Portland, Oreg	22.0	22.4
Cambridge, Mass	7.7	9.5	Philadelphia, Pa	22.3	17.5
Fall River, Mass	21.3	15.0	Pittsburg, Pa	24.6	27.8
Lowell, Mass	10.5	19.7	Scranton, Pa	16.4	16.9
Worcester, Mass	8.4	15.7	Providence, R. I	11.4	17.9
Detroit, Mich	20.5	23.0	Memphis, Tenn	48.8	27.4
Grand Rapids, Mich	17.2	28.3	Nashville, Tenn	52.0	48.9
Minneapolis, Minn	21.0	58.7	Richmond, Va	24.1	21.9
St. Paul, Minn	18.9	19.5	Seattle, Wash	23.8	14.2
Kansas City, Mo	29.3	54.4	Spokane, Wash	43.2	45.4
St. Louis, Mo	16.2	14.9	Milwaukee, Wis	21.4	45.7

These 50 registration cities in the United States have an aggregate population of over 20,000,000. The typhoid death rate in these cities for 1910 was 25 per 100,000.

Unit of comparison.	Aggregate population.	Deaths per 100,000 typhoid fever, 1910.
Thirty-three principal European cities in Russia, Sweden, Norway, Austria-Hungary, Germany, Denmark, France, Belgium, Holland, England, Scotland, and Ireland	31,500,000	6.5
Fifty American cities of 100,000 inhabitants or over	20,250,000	25.0
Excess of deaths, typhoid fever in American cities per 100,000 population		18

So that on an average in every 100,000 population we had, compared with European results, 18 deaths and at least 180 cases of typhoid fever which should never have occurred. A conservative estimate for 1910 will place the deaths from typhoid fever above 25,000. When we consider that the smaller cities in America have in general higher rates than the larger, that the rural typhoid is high and in many sections higher than the urban, that the sections not included in the registration area sanitary conditions are probably worse and typhoid fever rates higher than within the area, we are forced to conclude that a general death rate of 25 is probably below the actual deaths from typhoid fever per 100,000 population in the entire United States.

The excess of 18 deaths per 100,000 in the urban population alone shows that we have had in the 50 cities mentioned above yearly,

at least, 3,600 deaths, and probably 36,000 cases of typhoid fever which were preventable and should never have occurred. For the whole United States the number of cases for each year preventable by methods within our grasp would probably reach 175,000, and the deaths so avoided would total 16,200. In 1909 there were more cases of typhoid fever in the United States than cases of plague in India, in spite of the fact that India's population is two and one-half times that of the United States.

From January, 1907, to October, 1911, there occurred in Russia 283,684 cases of Asiatic cholera. This included the appalling epidemic of 1910. According to a conservative estimate there occurred in the United States during the same period one million and a quarter cases of typhoid fever, or more than four cases of typhoid fever in the United States for every case of cholera in Russia. We heard a great deal of the ravages of cholera in Italy in 1910–11, yet in these two years there occurred in Italy about 16,000 cases of cholera and about 6,000 deaths and in the United States in the same period we had more than a half million cases of typhoid fever and 50,000 deaths.

We are accustomed to speak of these countries as pest ridden, and a residence there or even a brief visit is considered with apprehension. But do we consider the prevalence of typhoid fever in our own country with sufficient seriousness? These 25,000 deaths annually do not represent our total loss from typhoid fever. At a conservative estimate they are accompanied by a quarter of a million of cases of typhoid fever each year.

These cases represent an average illness for each individual of four weeks, and probably six or eight weeks enforced abstinence from any gainful occupation. The economic loss is appalling and, computing the value of the lives lost to the community, the cost of medical attendance and hospital care, the loss of earning capacity for many weeks, the decreased earning capacity and impaired efficiency due to sequelæ, the total loss would reach a sum of not less than $100,000,000 annually.

To understand fully the menace of typhoid fever, one must remember that it can not be prevented by ordinary personal cleanliness as typhus fever may be prevented, and is not confined to the poor and dirty, but reaches all classes.

It is not something we have in childhood and consign to history as scarlet fever or measles, but a disease which attacks the most robust adult individuals during the period of their greatest activity and their greatest economic value to the community. Typhoid fever is a disease against which the individual is in great measure helpless,[1] and

[1] Vaccination against typhoid affords the individual at least a considerable degree of protection. As a general measure of protection of the civilian population, it is not likely to prove practicable, however, although of immense advantage in protecting military units against typhoid where compulsory vaccination is feasible.

protection of the individual can only be effected by sanitary control of the entire food and drink supply and the sanitary disposal of human excreta.

It is interesting to note the differences in sanitary conditions between European and American cities, which may explain the difference in the typhoid rates. High typhoid rates may be said to depend upon water, milk, and a third factor—a group of conditions which facilitates the spread of typhoid fever by contact and flies. These latter conditions include overcrowding, lack of sanitary necessities, and failure to care for human excreta in a safe manner.

The European cities with low typhoid rates all have good safe water supplies. The city of St. Petersburg has a polluted public water supply, and it is the only large city in northern Europe with a high typhoid rate, according to American standards. Whenever water is a considerable factor in typhoid fever prevalence the fact is apt to be apparent from the high rate in the first half of the year.

The following table shows the typhoid fever death rate per 100,000 for the two halves of 1910 in northern European cities whose water supplies are recognized as safe:

TABLE 5.[1]

Cities.	Typhoid fever deaths per 100,000, year 1910.		Cities.	Typhoid fever deaths per 100,000, year 1910.	
	First half, January to June.	Second half, July to December.		First half, January to June.	Second half, July to December.
Stockholm	0.6	3.0	Dresden	0.8	3.6
Munich	.8	2.0	Berlin	2.0	3.8
Christiania	2.4	.8	Hamburg	3.2	5.0
Frankfort	1.2	.6	Vienna	4.6	3.0
Antwerp	2.0	2.6	Edinburgh	.6	.0
Bristol	2.6	1.6			
London	2.4	4.2	Average	1.8	2.6
Copenhagen	2.2	5.0			

It must be borne in mind that these European cities have all had safe water supplies for many years. Such good results can not be expected immediately after the installation of a safe water supply. The rate for contact typhoid may be abnormally high under certain conditions, and it may be several years before this contact rate drops to the minimum residual rate which has been attained in these northern European cities.

It is certain, however, that if the water plays no part, and the milk is not a factor, the contact typhoid fever rate tends to steadily diminish until a minimum is reached. This minimum rate should not be above two in the first six months of the year in European cities. It is evident that with a safe water supply and other conditions as good as those existing in Germany, the rate from January to June should not exceed two. In fact, the average for the 13 cities with an aggregate

[1] Compiled from Public Health Reports.

population of 16,000,000 is less than two deaths per 100,000 during the first half of the year.

Contact infection in typhoid fever is probably the greatest factor in perpetuating the disease. It does not tend to produce high rates, but coupled with carriers is responsible for the persistence of the disease in quiescent periods and from one year to another. Contact infection is most active in communities where water and milk furnish many carriers and create many new foci from which the contact infection operates.

The direct result of control of milk and safe water is to reduce the number of foci and the number of carriers; as a secondary result in northerly cities there is a fall in the residual typhoid rate to a point where it may be barely sufficient to continue the disease from year to year.

In 1910 in the registration area there were 21 cities with rates of 20 or less. These might be presumed to have safe water supplies, yet in the first half of the year the rates were abnormally high in some of these—"our best" cities.

It is difficult to say what should be the minimum winter rate in American cities due to contact and carriers soon after water and milk are eliminated as factors in transmissions. After a period of years it should be no higher than those of the German cities, and certainly not above 2 deaths per 100,000 provided that adequate precautions as now taken in German cities be exercised in control of cases and carriers. Unfortunately some cities with filter plants suffer from faulty operation. Some use the unfiltered surface water from a source "usually" safe, but which suffers occasional or dilute pollution, and practically all suffer more or less from contaminated milk.

TABLE 6.

Cities.	Population.	Typhoid-fever death rate per 100,000 per annum, 1910.		Character of water supply.
		January to June.	Entire year.	
Bridgeport, Conn	102,054	1.8	4.9	Good.
Jersey City, N. J	267,779	3.6	11.5	Safe.
Scranton, Pa	129,000	4.6	16.9	Safe.
Boston, Mass	670,585	4.8	11.3	Good.
Fall River, Mass	119,295	5.0	15.0	Good.
Worcester, Mass	145,986	5.4	15.7	Good.
Cincinnati, Ohio	364,463	5.6	8.8	Safe.
Newark, N. J	347,469	6.8	13.1	Safe.
Lowell, Mass	106,294	7.4	19.7	Safe.
New York, N. Y	4,766,883	7.6	11.6	Good.
Paterson, N. J	125,600	8.0	7.1	Safe.
Rochester, N. Y	227,103	8.2	13.7	Good.
Chicago, Ill	2,185,283	8.4	13.7	Doubtful.
New Haven, Conn	133,000	9.0	17.9	Good.
Cambridge, Mass	104,839	9.4	9.5	Good.
Columbus, Ohio	181,548	9.8	18.1	Safe.
Providence, R. I	224,326	10.4	17.7	Good.
Albany, N. Y	100,859	12.0	14.0	Safe.
Cleveland, Ohio	560,663	15.2	17.9	Doubtful.
Philadelphia, Pa	1,549,008	19.0	17.5	Four-fifths safe.

Bridgeport, Conn.; Fall River, Mass.; Boston, Mass.; Scranton, Pa.; Worcester, Mass.; Jersey City, N. J.; and Cincinnati, Ohio, have rates for the first half of 1910 below 6 and these are the best. We know that outside of water and shellfish the other factors in the spread of typhoid are most active in warm weather. Therefore if Philadelphia has a rate of 16, from July to December, the rate from January to June should be less. As a matter of fact it was greater in 1910. It is difficult to say how much of this excess of winter and spring typhoid is due to water, because of the difficulty of excluding milk. It is true that most milk outbreaks occur in warm weather, but they may occur at any time. A milk epidemic in Boston, April, 1908, raised Boston's typhoid death rate from January to June to 31.6. Of 179 milk epidemics compiled by Trask,[1] 147 gave the month of onset as well as the year. Of these 147 outbreaks, 106 occurred between July and December, and 41, or 27 per cent, occurred from January to June. Northern cities with yearly typhoid death rates below 15 per 100,000 should not have rates from January to June above 8 if the water supply is above reproach. A rate higher than 8 might occur in a single year because of contaminated milk, as in Boston in 1908, or possibly due to some still more unusual factor, such as shellfish, but this would be unlikely to occur consistently every year for a period of years.

This rate of 8 for the first half of the year is four times the rate of northern European cities cited above and must be regarded as a minimum conservative claim for what American rates should be from January to June.

It is the writer's belief that if the water supplies were made entirely safe and the milk properly controlled, this rate within a few years in American cities would not be consistently above 2 in the winter and spring months, provided proper precautions were taken in the control of cases and carriers.

In speaking of the responsibility of water, it is intended to include in the water-supply factor all water from whatever source which may be used in the corporation. Many cities have a public water supply which is not patronized by more than 50 to 75 per cent of the citizens, the remainder depending upon shallow wells or other questionable sources. For this reason the typhoid records from a city with a safe filtered public water supply may show undue prevalence in March, April, or May because of the large number of people using wells or contaminated unfiltered surface water.

It is a well-known fact that the efficiency of a filter plant and the quality of the filtered water depend as much upon careful and intelligent operation as upon the mechanical perfection of the plant itself. Slow sand filters are sometimes scraped or cleaned in the winter and

[1] Hygienic Laboratory Bulletin 56.

put in service "green" because the ripening of the "Schmutzdecke" is a slow process in the winter months, or a mechanical filter is operated with too little coagulant, too short a period for chemical action and sedimentation or other operative defect. These things explain why, even if we have a "filter plant," the rate in the winter or spring months may be higher than normal.

To attain the low rates for typhoid fever which are reported for the northern European cities seems an ideal difficult of accomplishment in America. Yet there is no reason why we should not accomplish it and go even further toward the complete eradication of the disease. To approximate the low European rates necessitates work in four distinct lines of activity: (1) To secure safe water supply; (2) to secure safe milk supplies; (3) control of typhoid fever patients and carriers; (4) to reduce rural typhoid.

The question of safe water supplies will be the principal one discussed in the following pages. Some mention is made of the problems of safe milk, control of carriers and patients, and rural typhoid to show that the writer is taking up one phase of the problem, the prevention of water-borne typhoid with a full appreciation of the work to be done along the other lines of activity. Inasmuch as these problems are outside the scope of this investigation the mention is necessarily brief.

Milk plays a part in explaining the higher American rates for typhoid fever because of the difference in amounts consumed and methods of handling. Americans use more milk as a beverage than Europeans, and in Europe the practice of boiling or heating is almost universal, partly for sanitary reasons, but more often to prevent souring of the milk in the absence of ice. It seems that some of the northern European cities have practically eliminated milk and water as causative agents and reached the minimum point in residual typhoid which is just short of complete eradication.

To render milk safe is a more difficult problem in America than in Europe. The Europeans use less milk as a beverage and usually boil or heat their milk. The Americans use larger amounts of milk and have a deep-rooted dislike to boiled milk. The heating of milk to the degree necessary to kill pathogenic organisms and its prompt refrigeration seems the only safeguard which can be applied to milk without materially changing its character, which will afford protection to the consumer. There are too many ways in which contamination may reach milk between the cow and the consumer to make milk inspection effective as a safeguard under existing conditions. We hear constantly of the efficiency of inspection, and of preventing further infection by measures taken at the farm, but this is always accomplished after the milk epidemic has occurred. Ideal dairy farms, ideal handling in transit and delivery must and should be

striven for, but in the meantime the people should be protected by the means at hand. Inasmuch as we can not depend as yet upon the individual to protect himself, we must protect him by heating his milk for him. The milk supply should be considered as a public utility and should be controlled by municipal authority, as efficiently as the water supply, for sanitary reasons. This control necessitates pasteurization or heating for prompt protection of the public. The heating of milk as a prophylactic measure in the campaign against typhoid is comparable to the filtration or treatment of a water supply exposed to pollution.

If the ideal could be attained, neither procedure would be necessary. Unfortunately the attainment of the ideal of pure milk is as far removed as the ideal of perfect disposal of all human excrement. Even if these ideals are attainable, it is a question whether other measures are not more economical and equally effective.

Without waiting for sewage disposal to protect a water supply the wise health officer advocates immediate protection to the public by filtration or treatment of the endangered or polluted supply. In the same way it is the part of wisdom to heat or boil milk pending the accomplishment of an ideal, which its most ardent advocates admit to be far distant. To accentuate what may be accomplished in large cities by these two measures alone, installation of a safe water supply and the elimination of the milk factor, the typhoid history of Naples is interesting.

In Naples the conditions which usually are considered favorable to the spread of typhoid fever by contact and flies are present in an exaggerated degree.

The bulk of the poor people who inhabit the "bassi" or lowest floor of the largest tenements, have no closet facilities whatever. Fecal matter is deposited in the streets, alleys, and along the sea wall, and only the activity of the street sweepers (spazzini) makes it possible for pedestrians to avoid actual contact. Urination is practiced in all the streets and many of the urinals are simply V-shaped inserts in walls and the urine trickles over the sidewalk to the gutter. In the dark ill-ventilated "bassi" the people are crowded together so that close personal contact is unavoidable.

The conditions for spread of typhoid fever by contact are ideal. Add to this the fact that flies in the poorer quarters are very numerous, and we have every condition necessary for a high prevalence of typhoid fever by contact and flies. Yet Naples has had a very low typhoid-fever rate. In 1909 the typhoid death rate per 100,000 was 9, and in 1908 only 6.5. Why, with such ideal conditions for contact infection and infection by flies, has Naples such a low rate? Naples has two things which go far to explain this low rate. The Naples water supply is safe and, moreover, available free to all the poor

people. Consequently, there is no incentive to use dangerous shallow well water. The other fact which has a bearing on the low typhoid-fever rate is that there is no milk problem in Naples. The poor do not use cow's milk, and many of them use no milk at all. The goats' milk used is milked from the goat into the receptacle of the consumer and, in addition, it is usually boiled before using to prevent spoiling, as the purchase of ice is beyond the means of the poor. With the class sufficiently prosperous to have cows' milk the same is true. The cow is driven through the streets, milked at the door, and the boiling of the milk in lieu of refrigeration is almost universal. Water and milk being eliminated, naturally explosive outbreaks are out of the question. Contact infection and flies have to depend on a chain of foci due entirely to bad personal hygiene.

The result is that while the factors concerned in the transmission of typhoid fever by flies and by contact are present, the indirect effect of water and milk upon these factors by furnishing them new foci from which to operate is absent. Carriers are few and depending upon contact and flies alone the residual rate declines to a minimum barely sufficient to perpetuate the disease.

In regard to control of typhoid-fever patients and carriers, much remains to be done. In Germany this control has been established and maintained by regulation and we have attempted to do the same. Their results have been better largely because of the difference between German and American character. This control in America must be effected by popular education rather than by regulation. As it is largely personal hygiene or family hygiene, the citizen must be educated to do voluntarily, without compulsion, things which under compulsion seem to him an infringement upon personal liberty and rights. This difference in attitude toward sanitary measures between the German and American necessitates a campaign of popular education in America in order to effect that which may be accomplished in Germany by regulation alone. This mental attitude of the American citizen toward sanitary regulations must not be considered a disadvantage. He simply demands demonstration of theories and facts which the German accepts without question, but once the demonstration is made and the American convinced, his is no perfunctory compliance, but he lends his aid with vigor and enthusiasm which yield prompt and lasting results.

The great problem of rural typhoid looms up wherever an investigation of typhoid prevalence is made. With rural typhoid should be classed the typhoid-fever prevalence of the lumber camps and iron ranges, where the factors in transmission are apt to be the same. No one measure promises so much as education in the campaign against rural typhoid, and this education will be followed by the sub-

stitution of the sanitary privy for the filthy yard privy and the proper care of the discharges of the sick.

The fly as a factor in typhoid-fever transmission probably plays a bigger part in the rural districts than in the large cities. Measures against the fly, attacking his breeding places, should not be deprecated, but with sanitary privies and proper treatment of excreta in the sick room the fly would be rendered a harmless nuisance so far as typhoid is concerned.

WATER-BORNE AND RESIDUAL TYPHOID.

As pointed out in a previous bulletin,[1] we must in America divide our fight against typhoid fever into two parts: (1) Water-borne typhoid; (2) residual typhoid.

In many American cities we have not completed the first stage, and some of our largest cities are supplied by unfiltered surface waters. We must appreciate fully that after the installation of a safe water supply and the elimination of water-borne typhoid our real fight begins on the typhoid fever which remains and which has been variously named "residual," "endemic," "contact," and "prosodemic" typhoid. This includes infection due to milk, flies, personal contact, etc.

It is essential that the water-borne typhoid be attacked first for several reasons. A sewage-polluted water supply is capable of producing disaster on a large scale in the shape of an explosive, massive epidemic. A polluted water supply is not only responsible for the cases which occur in the first sudden explosive outbreak, but may also be responsible for many cases not easily traceable to water, but which are due to a dilute pollution at the intake.

Water-borne typhoid has other pernicious indirect effects. It obscures the other factors—carriers, lack of personal hygiene, lack of control of milk, lack of control of typhoid excreta, etc.—and furnishes suddenly many new foci from which these other factors operate.

Another strong reason for immediate action in eliminating water-borne typhoid is that the remedy is comparatively simple and can be applied promptly.

No single measure in reducing typhoid on a large scale has yet approached the effect which has been produced in certain northern cities by substituting a safe for a polluted water supply. As an instance of this wholesale saving of human life, the reduction of typhoid fever in Pennsylvania may be cited. Since the installation of the Pittsburgh plants there has been an annual saving in the city of Pittsburgh of 400 lives from typhoid fever alone. It is almost

[1] Hygienic Laboratory Bulletin No. 77.

certain that with the elimination of water-borne typhoid the residual typhoid would tend to slowly decrease at least to a very low point of endemic prevalence (in the German cities an average of less than 5 deaths per 100,000). Installation of safe water supplies in America has not always produced such brilliant results, but the failure to reach such low figures as the Germans have attained is due principally to three things: (1) Failure to supply pure water to all; (2) imported cases, usually from communities which are typhoid centers; (3) existence of insanitary conditions, such as contaminated wells, outdoor privies, and lack of control over milk and excreta. As an instance of high rate due to failure to furnish filtered water to all the people, the experience of Pittsburgh is interesting.

In the State of Pennsylvania the reduction of 1908 over 1907 was largely due to the installation of water filtration plants in Pittsburgh and Philadelphia. In 1908 in the entire State of Pennsylvania there were 1,088 typhoid deaths less than in 1907. Of this reduction, 829 less, or 76 per cent of the total reduction, must be credited to Pittsburgh, Philadelphia, and Scranton.

TABLE 7.—*Showing reduction in number of deaths from typhoid fever in the State of Pennsylvania, 1907–8.*

	Number of deaths from typhoid.		Number of deaths less.
	1907	1908	
Philadelphia	890	529	361
Pittsburgh Allegheny	645	255	390
Scranton	92	14	*78
The remainder of the State	1,911	1,652	259
Total State of Pennsylvania	3,538	2,450	1,088

In 1909 Pennsylvania effected a further reduction in typhoid-fever rate, having the greatest absolute decrease in total typhoid deaths of any State in the registration area. Pennsylvania's great decrease in 1909 was largely due to the improved conditions, especially the filtered water supply in Pittsburgh and Philadelphia. Of the 738 cases absolute reduction of total typhoid deaths in Pennsylvania in 1909, 313 must be credited to reductions in Pittsburgh (125) and Philadelphia (188), where improved water supplies are now being used.

The filter plant in Pittsburgh was first put in operation November, 1907. But a small portion of filtered water was supplied at first, and this was mixed with the unfiltered supply. The amount of water filtered was increased until October, 1908, when the supply of that part of the city between the rivers, about three-fifths of the total population, was filtered. The south side, a little less than one-

fifth of the entire population, was supplied with filtered water in March, 1909. The former city of Allegheny, recently annexed, is not yet supplied with filtered water. This part of the city includes a population of about one-fourth of the entire city.

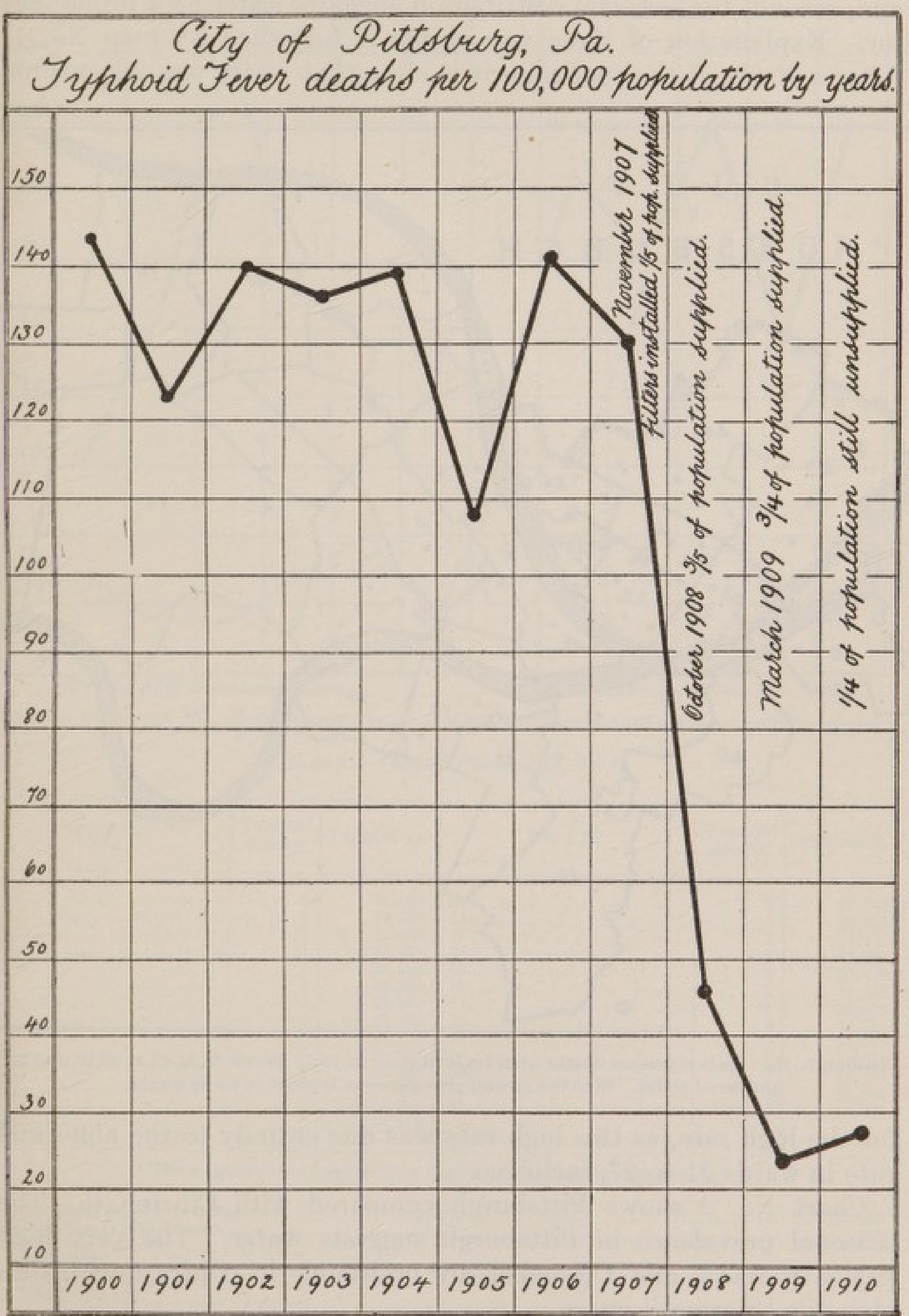
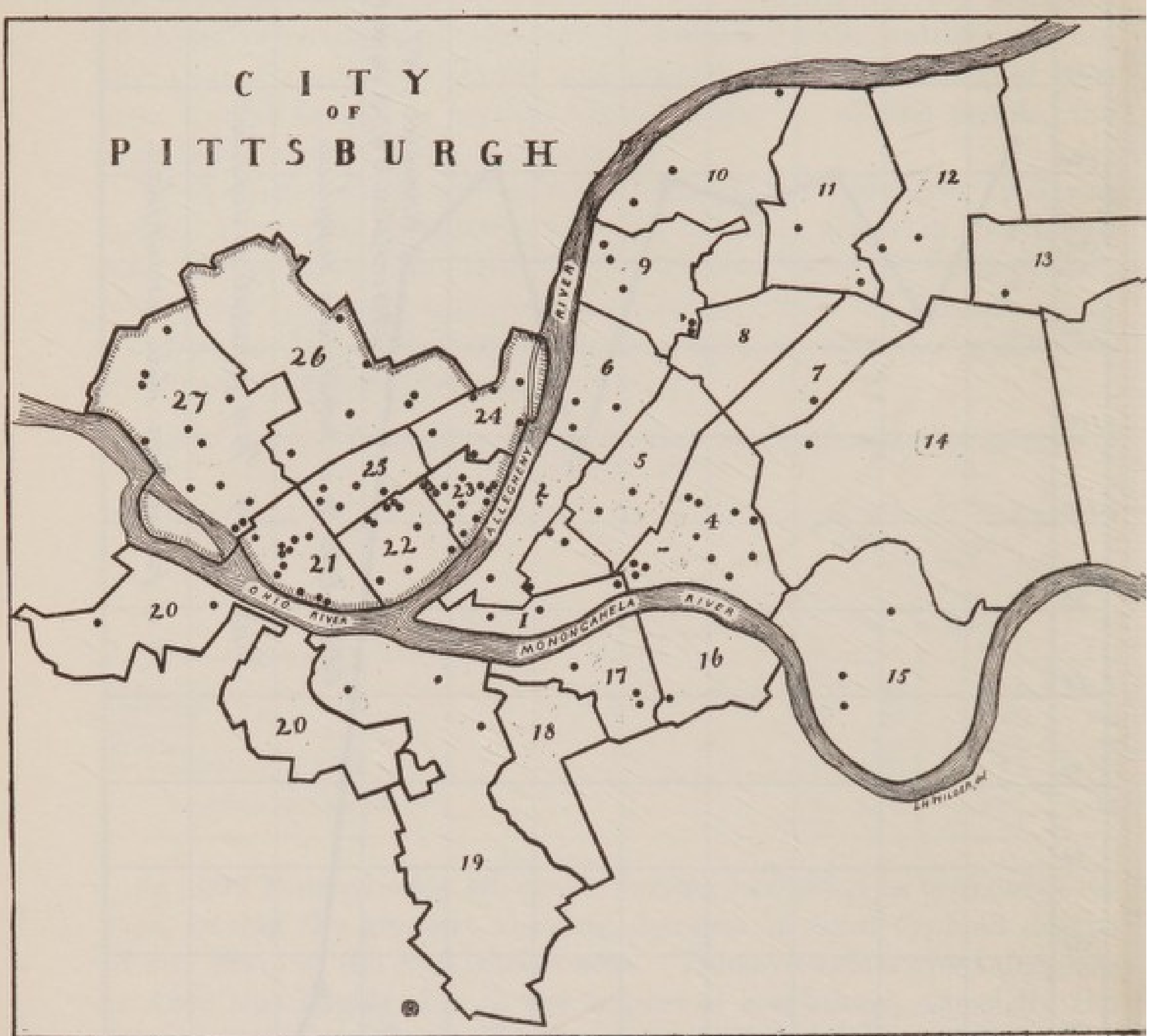


CHART 1.—Pittsburgh, Pa. Note the great reduction in typhoid fever rates following the installation of filters.

Chart No. 1 shows the remarkable decrease of typhoid fever in Pittsburgh progressively coincident with the increase of area supplied with filtered water. In spite of all this remarkable reduction two points stand out prominently: First, the rate is still high (1910); and, second, the seasonal distribution suggests water as a prime factor. Explanation of these two points is furnished by map No. 1. After a study of the spot map it is clear that water was responsible



MAP 1.—Pittsburgh, Pa. Spots represent deaths from typhoid fever in 1910. Wards 21, 22, 23, 24, 25, 26, and 27 rece unfiltered water. Note the greater prevalence of typhoid in these wards.

for the high rate, as this high rate was due entirely to the abnormal rate in wards 21 to 27, inclusive.

Chart No. 2 shows Pittsburgh compared with Cincinnati. The seasonal prevalence in Pittsburgh suggests water. The very high peaks in March and December are noticeable in contrast with Cincinnati's "normal" curve.

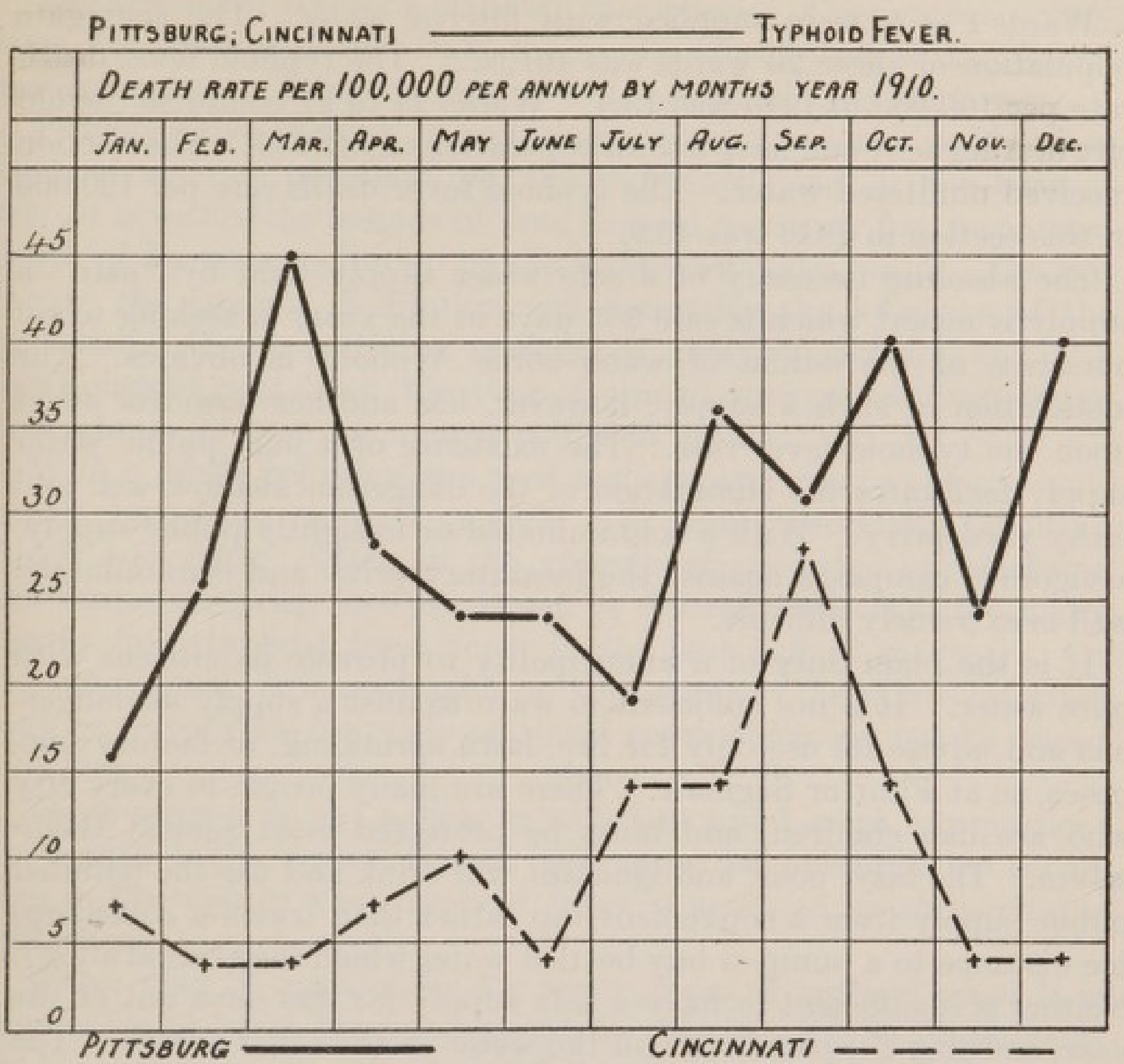


CHART 2.—Pittsburgh, Pa., compared with Cincinnati, Ohio, showing the difference in seasonal prevalence.

TABLE 8.—*City of Pittsburgh, Pa.*[1]

Ward No.	Typhoid deaths.	Population.	Ward No.	Typhoid deaths.	Population.
1	3	11,623	15	3	20,141
2	1	14,386	16	1	20,833
3	3	26,462	17	3	25,213
4	11	25,055	18	1	17,994
5	2	24,495	19	3	23,482
6	3	26,261	20	2	18,648
7	1	13,263	21	11	22,506
8	0	18,204	22	9	15,716
9	6	17,795	23	13	21,799
10	3	21,205	24	6	17,354
11	2	17,066	25	5	16,037
12	2	22,342	26	6	15,291
13	2	24,080	27	6	15,291
14	1	13,074			

[1] These figures were furnished by the Pittsburgh health department.

Total population of Pittsburgh	533,905
Total deaths, typhoid fever	115
Death rate per 100,000:	
Entire city	21.3
Wards 1 to 20	13.4
Wards 20 to 27	46.9

Wards 1 to 20 were supplied with filtered water. The aggregate population of these 20 wards was 401,622. The typhoid fever death rate per 100,000 in 1910 was 13.4. Wards 21 to 27 comprise the old city of Allegheny and have a total population of 132,283. This section received unfiltered water. The typhoid fever death rate per 100,000 in this section in 1910 was 46.9.

The absolute necessity of a safe water supply (and by "safe" a supply is meant which is safe 365 days in the year) in seeking to rid ourselves of the odium of water-borne typhoid is obvious. The installation of such a supply, however, has another powerful effect upon the typhoid-fever rate. The existence of a pure public water supply facilitates the elimination of the dangerous shallow well and filthy yard privy. With a contaminated or unsightly public supply, a vigorous campaign against the insanitary privy and contaminated well is extremely difficult.

It is the plain duty of a municipality to provide its citizens with pure water. It is not sufficient to warn against a supply as dangerous and advise its use only for fire, lawn sprinkling, or factory purposes, as at Flint or Saginaw. There are many people in every city who are like children, and must be protected even against themselves. The lazy, poor, and ignorant will drink and use the polluted public supply from a convenient tap rather than travel a considerable distance to a pump or buy bottled water which they can ill afford. Neither is it sufficient to have a safe supply for 360 days out of the year, warning the people to boil the water on the other 5 days. The notice to boil the water is based on bacteriologic findings which are 24 hours late. The notice is often ineffective in reaching the intelligent and is quite as often ignored by the ignorant. Typhoid fever contracted by such an ignorant, careless, or lazy individual unfortunately does not stop there, but he becomes a focus from which many other cases may be derived.

The relation of a sewage-polluted water supply to the typhoid fever rate was fully discussed in a previous bulletin.[1] Instances without number can be cited showing a remarkable drop in the typhoid-fever rate synchronous with the substitution of a safe for a contaminated water supply. It will be unnecessary to add anything further to prove this point. Still there is an unfair tendency on the part of some municipal officials to assume that their water supply is safe if they are fortunate enough to escape big explosive outbreaks easily traceable to water.

The factors affecting sewage pollution of a water supply and which determine the relative danger to be anticipated from such pollution are:

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[1] Hygienic Laboratory Bulletin No. 77.

The amount of polluting material, the presence of pathogenic organisms, the time of transit from the source of pollution to the waterworks intake, and the amount of water available for dilution.

Provided the amount of polluting material is considerable, that typhoid fever is prevalent on the watershed, and at the time of transit is within the bounds of time deemed necessary for the natural death of bacteria, pollution of the intake will take place. The last factor, the amount of dilution, will determine the intensity of the pollution. If the polluting material is great in amount, and if a swift current cuts down the time of transit prevents sedimentation and retards dilution, then gross pollution results.

With a dilute pollution one need not expect a great explosive outbreak, but many cases of typhoid may result, especially following floods and rains. Often in the absence of explosive outbreaks in the winter or spring months, it will be demonstrable that too many deaths from typhoid fever occur in the first half of the year. On the other hand, it is reasonable to suppose that the dilute infection may be responsible for many scattered cases which can not be traced to water.

These cases may not appear in sufficient numbers in any particular month to be remarkable or they may be obscured by occurring in the months when typhoid fever is accepted as an inevitable visitation.

Water may be responsible for many cases of typhoid when it is impossible to prove the case against it. We are able to fix the guilt on the water supply only in massive outbreaks of explosive character, but smaller doses can be responsible for smaller outbreaks or many cases spaced over a long period without any hope of proving this causation.

It seems quite probable that a dilute pollution of a water supply with typhoid organisms may exert an influence indirectly through the agency of milk. The very few organisms in the water through multiplication in the milk may be enormously increased.

THE RELATION BETWEEN TYPHOID FEVER, INFANT MORTALITY, AND ENTERITIS.

The percentage of total deaths, all ages and causes, which occurs under 1 year of age is a very good index of sanitary conditions. The relationship between infant mortality and insanitary conditions is admitted by all. These "insanitary conditions" include social and economic conditions dependent upon poverty—the manner of disposal of excreta and the character of the food, milk, and water supply.

It will be found almost invariably that where these insanitary conditions obtain a high infant mortality is coexistent. The same

factors which increase infant mortality—careless disposal of excreta, overcrowding, improper care and handling of milk and food, etc., also increase the endemic or contact typhoid in the season most favorable to typhoid, viz, July, August, and September. These factors are all chargeable to two things—ignorance and poverty. If the householder appreciated the significance of such conditions and had sufficient money he would move to more favorable environment. Unfortunately, many of the poor are ignorant of the death-dealing influences exerted by insanitary conditions, and many more are unable because of poverty to extricate themselves from their surroundings.

The infant mortality due to insanitary conditions may be obscured by undue prevalence of the communicable diseases of childhood—measles, scarlet fever, whooping cough, and diphtheria. The more reliable method is to take the deaths from enteritis as an index of the infant mortality due to insanitary conditions.

In the United States census mortality statistics, under the name of "Diarrhea and enteritis,"[1] are grouped a number of different entities of diverse etiology. About 85 per cent of these deaths occur in children under 2 years of age. The fact that several distinct entities are included complicates the study of this group, and usually no attempt is made to separate these entities upon a specific etiologic basis. It is generally conceded, however, that certain nonspecific factors bear an etiologic relation to enteritis. At least the presence of one or more of these factors in marked degree is deemed sufficient to explain a high rate for enteritis in cities. These nonspecific etiologic factors may be divided into climatic, racial, social, and economic.

CLIMATIC INFLUENCES.

The influence of climate upon enteritis is conceded, but the manner in which this influence is exerted is still in doubt. The enteritis of children, including cholera infantum, is a summer disease, and if we exclude water or milk-borne epidemics of specific enteritis it should have a very low prevalence in the months from November to April. Naturally because of hot weather the southern cities, with their longer summer, would be expected to have a higher rate for enteritis of children. Table No. 9 shows American cities with populations ranging from 100,000 to 300,000.

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[1] The word "enteritis" is used for the sake of brevity in the following pages to indicate the group classified in the United States census reports as "Diarrhea and enteritis."

TABLE 9.—*Cities with population from 100,000 to 300,000—Death rate per 100,000—Enteritis, all ages—Average for eight years, 1901 to 1908.*

Cities.	Rate.	Cities.	Rate.
St. Joseph, Mo	37.5	Syracuse, N. Y	111.3
Omaha, Nebr	54.8	New Haven, Conn	116.6
St. Paul, Minn	57.5	Worcester, Mass	127.2
Minneapolis, Minn	58.5	Paterson, N. J	133.4
Columbus, Ohio	60.9	Providence, R. I	150.8
Louisville, Ky	63.9	Bridgeport, Conn	156.1
Kansas City, Mo	64.9	Nashville, Tenn	156.2
Dayton, Ohio	70.7	Atlanta, Ga	168.0
Denver, Colo	80.5	Jersey City, N. J	169.4
Indianapolis, Ind	84.7	Richmond, Va	176.3
Toledo, Ohio	86.6	Scranton, Pa	178.2
Rochester, N. Y	91.3	Lowell, Mass	274.1
Memphis, Tenn	101.1	Fall River, Mass	376.5
Grand Rapids, Mich	103.1		

It will be noted that the first 10 cities have rates below 90 and that every one of these is north of the thirty-eighth parallel of latitude and west of the eighty-third meridian.

It must not be inferred that the low rates in this area are entirely due to climatic influences. In most of these cities there is an absence of other factors, racial or economic, which plays its part in the low rates.

On the other hand, favorable climatic conditions are not sufficient to prevent high rates in those northeastern cities, such as Fall River and Lowell, which possess the other factors, racial, social, or economic, which make for high enteritis rates. In this class of cities (100,000 to 300,000) the eastern and southern cities, as shown above, have higher rates than those of the North and West, though probably for different reasons. The cities in the South have the climatic factor exaggerated greatly by the length of the summer and comparatively mild winters. The New England cities have high rates entirely independent of climate and depending in greatest measure upon certain economic conditions.

THE RACIAL FACTOR.

Racial characteristics are potent factors for good or ill in the prevention of infant mortality, although it is difficult to separate racial from economic influences. The pernicious effect of race is not great because of the race itself, but rather because the economic condition of the race is poor, and poverty and ignorance usually go hand in hand.

The southern cities suffer most from racial influences. The large negro population furnishes a very much higher rate per 100,000 for enteritis than the white population.

Diarrhea and enteritis, number of deaths per 100,000 population.

Cities.	1906		1907		1908	
	White.	Colored.	White.	Colored.	White.	Colored.
Washington, D. C.	98.4	216.1	88.0	227.1	94.0	202.5
Baltimore, Md.	123.1	172.9	143.3	224.1	122.0	153.8
New Orleans, La.	161.4	218.7	176.8	229.4	166.3	239.8

These higher rates are due in greatest measure to the insanitary conditions under which the people live.

SOCIAL AND ECONOMIC CONDITIONS.

This includes the well-known influence of the slums of our large cities on infant mortality. It also includes the high mortality among children of working mothers in mill and factory towns. These conditions are due primarily to poverty and ignorance, and prevail in greater degree in the foreign quarters and among the negro population. The rate to be expected from slum conditions should be in direct proportion to the size of the city. Owing to the complex problems involved, this is not always the case, as some of the small cities have high rates due to other causes than slums. In general, however, all cities in America above 300,000 population have high rates. St. Louis, Mo., is the only exception.

TABLE 10.—*Enteritis, all ages, death rate per 100,000, average for eight years, 1901 to 1908—Cities with populations of over 300,000.*

Cities.	Rate.	Cities.	Rate.
Pittsburgh, Pa.	205.1	Chicago, Ill.	135.4
New Orleans, La.	177.4	Newark, N. J.	134.7
New York, N. Y.	162.6	Milwaukee, Wis.	128.5
Buffalo, N. Y.	155.2	Detroit, Mich.	122.9
Philadelphia, Pa.	144.7	Cincinnati, Ohio.	117.9
Baltimore, Md.	140.7	Boston, Mass.	115.4
Cleveland, Ohio.	136.6	St. Louis, Mo.	88.1
Washington, D. C.	135.6		

The high rates in these large cities are not surprising. New York, because of its size, should head the list, but New York has a very good water supply, and must give place to Pittsburgh (previous to 1908), with a polluted water supply, and the southern city of New Orleans, where the racial and climatic factors are accentuated. Buffalo's rate is altogether too high, considering its population, but Buffalo also has suffered from a polluted water supply.

If we could eliminate the enteritis due to water we would have in these rates a very fair index of the city's sanitary condition. The city which is too small to have slums, and which in spite of a good water supply has a very high enteritis rate, has also in all probability insanitary conditions which are not essentially different from the slums of the large cities, at least in their effect upon infant mortality.

The enteritis rate for the smaller cities (less than 100,000) is even more accurate as an index of sanitary conditions, if we exclude water-borne enteritis. Table No. 11 shows the average rate for five years (1904–1908) for enteritis in cities with populations between 50,000 and 100,000. These may be divided conveniently into three classes: The first 15 have rates from 50 to 100; the second 15 have rates from 100 to 150; the third group of 13 have rates ranging from 164.7 in Schenectady, N. Y., to 342.3 in Charleston, S. C.

TABLE 11.—*Enteritis, all ages, death rate per 100,000 in cities with a population from 50,000 to 100,000.*

Cities.	Rate.	Cities.	Rate.
Canton, Ohio	50.9	Johnstown, Pa	122.6
Lincoln, Nebr	56.9	South Bend, Ind	128.7
Saginaw, Mich	59.6	Utica, N. Y	133.7
Covington, Ky	65	Allentown, Pa	134.9
Harrisburg, Pa	65.2	Mobile, Ala	135.8
Fort Wayne, Ind	72.2	Pawtucket, R. I	137.1
Somerville, Mass	75.9	Hoboken, N. J	145.7
Portland, Me	77.4	Wilkes Barre, Pa	147
Evansville, Ind	82.3	Schenectady, N. Y	164.7
Springfield, Mass	87.6	Youngstown, Ohio	186.5
Altoona, Pa	91.6	Elizabeth, N. J	191.7
Lynn, Mass	94.4	Manchester, N. H	195.8
Springfield, Ill	95.3	Holyoke, Mass	199.8
Terre Haute, Ind	96.2	Yonkers, N. Y	207.7
Hartford, Conn	97	Waterbury, Conn	217.9
Duluth, Minn	103.1	Bayonne, N. J	224.9
Wilmington, Del	106.3	Passaic, N. J	230.7
Troy, N. Y	112.4	Lawrence, Mass	257.1
Camden, N. J	113.9	New Bedford, Mass	257.6
Erie, Pa	116.6	San Antonio, Tex	268.3
Savannah, Ga	119	Charleston, S. C	342.3
Reading, Pa	121.8		

The first group of 15, with rates below 100, contains no city from the country south of the thirty-eighth parallel of latitude. Some eastern cities are in this group. They are not "mill" towns, however, but cities of quite a different type, as Somerville, Mass., Hartford, Conn., and Harrisburg, Pa.

The second group has cities from all sections. The rates 100 to 150 are too high for cities of this size, and an intensive study of conditions will show the special reason or reasons in each case.

Duluth's rate of 103 is higher than one would expect. St. Paul and Minneapolis have rates below 60; considering it climatically, Duluth should be no higher. There is no negro factor to raise the rate, but there is quite a large foreign population. South Bend, like Duluth, has very much higher rates than cities in the surrounding territory. Wilmington, Del., Savannah, Ga., and Mobile, Ala., have rates no higher than might be expected with the large negro population. The excessive rates in Group 3 are best explained by the insanitary conditions, maternal neglect, ignorance, and poverty of mill and factory towns. The last two cities are southern cities, and the explanation of their high rates is probably to be found in climatic and racial influences.

During this investigation of cities in the drainage basin of the Great Lakes, the writer was struck with the high rates for diarrhea and enteritis in some northern cities coincident with absence of slums and a polluted water supply, and the close relation existing between the rates for enteritis and typhoid fever. The following table shows 12 New York cities. The first 4 have good water supplies, good sanitary conditions, and low rates for both typhoid and enteritis. The second 4 have good water supplies, low typhoid rate, bad sanitary conditions (mill and factory towns), and high enteritis rates. The last group of 4 have polluted water supplies, fair to good sanitary conditions, high typhoid-fever rates, and high enteritis rates.

TABLE 12.

	Typhoid death rate per 100,000, average for 10 years, 1900-1909.	Character of water supply.	Death rate, enteritis, average for 5 years, 1904-1908.	Remarks.
Rochester	13.7	Good.	89.5	Sanitary conditions good.
Syracuse	14.8	Good.	105.5	
Albany	21.9	Good.	80.0	
Binghamton	20.9	Good.	104.7	
Utica	17.3	Good.	133.7	Mill and factory towns.
Schenectady	22.4	Good.	164.7	
Amsterdam	18.6	Good.	150.7	
Yonkers	9.5	Good.	207.7	
Cohoes	83.8	Polluted.	170.9	Mill and factory towns—sanitary conditions, exclusive of water, good.
Niagara Falls	129.1	Polluted.	173.2	
Ogdensburg	148.5	Polluted.	175.0	
Buffalo	27.0	Polluted.	151.6	

A similar relation between typhoid and enteritis was found in certain Michigan cities, although these coincidently high rates were not always associated with a polluted water supply.

The Michigan rates are for diarrhea and enteritis under 2 years, instead of for all ages.

TABLE 13.—*Michigan cities, population from 12,000 to 50,000—Average deaths per 100,000 for six years, 1905–1910.*

Cities.	Typhoid.	Enteritis.	Water supply.
Escanaba	136.0	185.0	Polluted.
Sault Ste. Marie	52.3	134.6	Good.
Alpena	46.7	162.6	Polluted.
Ironwood	43.5	124.5	Doubtful.
Port Huron	42.0	78.6	Polluted.
Flint	43.0	63.0	Polluted.
Traverse City	42.0	53.5	Polluted.
Bay City	37.3	56.3	Polluted.
Lansing	33.3	56.6	Good.
Battle Creek	31.3	44.0	Doubtful.
Kalamazoo	29.5	59.0	Good.
Jackson	28.3	45.5	Good.
Muskegon	24.7	59.8	Doubtful.
Saginaw	24.6	42.0	Wells safe, river polluted.
Pontiac	24.5	44.0	Good.
Ann Arbor	22.1	18.6	Good.
Manistee	20.8	48.0	Good.

This table shows that in every instance, except Traverse City, a typhoid-fever rate above 40 was accompanied by an enteritis rate above 60. This is a high rate for these cities, considering climatic, racial, and social-economic conditions, as this rate is for enteritis under 2 years only. On the other hand, the cities with good water supplies had low rates for typhoid fever and enteritis, except Sault Ste. Marie, which will be referred to later.

Enteritis or diarrhea in children as a fatal disease may be expected to be excessively prevalent in large cities with slum districts and a large foreign population. The same excessive prevalence may be expected in so-called mill towns, where the mothers are employed in the mills and child neglect is common. Under these conditions the mortality among poor children is very great, but it is almost entirely in the period from July to October.

The relation between enteritis in children and typhoid fever can not be said to be clear. Certain facts, however, stand out prominently in studying the statistics. In cities which are too small to have slums and which have abnormally high typhoid-fever rates there is also an excessive mortality from enteritis and diarrhea in children under 2 years of age. Cities of the same class with low typhoid rates have comparatively low rates for enteritis and diarrhea of children.

The seasonal prevalence of enteritis also closely follows that of typhoid. If the excessive typhoid in these cities is due to water, then we have a high enteritis rate not only in the summer and autumn, but also in the winter and spring months. If the typhoid is independent of the water supply, then the enteritis rate, like that of typhoid, will be high in the regular season from July to October and low during the remainder of the year.

Instead of one disease designated under several different names we are probably considering several diseases with common factors of transmission. Whatever the real relation between typhoid fever and enteritis or diarrhea of children may be, one fact is clear, the same causes operate to cause excessive prevalence of both. It is probable that cases of typhoid in children under 2 years in many cities are often incorrectly diagnosed as enteritis. It must be remembered, however, that the causative agent of bacillary dysentery is transmitted in the same way and by the same media as that of typhoid. There are too many cases of fatal illness in children under 2 years classed as diarrhea and enteritis, and an exhaustive investigation should be made to establish the real cause of death in enteritis and diarrhea of children. Without such an investigation it is impossible to assign the real cause of the excessive child mortality from diarrhea and enteritis. In cities of less than 50,000 population without slums and which are not "mill" towns an enteritis rate

in children under 2 years above 100 deaths per 100,000 indicates prevalence of an acute intestinal disease preventable by the same measures which prevent typhoid fever. It is probable that in such cities proper enforcement of prophylactic measures against typhoid fever would reduce the enteritis rate below 40 deaths per 100,000. Enforcement of prophylactic measures would include the installation of pure water supplies and proper sewerage systems, coupled with a vigorous campaign against the insanitary outdoor privy and the equally dangerous shallow well.

THE SIGNIFICANCE OF TYPHOID FEVER FROM AN INTERSTATE STANDPOINT.

The prevention of the spread of typhoid fever from one State to another is necessary to reduce the prevalence of typhoid fever in cities and States, so that the prevention of typhoid fever is a national problem and a local or State problem as well. The careless pollution by sewage in one State by town A of a stream used as a water supply without filtration in another State by town B is an illustration of interstate spread of typhoid fever which is common enough. In such an instance the town A polluting the stream insists that the town B below protect itself by filtering its water supply; B insists that the town A above should render its sewage inocuous before discharge into the stream. As a matter of fact, both may be indicated, and both of these great agencies for preventing water-borne typhoid may be necessary. It is difficult for these communities to adjust their differences and decide to just what point sewage purification must be carried at A in order that too great a strain and too great a responsibility may not be placed on the filter plant at B. This is clearly an interstate matter and should be decided by a Federal authority acting under Federal law.

The significance of polluted water supplies in large industrial centers from an interstate standpoint is enormous. Trains and steamboats take their water supplies at such points and this polluted water is drunk by the passengers throughout the trip. Common carriers in interstate commerce also contribute to the spread of typhoid in interstate traffic by failure to have their railroad trains and steamboats provided with retention tanks for excreta. Human excreta may in this way be deposited in streams used as water supplies or in lake water in the vicinity of waterworks intakes.

Excessive prevalence of typhoid fever in any city which by reason of its commercial or industrial importance attracts large numbers of visitors has an important bearing upon the spread of typhoid from one State to another. The same is true of other cities which because of great natural advantages, the beauty of their surroundings, or other reasons attract thousands of tourists and visitors from other

States. For these reasons the prevalence of typhoid and the character of the water supplies in cities like Pittsburgh and Detroit, Niagara Falls, or Mackinac Island become a matter of serious moment from an interstate standpoint. The excessive prevalence of typhoid fever for years in Niagara Falls and Pittsburgh was not only a matter of local or even State concern, but a grave national danger as well.

During the five years 1904–1908, inclusive, the Michigan State Board of Health traced the origin of 663 outbreaks of typhoid fever in all parts of the State. While the figures were compiled in order to compare urban and rural communities as places of origin for the spread of typhoid, the results throw an interesting sidelight on the spread of typhoid fever from one State to another. The outbreaks traced were all in Michigan, and the figures do not show the spread from Michigan cities to other States, but reciprocity in this respect is probably the rule. The Michigan statistics show that many outbreaks were traceable to Chicago, Toledo, and Indiana cities, and occasionally to Pittsburgh, Buffalo, Philadelphia, and Washington. The following table shows the number of times responsibility for outbreaks was placed:

TABLE 14.

Origin of infection.	Times typhoid was introduced.	Percentage of total cases traced.
Grand Rapids	79	11.9
Detroit	30	4.7
Lansing	17	2.5
Ohio cities	34	20.0
Illinois cities	28	
Indiana cities	21	
Other States	50	
Canada	11	1.6
Other Michigan communities	393	59.3
Total	663	100.00

To summarize briefly, 20 per cent of the new outbreaks were traced to other States, and generally to large cities, such as Chicago or Toledo. Nearly 12 per cent of the outbreaks investigated were traced to infection in Grand Rapids.

Grand Rapids is only one-fourth the size of Detroit, and yet the number of times typhoid was introduced into other localities from the former city was two and one-half times that of Detroit. The influence of Grand Rapids in spreading the disease to other States can be inferred, as the distance from Grand Rapids to Wisconsin, Illinois, or Indiana is not much greater than the distance from Grand Rapids to points in Michigan to which the infection was carried from Grand Rapids. It is disheartening to combat typhoid fever in a restricted area which is being fed constantly by streams of typhoid carriers and patients from other communities.

In typhoid fever we have what has been called a national disgrace and what undoubtedly constitutes a national problem. Its widespread prevalence demands a concentration of effort, a coordination of all governmental forces and a simultaneous concerted action throughout the entire country directed for the sake of uniformity by a central Federal authority.

THE DUTY OF MUNICIPALITIES TO FURNISH SAFE WATER WITHOUT DELAY.

When cities have a public water supply polluted by sewage or admittedly exposed to pollution the obvious thing to do is to filter or treat the water and promptly protect the public from infection. Unfortunately there is a deplorable tendency to censure the town above and to spend years in an effort to compel (usually without legal process) sewage purification in the offending municipality. In other cities where the pollution is due to their own sewage years are lost in discussion of methods of sewage purification, while the dangerous untreated and unfiltered water is furnished to the citizens.

Two results may be attained by treatment of sewage: (1) The putrescible material may be changed to more or less stable constituents so that the effluent is stable or nonputrescible, thus obviating nuisance; (2) the bacterial content may be reduced and the pathogenic bacteria eliminated, so that the effluent will not be a factor in the transmission of disease. Sometimes sewage purification methods effect both these results. Sometimes necessity demands only the avoidance of nuisance. At other times where there is ample dilution available no nuisance can result, and the only necessary object is to secure an effluent which is not dangerous to health as a carrier of pathogenic bacteria.

Contact beds, sprinkling filters, and many other more or less complicated and expensive processes were devised primarily to avoid nuisance by charring or oxidizing the putrescible material in sewage, so that the effluent could be discharged into some watercourse without causing an offense to the senses. Various kinds of septic tanks were devised to effect the same result in another way, viz, by making use of the anærobic bacteria for getting rid of at least a portion of the solid matter by digestion—and carrying out the putrefactive changes in the tank, hoping to get a stable effluent. The amount of sludge digestion in septic tanks[1] and the character of their effluents have been a disappointment, but these methods, and especially the oxidation processes effected by sprinkling filters, are useful and often nec-

[1] The Imhoff or Emscher tank has distinct advantages over the ordinary septic tanks. The Imhoff is a "double decker," combining an upper compartment which serves as an ordinary sedimentation basin for the fresh sewage, and a lower compartment in which the solids deposited by sedimentation are held for septic action. It has all the advantages of a septic tank without its disadvantages. Moreover, the sludge which is drawn from the septic compartment dries more easily, is less offensive, and is handled with less trouble than ordinary septic sludge.

essary to prepare sewage effluents for discharge into streams with small flow to avoid nuisance and preserve fish life. From the standpoint of transmission of disease it must be remembered that these processes do not render the effluent safe, and although the putrescible material is reduced or removed the bacterial count remains high.

In considering sewage purification in cities on the Great Lakes or their connecting rivers, the question of preventing nuisance is not difficult of solution. It is estimated that a stream flow of 3 to 7 cubic feet per second will care for the sewage of 1,000 persons without nuisance, or that a dilution of 15 to 20 times the quantity of sewage discharged will be sufficient to obviate nuisance.

In view of the enormous quantity of water available for dilution, the only object to be obtained in the Lake cities by sewage-disposal plants is to obtain an effluent which does not endanger the public health by transmission of pathogenic organisms.

For public-health protection on such large bodies of water as the Great Lakes and their connecting rivers, simpler measures of sewage treatment will suffice than are necessary where avoidance of nuisance is a factor. These measures will consist of screening, sedimentation, and disinfection of the effluent. The combination of these measures to be employed, the size of the screens, the length of time of sedimentation, the degree of disinfection required, and other details will vary according to local conditions.

Disposal of sewage by dilution is the cheapest known means, and where this method can be employed without detriment to the water supplies or danger to the health of other communities the exaction of more complicated and expensive methods is scarcely justifiable.

The point to which this method of disposal may be permitted must be determined by local conditions. There is an urgent need in the United States for official standards of drinking water. These should fix the permissible number of bacteria in both raw and filtered or treated water. It is not the purpose of this bulletin to discuss such standards, but it may be suggested tentatively that the bacterial count in raw water from the Great Lakes at the intakes should not exceed 5,000 per cubic centimeter at any time and should not average above 1,000. Filtered or treated water should not contain more than 100 organisms per cubic centimeter at any time, and the average should be 20 or under.

In view of the fact that bacterial counts may be low in a comparatively dangerous water, and sometimes a high count might be found in water containing no evidence of fecal bacteria, the colon estimation is of primary importance in judging the character of a raw water. There should be standards for the permissible colon content of raw water. These should be fixed after careful study of the ability of filter plants and other processes to remove colon bacilli and other

fecal bacteria. These standards for raw water and for filtered or treated water would enable us to strike a balance between sewage purification and treatment of water, and to determine the degree of sewage purification necessary to assure a raw water of reasonable quality at a given point.

With fixed standards for raw water the disinfection of a sewage effluent with hypochlorite may be necessary only part of the time. The addition of 10 parts of available chlorine per million may be necessary to sterilize a sewage effluent or even to remove above 99 per cent of the B. coli, yet 2 parts per million may remove about 90 per cent of the B. coli, and coupled with other factors may be sufficient purification to furnish a good raw water. Instances will be found as at Rochester, N. Y., where simple screening, slight sedimentation, and discharge a mile or more from shore through multiple outlets in deep water will apparently suffice. In all such instances the right must be reserved by the authority granting the permit to require further purification when necessary by lengthening the time of sedimentation, disinfection of the effluent, and other details. Similar standards to these tentatively suggested, if officially indorsed, could be used as a basis for determining to what extent disposal by dilution is permissible. Municipalities would be unwise if they failed to avail themselves of dilution as a means of sewage disposal, provided such use of streams or lakes did not endanger the water supplies or affect the public health of other communities.

In regard to sewage disposal it must be remembered that no general rule can be formulated which will cover with justice every case. Each municipality becomes a separate problem, and local conditions must be studied. Remedies for correction of improper sewage disposal will differ according to the local conditions. It is safe to assume in a general way that no crude sewage should be discharged into Lake Erie, or perhaps the southern end of Lake Michigan, because of shallow depth and exposure to wind action. The same conditions do not exist on the other lakes, and different remedies may suffice. Even in Lake Erie, the kind of purification and the extent to which it must be carried will differ according to local conditions. Even if all the sewage from our large cities and towns was prevented from reaching the Lakes, it would be impossible to prevent pollution from entering the lake in times of storm and flood, so that sewage disposal even carried to the degree of sterilizing the effluent does not give us a substitute for water filtration or treatment. While it is impracticable to prevent pollution of the Great Lakes, it is possible and imperatively necessary that such pollution be controlled and kept within safe bounds. It would be inadvisable from an economic standpoint not to avail ourselves of the cheapest and simplest method of sewage disposal, viz, disposal by dilution, provided that

this may be done without danger to the water supplies of other communities and without putting an unreasonable burden and excessive responsibility upon the filter plants of those communities. In general, it is cheaper to treat drinking water than to purify sewage. The economic side of the question must be considered. How far is it necessary to carry the treatment of sewage as an adjunct to water purification? The balance between these two powerful agencies in the protection of the public health must be struck, and, as intimated above, this must be done separately for each local problem, and no definite rule for the relation of these agencies can be made.

Simple justice would demand that sewage purification at A should be carried far enough so that the raw water at B's intake would be reasonably good. On the other hand, B is not absolved from the duty of protecting its citizens by filtering or treating its water supply by the fact that sewage purification should be effected at A. Further, the installation of a filter plant or other device for rendering the public water supply safe at B does not justify the unrestrained discharge of untreated sewage by B which would produce for itself, or other cities, a raw water of a dangerous character.

For impartial treatment of all conflicting interests concerned in sewage pollution of interstate waters, the control of pollution and the power to prevent the passing of the boundary of permissible pollution should be defined by law. This would insure a minimum requirement of safety, leaving to the States, precisely as in quarantine law, the power to impose additional restrictions upon municipalities within the State boundaries.

These sewage problems are often difficult of solution, present great engineering difficulties, and necessitate the expenditure of large sums of money. This means that much time must elapse before the proper method is selected, and a great deal more time will pass before the works are completed. In the end, though necessary, the sewage purification does not remove all pollution, and treatment of the water supply is still a necessity after the sewage-disposal plant is in operation. On the other hand, the dangerous public water supply is a simpler problem. Immediate protection can be afforded by treating with "hypochlorite," using a temporary plant until the method to be finally adopted is decided upon. In a word, there is every excuse for deliberation and reasonable delay in settling the sewage-disposal problems, while there is no excuse for any municipal government to delay in applying the remedy which protects immediately, viz, treatment or filtration of the public water supply. Sewage-disposal measures for improving the quality of the raw water for preventing its deterioration or for other reasons may be undertaken when necessary and feasible.

II. LAKE SUPERIOR AND ST. MARYS RIVER.

The drainage area of Lake Superior in United States territory comprises part of northern Minnesota and Wisconsin and about half of northern Michigan. The watershed is narrow and the streams short and unimportant, with the exception of the St. Louis River. The rural population is very small and scattered and a negligible quantity in the the question of lake pollution. There are no communities on the watershed of more than 10,000 population, except Duluth, Superior, Ashland, Marquette, and Sault Ste. Marie. These cities are distributed along a coast line of more than 350 miles. Obviously under these conditions sewage pollution can have only local effect with Lake Superior's great depth and enormous volume of water.

The only cities in close proximity to each other are Duluth, Minn., and Superior, Wis. The others are so situated that each constitutes a purely local problem.

Sault Ste. Marie presents slightly different features, being situated on the St. Marys River, a very rapidly flowing stream. Even here sewage pollution from Sault Ste. Marie can not be considered a menace. It travels through a long stretch of rapidly flowing river, passes a series of natural sedimentation basins, and finally passes through Detour Passage into Lake Huron. Through the entire route no towns or cities are met with, and the ultimate disposal into the great, deep Lake Huron effectually cares for any lingering traces of pollution which might persist to this point.

The water of Lake Superior is of excellent quality and safe for drinking purposes if it can be drawn from a point beyond the zone of pollution which surrounds the water front of each of these cities. Even here, however, the zone of pollution varies with the effects of storm and flood and of winds and currents, so that to be sure every day in the year of being outside of the ever-changing boundary of this polluted zone it would be necessary to go considerable distances from shore. In this deep lake the placing of such an intake would often present engineering difficulties and necessitate expenditures which would be in excess of the cost of other methods of rendering the water safe. There are other special features of Lake Superior water. Because of its great depth, the wind action disturbs the bottom often only a short distance offshore, and turbidity is avoidable most of the time with deeply placed intakes. This suggests that treatment other

than filtration would in some instances fulfill every sanitary indication by destroying the pathogenic organisms, the water in itself being palatable and clear. The hypochlorite method of treating water would be very useful with such waters. There is said to be very little organic matter in the deep lake water, however, and careful supervision would be necessary to avoid overdosing with the hypochlorite. The dearth of organic matter and the clearness of the water suggest the use here of the ultra-violet rays for sterilization, especially where electric power is available and cheap.

This method of sterilization or disinfection of water is in the experimental stage, but the small quantity of colloidal material and the clearness of the water suggest possibilities for this method with the water of Lake Superior. Further experimentation is necessary to show whether the cost of installation and maintenance is less or greater than other methods. The same is true of ozonization. The possibility that the usual preliminary treatment might be unnecessary in Lake Superior and the existence of abundant electric power suggest possibilities for this method also.

DULUTH.

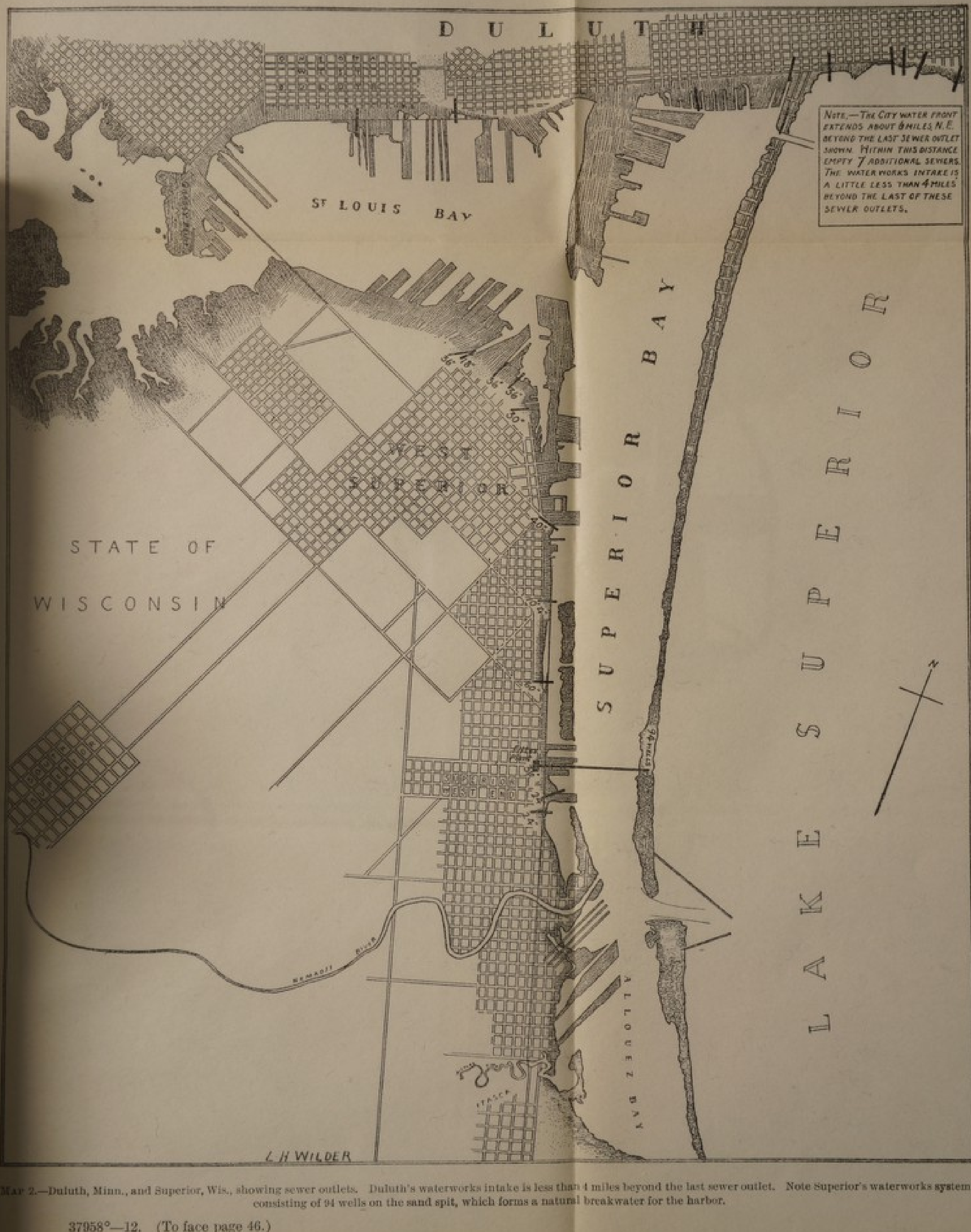
Duluth had a population in 1910 of 78,466. Its harbor, owing to natural and artificial advantages, is one of the most important on the Lakes. Duluth, by reason of its fine harbor facilities and position, has always been regarded as a metropolis in embryo. Its commercial and industrial development has been slower than anticipated by many, but is steady, nevertheless, and Duluth is now one of the most important ports in lake traffic.

SEWER SYSTEM.

The sewer system of Duluth is of the combined type. The outfalls discharge into the St. Louis Bay, the harbor, and Lake Superior. (See map No. 2.) There are 5 large sewer outfalls discharging into St. Louis Bay, 3 into Duluth Harbor, and 12 into the lake from the harbor entrance to Lester River, a distance of about 4 miles. There is a so-called septic tank on the east side of Lester River, but no sewer outfalls exist beyond this point, which is a little less than 5 miles from the waterworks intake.

The steep grade from the water's edge to the high ground behind Duluth retarded the growth of Duluth except along the water front. As a result, Duluth is situated on a long and narrow strip of land and extends for about 15 miles along the shore of St. Louis Bay and Lake Superior.

To pick up these various sewer outlets with an intercepting sewer would be a difficult engineering feat, because of its length and the



MAP 2.—Duluth, Minn., and Superior, Wis., showing sewer outlets. Duluth's waterworks intake is less than 4 miles beyond the last sewer outlet. Note Superior's waterworks system, consisting of 94 wells on the sand spit, which forms a natural breakwater for the harbor.

flat grade. Unless pumping was resorted to, several stations would be necessary in disposing of Duluth's sewage.

Sewer construction in Duluth is also costly, because excavation is usually through rock. Considering the difficulties and the cost, Duluth is one of the cities where sewage disposal other than by simple dilution should not be required, unless absolutely essential for the protection of the public health. Sewer extension and also extension of water mains have been retarded by the cost of construction through rock, and even where the city sewers and water mains are available, often the property owner finds the cost of connection excessive largely as a result of the underlying rock. There are far too many privies in use in Duluth.

WATERWORKS.

The intake of the Duluth waterworks is 9 miles northeast of the harbor entrance and 1,500 feet offshore in a 75-foot depth. The intake is 15 feet above the lake bottom and 60 feet below the lake surface.

The water is taken through a 60-inch steel pipe to the pump well and from thence pumped by electric pumps to the various reservoirs because of the different levels from which the water must be distributed. Their storage capacity is not sufficient to be considered a factor in purifying the water. There is no filtration or other treatment of the water. The water is said to be free from turbidity at all times, even when the flood waters of the St. Louis may be seen on the lake surface over the intake. The great depth is pointed to as the explanation of this lack of turbidity. Ordinary wave action does not disturb the lake bottom in the 75-foot depth. Only rarely do the stained and muddy flood waters reach over the intake, and possibly at these times there is some turbidity, or the flood water may be carried away by surface currents before sufficient sedimentation has taken place to be apparent in the intake water.

Analyses have been made of the public supply and seem to show a good potable water. Analyses made by the local bacteriologist showed the presence of B. coli July 19 in the West Duluth reservoir and on July 25 in the Thirty-fourth Avenue east reservoir.

The presumptive test for B. coli was probably used.

On July 24 a sample was examined by the Wisconsin State Laboratory, at Madison, Wis., with the following result:

Number of bacteria per cubic centimeter in gelatin, 18.

No liquefiers were found among the organisms, the bacteria found being of the common water type.

Glucose fermentation tubes—1 c. c., no growth; 10 c. c., growth in open arm only; 10 c. c., growth, with production of 15 per cent gas. The gas formula was apparently all hydrogen.

The organisms found were not of the colon type.

On the basis of the analysis made, it appears that the water sample is of good quality and shows no signs of contamination with sewage water. The water can accordingly be regarded without suspicion.

On July 26 a sample from the Thirty-fourth Avenue reservoir was found negative for B. coli by the local bacteriologist. On September 12 a sample was examined at the Wisconsin State Laboratories and reported on September 20, 1911, to the Duluth Water Commission by Prof. Russell, as follows:

The sample of water submitted by you for analysis was received in good condition September 12 and shows the following conditions upon examination:

Number of bacteria per cubic centimeter in gelatin, incubated for 48 hours............90.

Character of bacteria found...................Ordinary water organisms.

Glucose fermentation tubes:

No growth in 0.1 c. c.

10 per cent gas in 1 c. c.

18 per cent gas in 10 c. c.

Litmus lactose agar plates....................6 colonies, 2 of which were acid-forming types.

Character of organisms isolated from acid colonies does not indicate same to be of fecal type.

The above conditions are substantially similar to those which have occurred in previous analyses, in which there has been the development of gas in glucose fermentation tubes. The character of the organisms isolated therefrom does not appear to be of the colon or fecal type, and while the presence of such organisms is indicative of the introduction of land drainage, there are no indications that such pollution can be traced to sewage origin.

These results are inconclusive; gas formers in glucose fermentation tubes and acid formers on litmus lactose agar plates were found by both bacteriologists. The local bacteriologist interpreted this to mean the presence of B. coli; Prof. Russell that "the character of the organisms isolated from acid colonies does not indicate same to be of fecal type," and later "while the presence of such organisms is indicative of the introduction of land drainage, there are no indications that such pollution can be traced to sewage origin."

The analyses of which I was able to obtain copies were made at the most favorable season of the year when weather conditions make pollution of the intake unlikely.

POSSIBILITY OF POLLUTION AT THE INTAKE.

Pollution of the Duluth intake may take place from two sources: First, the so-called shore pollution or washings of the land surface during and after heavy rains; and, second, the sewage of Duluth itself. The pollution following heavy rains forms a zone along the shore line which reaches at times beyond the intake. Under normal conditions this shore pollution would be disposed of by surface currents in shallow water along the shore without involving the lower stratum of water about the intake 60 feet below the surface and 1,500 feet off-

shore. At times, however, northeast gales pile up the water at Duluth. In spite of continuance of the gale, the water does not rise more than a few feet. The enormous volume of water being driven inshore by a surface current with the wind is carried back by an undertow which prevents the rise beyond 2 or 3 feet at first and soon equalizes the lake level, the water line dropping to normal. This undertow during the first hours of its operation carries the polluted surface water near shore down with it over the intake even at a depth of 60 feet. That this actually takes place is strongly supported by a series of observations made by the engineer at the waterworks. He keeps close record of the temperature of the water on the lake surface and in the well as it comes from the intake.

It was noted that when a northeast gale began to blow, the temperature of the surface water was 12° higher than the temperature of the intake water. As the gale continued the temperature of the intake water increased till it reached the temperature of the surface water. The enormous mass of surface water driven inshore could not find its way back in the face of the gale, but returned as an undercurrent, passing over the intake, which at such times receives surface water. During the first few hours this surface water is from the polluted zone near shore; later it is the surface water driven in from the lake by the force of the wind. This undercurrent, which undoubtedly operates at times, makes possible the pollution of the intake provided sewage pollution exists in the surface water near the intake. This pollution of the surface water near the intake may be due to washing of the land surface during and after heavy rains and to currents which carry sewage from Duluth's outfalls toward the water intake.

In considering pollution from surface washings, it must be remembered that this is a "quick spilling" country, with steep grades for the water courses, and rock very near the surface. The surface washings of the whole countryside are quickly carried to the lake without opportunity for the action of the natural agencies of purification. The country behind the intake is suburban and settling up rapidly. That portion of Duluth between Lester River and the intake has no sewers, but the pollution from cesspools and privies is washed quickly into the lake. Pollution from Duluth's sewers may reach the vicinity of the intake. There are 12 outlets outside the harbor entrance, one of them less than 5 miles from the intake. The discharge of St. Louis Bay and Duluth Harbor, polluted by the sewage of Duluth and Superior and the pollution carried down by the St. Louis River, is about 9 miles from the intake. The main discharge of this polluted water is through the entrance to Duluth Harbor, although Superior entry carries its quota to the lake.

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The currents in the harbor entrance, or Duluth Canal, vary according to the oscillations of the lake level, the direction and velocity of the wind, and the stage of water in the St. Louis River. Occasionally a velocity of 6 miles per hour is reached. The duration of such a current depends upon the amplitude of the oscillation in the lake, and is therefore the length of time necessary to fill or empty the harbor to the level of the lake. Ordinary surface currents due to wind could easily carry sewage pollution 4 or 5 miles to the vicinity of the intake.

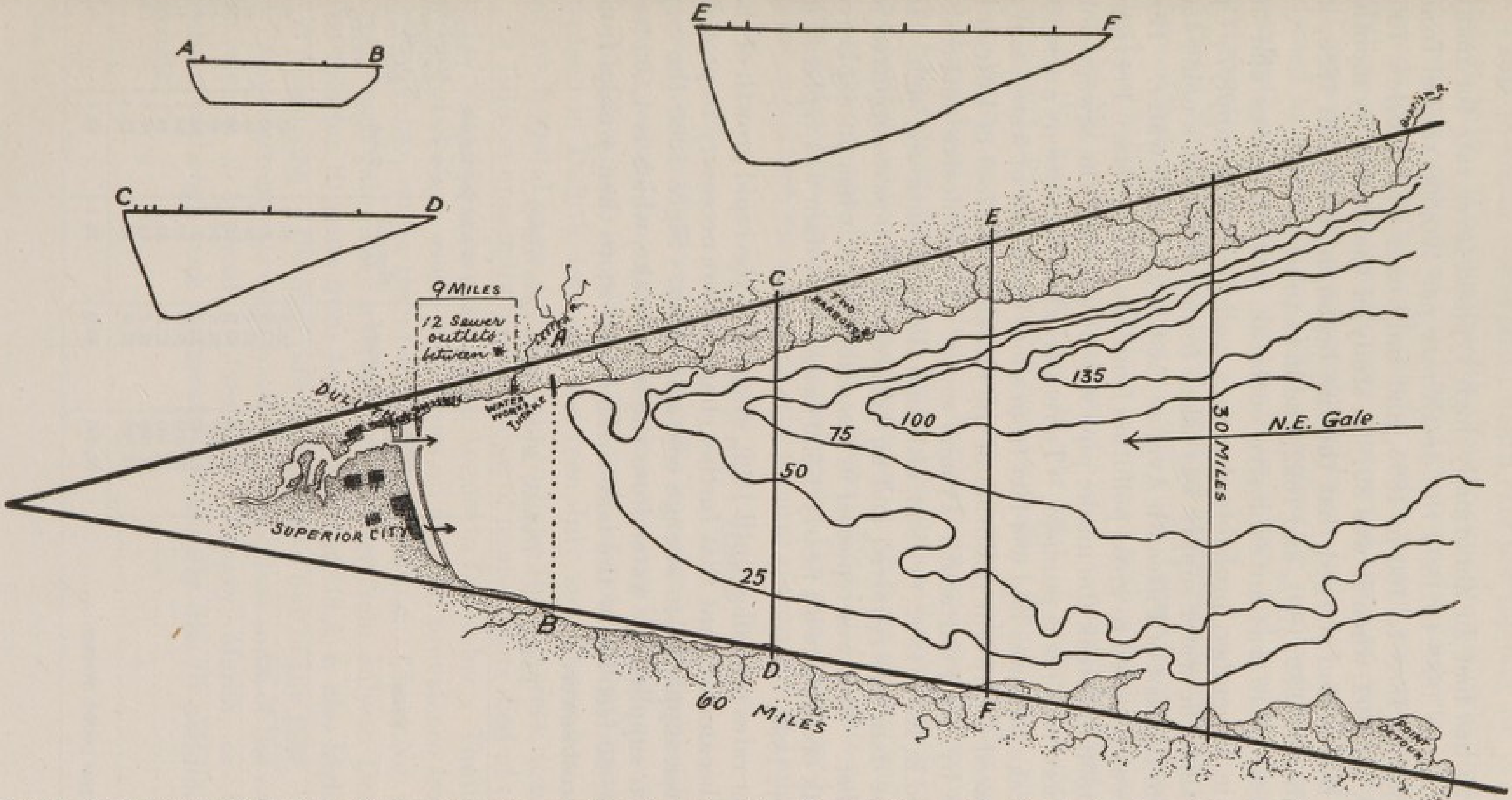
During floods in the St. Louis River there are outward currents through the canal of 4 to 7 miles per hour continuing for several days. Such floods occur only once in four or five years, but at such times the flood water is projected far out into the lake, and its presence is indicated by its distinctive color. It is possible also that pollution from as great a distance as 10 miles (from within the harbor) may be carried to the intake by an undercurrent.

In estimating the effect of this undercurrent it is necessary to consider separately that portion of Lake Superior which lies west of the Apostle Islands. This is a body of water comparatively long and narrow with a general direction for its long axis from northeast to southwest. It is roughly a triangle, with Duluth and Superior in the apex. The base line from Point Detour to Baptism River would be about 30 miles across, and from base to apex measures about 60 miles.

Into this triangular area, northeast gales drive the surface water toward the apex at Duluth. The rising of the water at Duluth to an abnormal height at such times is only prevented by the powerful undercurrent, which carries the water back toward the principal portion of the lake. With this undercurrent operating, the contents of Duluth Harbor and St. Louis Bay would be carried out toward the lake and replaced by lake water brought in by the surface current. A portion of the polluted harbor contents would necessarily pass over the intake diluted by the purer lake water. The amount of dilution which would take place is problematical.

The triangle is 10 miles wide outside the harbor entrance and widens gradually to 30 miles at the base; at the intake it is 14 miles from shore to shore. The depth also increases from 20 feet to 180 at the intake line and to 800 to 900 before the base line is reached. This increase in width and depth enormously increases the area of the cross section, increases dilution, and slows the velocity of the current.

The depths given on lake survey charts indicate that the deep channel is on the intake side of this triangular body of water. The contour lines on Map 3 show that the current on this side would have greater velocity and that the bulk of the water is returned to the lake on the intake side. With a sudden emptying of the Duluth Harbor, the bulk of the polluted water would pass on the intake side of the triangle toward the lake, and moreover would be carried more rapidly on this side than on the shallower side.



MAP 3.—Shows the triangular shape of the extreme western portion of Lake Superior. The small figures, AB, CD, EF, show the relative depth in cross sections of the lake at these points. The contour lines indicate that the intake side has the greatest depth, and carries the bulk of the water returning as an undertow to equalize the lake level during or after prolonged northeast gales.

TYPHOID FEVER IN DULUTH.

Duluth has had an abnormally high typhoid-fever rate for many years. From 1888 to 1895 the death rate per 100,000 ranged from above 300 in 1888 to 160 in 1895, and only once was it below 100, namely, in 1892, when it was 89. A study of the deaths by months during this period showed that the rise began in August in 1888, in September in 1889, 1891, and 1892, and in October in 1893.

In 1890 there was an explosive outbreak with 250 cases and 30 deaths in December, probably due to a polluted water supply. Up to this time the water supply was taken from the lake at a point 450 feet from the foot of Fifteenth Avenue East in 25 feet of water. This intake was exposed to gross pollution from near-by sewers. Previous to the 1890 outbreak the intake pipe was broken and the sewage-polluted shore water was pumped. To remedy these conditions a new 20-inch intake pipe was laid 684 feet from shore in 59 feet of water, and a dam placed to prevent pollution of the intake at the foot of Fifteenth Avenue by the Fourteenth Avenue sewer. No explosive outbreaks occurred in 1891, 1892, or 1893, although the rate continued high. In 1894 the dam was removed and an outbreak of 300 cases occurred in December. This was repeated in December, 1895, when an explosive outbreak occurred with nearly 1,500 cases. The dam was replaced in January, 1896.

Lower rates prevailed until 1899, when, with the rapid growth of the city, it became evident that further changes were necessary to protect the water supply from sewage contamination. Since 1900 the city has been supplied by water from the new intake, which is 1,500 feet offshore, 60 feet below the lake surface, and more than 4 miles from the nearest sewer.

TABLE 15.—*Duluth, Minn., health office records.*

Years.	Estimated population.	Typhoid fever deaths per 100,000.			United States census reports, typhoid-fever death rate per 100,000, Duluth.
		Resident.	Nonresident.	Total.	
1901	55,000	36.3	25.4	61.7	75.3
1902	57,500	27.8	20.8	48.6	55.4
1903	60,000	45.0	20.0	65.0	67.9
1904	62,500	40.0	12.8	52.8	54.4
1905	65,000	24.6	24.6	49.2	44.7
1906	67,500	22.2	20.7	42.9	46.0
1907	70,000	28.5	10.0	38.5	41.6
1908	72,500	27.5	22.0	49.5	56.8
1909	75,000	21.3	18.6	39.9	52.0
1910	77,500	27.0	46.4	73.4	....
Ten-year period, average	66,250	30.0	22.1	52.1	....

Table 15 shows the typhoid death rate per 100,000, by years, from 1901 to 1910. The local health office records are somewhat lower than the records taken from the United States census reports. The local records give also the death rate for residents and nonresidents. Some of these nonresidents may have contracted the disease in Duluth, but all persons whose permanent residence was not in Duluth were classed as nonresidents. This classification into residents and nonresidents changes what appears to be a very bad record into merely a high rate.

Chart No. 3 shows the total typhoid death rate in Duluth and also the resident rate, for 10 years, 1901–1910, taken from the records of the local health office. Duluth is charged with a typhoid death rate per 100,000 (average for 10 years) of 52.1. As a matter of fact, according to the local records, over 42 per cent of Duluth's typhoid for 10 years has been imported from outside. Duluth does not suffer alone in this regard. Other northern cities on Lake Superior and Lake Michigan have large numbers of lumberjacks and miners brought into the hospitals for treatment. Some hospitals sell tickets to miners and lumbermen, while others have contracts with large mining and lumber companies to care for their sick. Even taking this fact into consideration and subtracting the imported cases, the remaining resident rate is much too high for a city with the natural advantages of Duluth.

CAUSES OF DULUTH'S TYPHOID.

It is reasonable to suppose that the importation of typhoid from the iron ranges into Duluth is a factor in increasing Duluth's resident rate. During the past 10 years 72 per cent of nonresident deaths from typhoid in Duluth occurred between July and December. Nearly all are hospital cases and are said to have their excreta disinfected.

In 1910 an unusually large number of nonresidents died of typhoid, and of these 88 per cent died from August to December. The influence of imported cases would be exerted on typhoid prevalence from July to December, rather than from January to June. Chart No. 4 shows a very high rate—40.5 average for 10 years from July to December. The rate for 10 years from January to June (18.4) is also high, but in just proportion to the high rate in the second half of the year.

The persistence through contact may explain some of the excessive prevalence of typhoid in January, February, March, or April in Duluth, although such outbreaks are usually due to polluted water or milk.

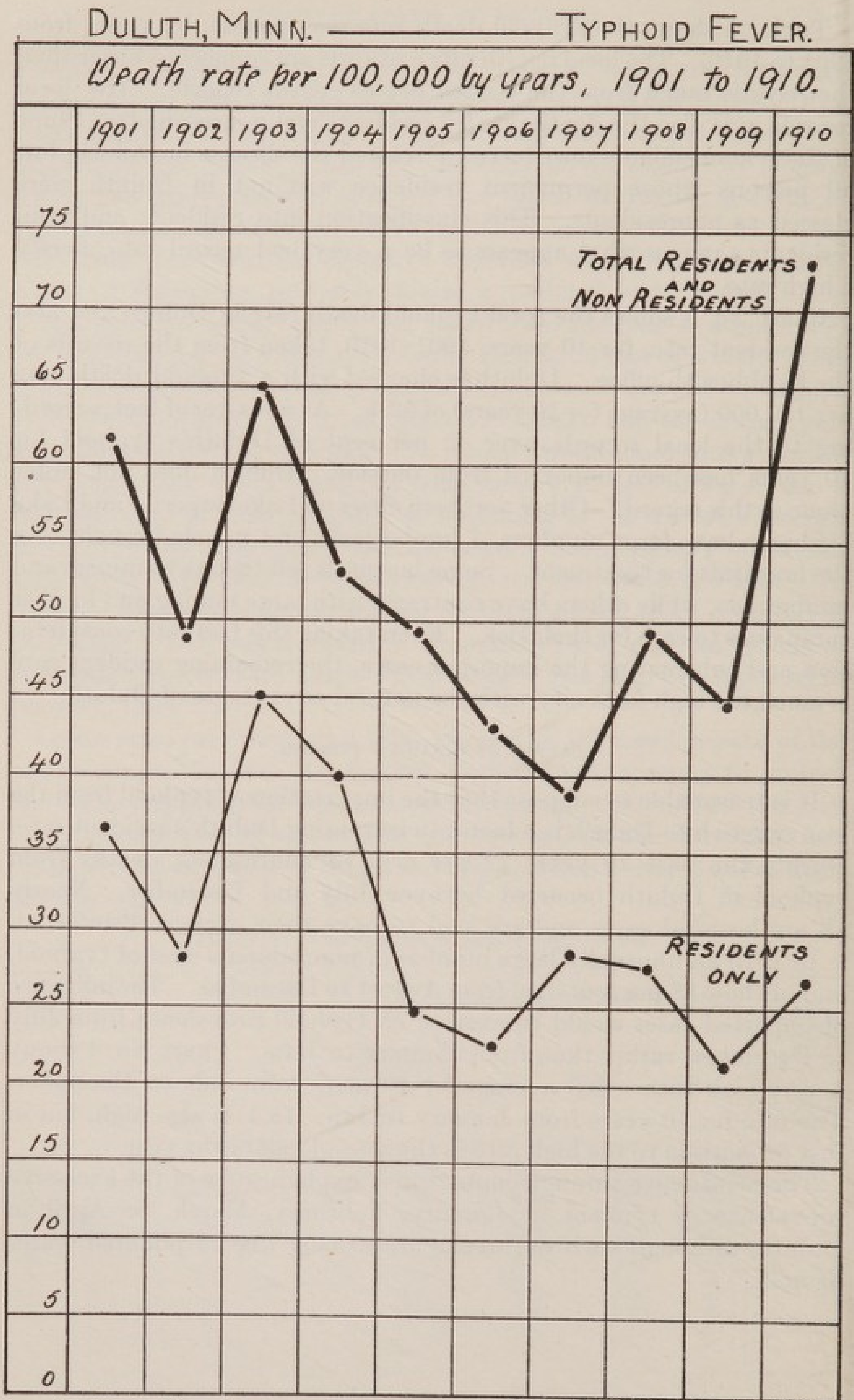


CHART 3.—Duluth, Minn. A large part of Duluth's typhoid is imported, but the rate for residents only is high.

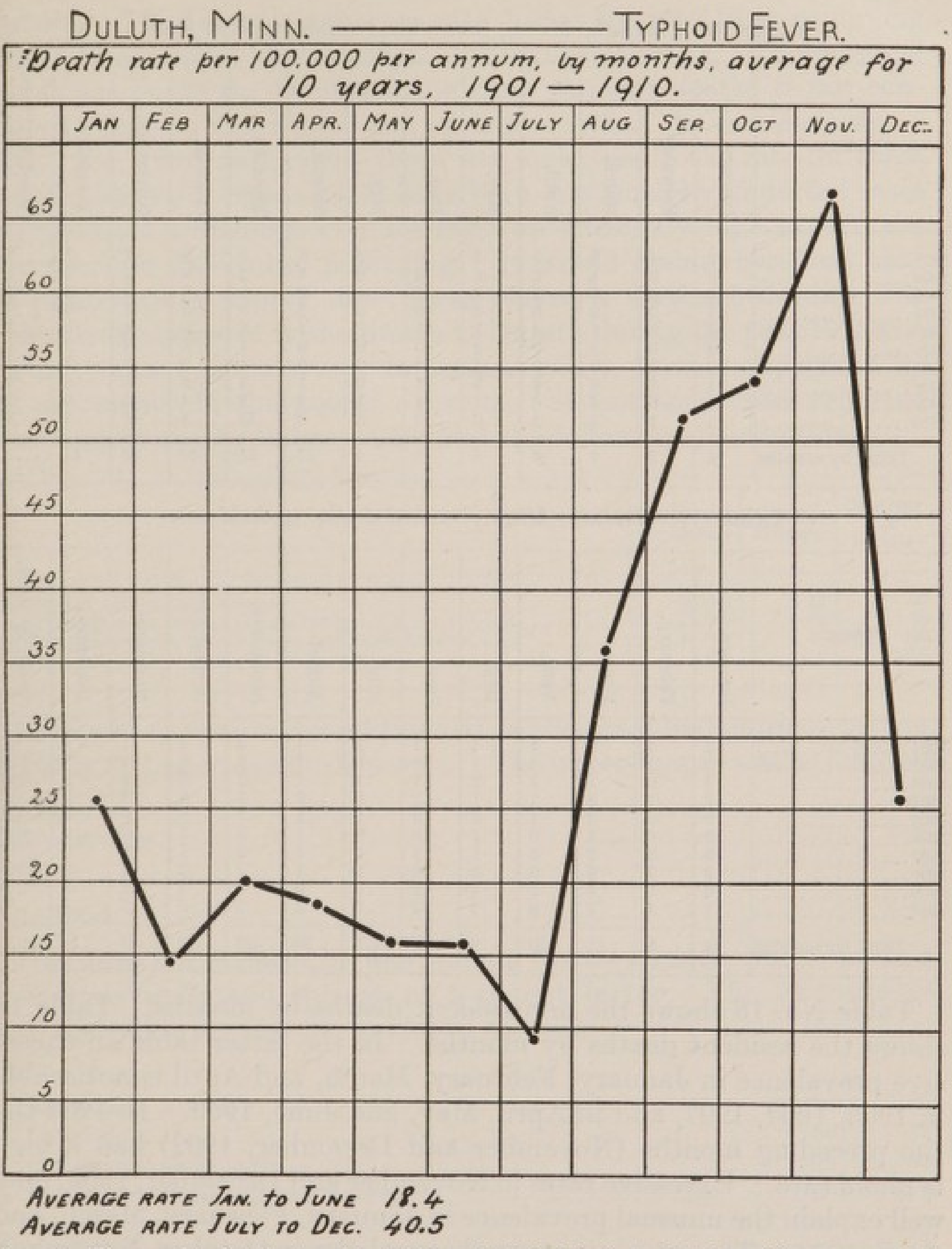


CHART 4.—The monthly distribution of typhoid fever in Duluth indicates that the public water supply is not a great or consistent factor

TABLE 16.—*Duluth, Minn., nonresident deaths, typhoid fever.*

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total, by years.
1901	2	1	0	1	1	0	2	0	3	2	1	1	14
1902	0	0	1	0	0	0	0	3	2	4	2	0	12
1903	0	0	1	5	0	0	0	0	1	3	1	3	14
1904	1	0	0	0	0	0	0	2	0	3	2	0	8
1905	0	0	1	1	1	1	1	1	2	2	6	0	16
1906	0	0	1	0	0	0	0	0	1	6	4	2	14
1907	0	1	0	0	1	0	0	0	1	2	1	1	7
1908	1	0	0	0	0	1	0	1	3	5	5	0	16
1909	1	0	4	0	1	1	1	1	1	4	0	0	14
1910	1	1	1	1	0	0	0	4	10	8	6	4	36
Total, by months	6	3	9	8	4	3	4	12	24	39	28	11	......

TABLE 17.—*Duluth, Minn., resident deaths, typhoid fever.*

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total, by years.
1901	2	1	2	1	1	1	2	1	3	4	1	1	20
1902	0	1	1	1	1	0	0	1	2	3	4	2	16
1903	4	0	1	3	2	1	1	1	2	6	4	2	27
1904	2	2	2	2	1	2	0	5	3	3	3	0	25
1905	0	0	0	1	0	0	2	1	3	2	6	1	16
1906	0	0	1	0	2	0	0	1	3	1	5	2	15
1907	3	2	2	0	1	2	0	4	2	1	3	0	20
1908	2	1	0	0	0	0	0	3	5	2	7	0	20
1909	0	0	0	2	1	3	0	0	3	3	2	2	16
1910	1	1	2	0	0	0	0	3	3	5	2	4	21
Total, by months	14	8	11	10	9	9	5	20	29	30	37	14	......

Table No. 16 shows the nonresident deaths by months. Table 17 shows the resident deaths by months. In the latter table an excessive prevalence in January, February, March, and April is noticeable in 1903, 1904, 1907, and in April, May, and June, 1909. In 1903 the the preceding months (November and December, 1902) had a high typhoid rate. Excessive rates in November and December, 1903, may well explain the unusual prevalence in January, February, March, and April, 1904. There was an unusual prevalence in October, November, and December, 1906, and it is not strange that January, February, and March, 1907, should have high rates also. In 1909 an excess is noticeable in April, May, and June. It is significant that 4 nonresident cases died in Duluth in March, 1909.

In 1905 and 1906 the prevalence in January, February, March, and April was low, and it will be noted that the preceding Decembers had very low rates. In December, 1908, there were no deaths reported in Duluth, and January, February, and March, 1909, had no deaths among residents.

Judged from the records furnished by the commissioner of health, imported cases are responsible for over 40 per cent of Duluth's gross

typhoid. This leaves an average rate during the past 10 years among Duluth residents of 30 deaths per 100,000 per annum. The seasonal prevalence curve for Duluth made from resident deaths is not consistently high in the winter and spring months. In certain years—1903, 1904, 1907, and 1909—there was an excess in the rate for these months, but such excess could have been explained by imported cases and persistence through contact from an unusually high rate in the November or December preceding. It would seem, therefore, that the public water supply must have played a very subordinate rôle in the transmission of typhoidfever in Duluth during the past 10 years.

That contact plays a very important rôle is further supported by the prevalence in the poorer districts. Seventy-one cases reported from August to December, 1910, had the following distribution:

	Estimated population.	Number of cases.	Case rate per 100,000.
Best district, east of Lake Avenue	40,000	15	37
Second best district, west of the ore docks	25,000	22	88
Poor district, between the ore docks and Lake Avenue	20,000	30	150
Worst district, in the vicinity of Park Point	200	5	250

In regard to sanitary conditions 41 of the cases had outdoor privies and only 30 had inside flush closets. The water supply was as follows:

City water	61
Wells or springs	5
Creek	5
Total	71

This does not necessarily incriminate the city water, but does tend to exclude wells and springs as a potent factor. The 71 patients gave the following history in regard to milk:

Use of milk:	
Not at all ... number	10
Coffee only ... do	19
Coffee and cereal only ... do	33
Coffee and cereal and as a beverage ... do	9
Total	71

While the above table does not point strongly to milk as a factor, and the control of milk in Duluth is above the average for American cities, the table showing incidence by ages is striking:

Ages.	Number attacked.	Ages.	Number attacked.
0–5	5	41–50	4
6–10	15	Over 50	2
11–20	15		
21–30	23	All ages	71
31–40	7		

It is often stated that excessive prevalence of typhoid in children under 10 suggests milk as the agency of transmission. It is doubtless true that infected milk will take its heaviest toll from the young children; on the other hand, children, especially in the poorer districts, are ideal subjects for contact infection, and may have a high incidence independent of the agency of milk. During the warm season in the insanitary districts with outdoor privies flies probably play a part in transmission.

It is undeniable that the water supply of Duluth from the present intake is infinitely superior to the old one and has prevented many cases of typhoid fever. That it is an absolutely safe supply is quite another matter. As shown above, it is exposed to pollution under certain storm conditions. That the pollution is dilute prevents explosive outbreaks; occurring probably at rare intervals, it may cause a number of cases which can never be traced to water with certainty.

HOW TO DETERMINE THE NECESSITY FOR SAFEGUARDS.

The prevailing storms on Lake Superior are from the northwest and the northeast. A gale from the northeast is one of the necessary factors in sewage pollution of Duluth's intake. The prevailing wind direction at Duluth is northeast from February to October.

The velocity of this northeast wind has been as high as 78 miles per hour (September, 1881) and has been as high as 58 and 60 in April and May. The amount of sewage dilution is large and the distance from the nearest sewers is over 4 miles. On the other hand the amount of pollution added daily by Duluth and Superior is considerable and growing progressively greater every year.

Unfortunately the Duluth water supply has not been examined frequently. The water company has examinations made about once a month, and the local board of health has examinations made occasionally. To settle definitely the question of sewage pollution of Duluth's intake will necessitate daily examinations with careful quantitative colon estimations, for a long period, preferably an entire year, during which at least one prolonged northeast gale occurs.

Duluth resembles Detroit in having selected an excellent site for its intake, and one from which the best available raw water can be secured. It is the duty of municipalities to furnish a safe water every day in the year and every day during a period of several years. There is a strong probability that Duluth's intake may receive a dilute sewage pollution at rather rare intervals. At any rate the possibility exists. The amount of dilution makes it unlikely that a massive explosive outbreak will occur, but occasionally cases may be due to the water, although the origin is difficult to trace.

The only way to definitely determine the necessity for treatment or filtration is by the daily examinations for a long period referred

to above. In such cases the greatest care should be exercised in the quantitative estimation of B. coli. The bacterial counts are of minor importance. These are often low in lake waters, and altogether too much dependence has been placed in this fact. In Prof. Russell's examination given above, the count on gelatin incubated for 48 hours was only 90, yet 1 c. c. produced gas in glucose fermentation tubes. On litmus lactose agar plates out of 6 organisms, 2 were of the acid forming type, which, however, Prof. Russell attributed to land drainage rather than sewage pollution. The present method of monthly examinations will never settle the question with any degree of certainty.

It is likely at the present time that some treatment or filtration of the water will be found necessary at certain times of the year. It is certain that such treatment or filtration will be more urgently needed as the cities at the mouth of the St. Louis grow.

SAFEGUARDS WHICH MAY BE APPLIED.

Probably the cheapest method will be the addition of hypochlorite. This will have to be carefully done under expert supervision. There is so little organic matter that overdosing might easily occur, which though not a serious accident, would result in imparting a decided taste and odor to the water and cause complaints from the consumers. The lack of turbidity and comparative freedom from organic or colloid material make possible the use here of two other methods in addition to the various methods of filtration, namely, ozonization and disinfection with ultra-violet rays.

Ozonization has been tried and found effective when proper preliminary treatment was used. This preliminary treatment added to the expense, and ozonization has therefore not become popular. It is possible that ozonization might be applicable economically at Duluth because preliminary treatment of the clear Lake Superior water would seem unnecessary.

The use of the ultra-violet rays for water disinfection is still in the experimental stage. Its economic use necessitates a clear, raw water with dearth of colloid material. The Lake Superior water fulfills these indications practically all the time. In view of these conditions and the existence of abundant electric power at Duluth, successful practical application of the ultra-violet rays to Duluth's water problem is a possibility.

The first thing to determine is the necessity for filtration or treatment. This can be done by the daily examination of the water for a long period. If such necessity is shown to exist, the selection of a remedy should be made by competent engineers after an intensive study of local conditions. The question is not solely one of securing a safe water at all times, but the method applied should be the one

which will secure this result with the least cost to the community. The various methods of filtration would of course be considered, and the other methods spoken of above are only mentioned because of the possibility of their successful application with low cost.

SUPERIOR.

Superior, Wis., is a rapidly growing city with a splendid harbor, separated from Duluth by the St. Louis River and Bay. In 1890 it had a population of about 12,000, which increased in 10 years to 31,000. The population in 1910 was 40,384.

SEWER SYSTEM.

The sewers of Superior empty by 12 outlets as follows: Five into St. Louis Bay, 6 into Superior Bay, and 1 into the Nemadji River. The sewers are of the combined type and have a total length of about 55 miles. There is no treatment of sewage. (See map 2.) Only about 60 per cent of the population have access to sewers, and the remaining 40 per cent depend upon privies, many of them of a most insanitary character.

WATER SUPPLY.

The Superior water supply is controlled by a private corporation, the Superior Water, Light & Power Co. The first intake was from Tower Bay Slip. Sewage pollution forced its removal to a point 2 miles southeast in the bay. The growth along the water front and increasing pollution forced the abandonment of this intake also. In 1889 the present water company took charge and in 1891 built the present plant. In 1900 this plant was enlarged to its present capacity. The 24-inch intake pipe at first extended 4,350 feet under the polluted water of the bay, 600 feet across Minnesota Point and 1,800 feet out into the lake. (See map 2.) A glance at the map will show the position of the intake between the two harbor entrances, 4 miles from the Duluth entry, and only 1¼ miles from the Superior entry. Sewage pollution occurred, and the lake supply after being used for 5 years was given up in 1897. A system of wells was installed on Minnesota Point. Eighty wells were jetted to depths of about 40 feet; these were all connected with a header, each well being separated from the header by a nipple and gate. They were connected to the old 24-inch intake which formerly supplied lake water and carried it across under the polluted bay water. The lake water was shut off by a gate which might be opened in case of emergency, permitting lake water to be pumped. The new water was a disappointment on account of color and high iron content. A plant was designed to primarily overcome these defects. The plant was similar in design to those in use in Far Rockaway, Long Island, and other places. In

these plants thorough aeration and the removal of the carbonic acid were the essential features. Such treatment chemically changed the iron from a soluble to an insoluble state, or, in other words, oxidized the iron. The Superior plant essentially consists of an aerating device, three covered concrete filters, each 67 by 107 feet, together with a regulating chamber and clear-water reservoir holding 350,000 gallons.

The present engineer in charge, Mr. Lounsbury, has demonstrated that the wells are too far from the lake to get a free flow in winter and that wells under the lake will yield an iron-free water abundant in quality and bacteriologically pure. Such wells are to be constructed and added to the system. Analyses of the water have been made daily since 1906. These seldom show counts above 5 per c. c. on gelatin, and frequently show a sterile water.

The only water problem in Superior is the existence of many wells. Forty per cent of the population depend upon wells. The public supply, though safe, reaches only 60 per cent of the people. Many of the shallow wells were found to be contaminated by Dr. Bulkley and he found some of the deep ones in 1907 to be contaminated because of defective casing and entry of surface pollution. There are 30 of these deep wells which were driven by the municipality.

The following synopsis of analyses shows the excellent character of the Superior water supply. These were furnished by Mr. W. C. Lounsbury, general superintendent of the company.

RAW WATER.

In 37 months, from June 1, 1908, to July 1, 1911, 194 samples gave an average count of 12 per c. c., with a maximun of 400 (only two samples giving counts above 100) and a minimum of 0 (occurring 15 times). Gas was present 9 times in 194 samples of 1 c. c. each in dextrose broth and 21 times in 235 samples of 10 c. c. each.

FILTERED WATER.

In 37 months, from June 1, 1908, to July 1, 1911, 192 samples gave an average count of 4 per c. c., with a maximum of 100 and a minimum of 0 (occurring 26 times). Gas was present twice in 180 samples of 1 c. c. each, in dextrose broth, and 13 times in 236 samples of 10 c. c. each.

The seasonal distribution of enteritis also indicates that the water supply is pure. The table No. 18 shows the number of cases by months for five years, 1906 to 1910.

TABLE 18.—*Deaths marked cholera infantum, Superior, Wis.*

Months.	1906	1907	1908	1909	1910	Total by months.
January	0	1	0	0	1	2
February	1	1	0	0	0	2
March	1	1	0	0	0	2
April	0	0	0	0	0	0
May	0	1	0	0	0	1
June	0	3	0	0	0	3
July	1	2	2	2	3	10
August	12	0	5	10	12	39
September	15	5	5	4	4	33
October	3	1	5	1	0	10
November	0	4	0	1	1	6
December	0	2	0	0	0	2
Total, by years	33	21	17	18	21	....

TYPHOID FEVER IN SUPERIOR.

Chart 5 shows the annual death rate per 100,000 for typhoid fever from 1902 to 1910. The rate has been continuously high with the exception of 1908, and in 1906 and 1910 the rate was 93 and 80, respectively.

Table 19 shows the typhoid deaths by months, 1902 to 1910, except 1905, for which figures were not available. Only one year, 1906, suggests water-borne typhoid by an excessive rate in January, February, March, and April. It is known that the intake pipe was broken by the dragging anchor of a large vessel about October 20, 1905.

TABLE 19.—*Typhoid fever deaths, by months, Superior, Wis.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1902	......	......	2	1	......	......	......	6	......	......	1	0
1903	......	1	......	3	2	1	1	1	3	4	1	0
1904	1	1	1	1	0	2	0	......	2	1	2	1
1905 [1]	......	......	......	......	......	......	......	......	......	......	......	......
1906	3	3	7	6	1	2	1	1	2	2	3	[2] 4
1907	......	......	1	......	......	......	1	......	2	4	......	1
1908	......	......	......	......	1	......	......	......	3	1	......	1
1909	1	1	2	1	......	1	1	......	2	2	2	1
1910	1	1	2	1	......	......	......	5	7	2	7	6
1911	3	0	......	1	......	1	......	......	1	......	......	......

[1] Not available.

[2] Milk outbreak.

The pipe was repaired and the mains flushed, and the water was then considered safe. An excessive number of deaths began to appear in the typhoid records following this. I was unable to secure typhoid deaths by months for 1905, but January, February, March, and April, 1906, indicate an extensive outbreak. At this time and formerly it was the custom to leave the gate valve (which kept the lake water out of the intake pipe) partially open, in order that it could be opened easily in freezing weather, in case of fire or scarcity of water. This

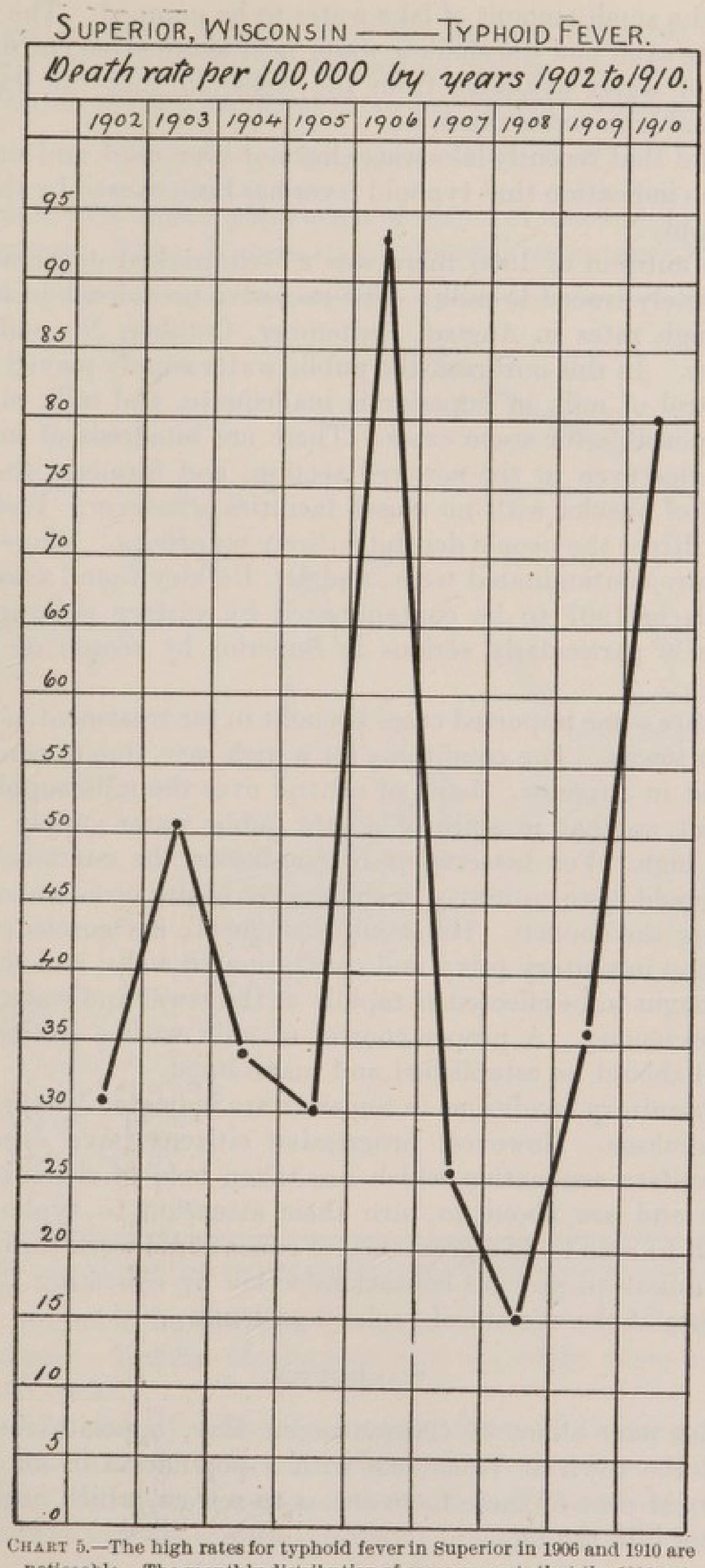


CHART 5.—The high rates for typhoid fever in Superior in 1906 and 1910 are noticeable. The monthly distribution of cases suggests that the 1906 outbreak was water-borne, while that of 1910 was due to other causes. (See table of deaths by months.)

permitted a small amount of lake water to be pumped. The freezing of the lake sand and the shallow water near shore often cut down the amount of water available from the wells, so that the valve was opened and lake water taken in.

It is said that recently lake water has not been used, and since 1906 there is no indication that typhoid fever has been caused by the public water supply.

In the autumn of 1906 there was a well-marked outbreak which was definitely traced to milk. The excessive prevalence in 1910 was due to high rates in August, September, October, November, and December. In this outbreak the public water supply played no part. The control of milk in Superior is inadequate, and milk may have been responsible for some cases. There are hundreds of insanitary yard privies even in the sewered section, and formerly there were numbers of shacks with no closet facilities whatever. East of the Nemadji River the people depend entirely on privies. There are said to be many contaminated wells, and Dr. Bulkley found some of the city wells in 1907 to be contaminated by surface pollution. Soil pollution is particularly serious in Superior by reason of the clay soil.

There are some imported cases brought in for treatment as in other northern towns. The conditions for a high rate, due to contact and flies, exist in Superior. Lack of control over the milk supply is also prominent, so that in spite of a safe public water supply the rate remains high. For betterment of conditions the commissioner of health should have authority to enforce the health ordinances without consulting the council. He should inaugurate a vigorous campaign against the insanitary privy and contaminated wells, and their elimination ought to be effected as rapidly as the sewer and water system can be extended. A proper control of milk with a bacteriological standard should be established and maintained.

The insanitary conditions in Superior are indicated by the increase in tuberculosis. However, progressive citizens have organized public welfare association which has taken hold of the tuberculosis problem and are about to turn their attention to typhoid fever. They will be able to do a great deal of educational work through their trained nurses to prevent contact infection by educating the people in the care of the excreta of typhoid patients.

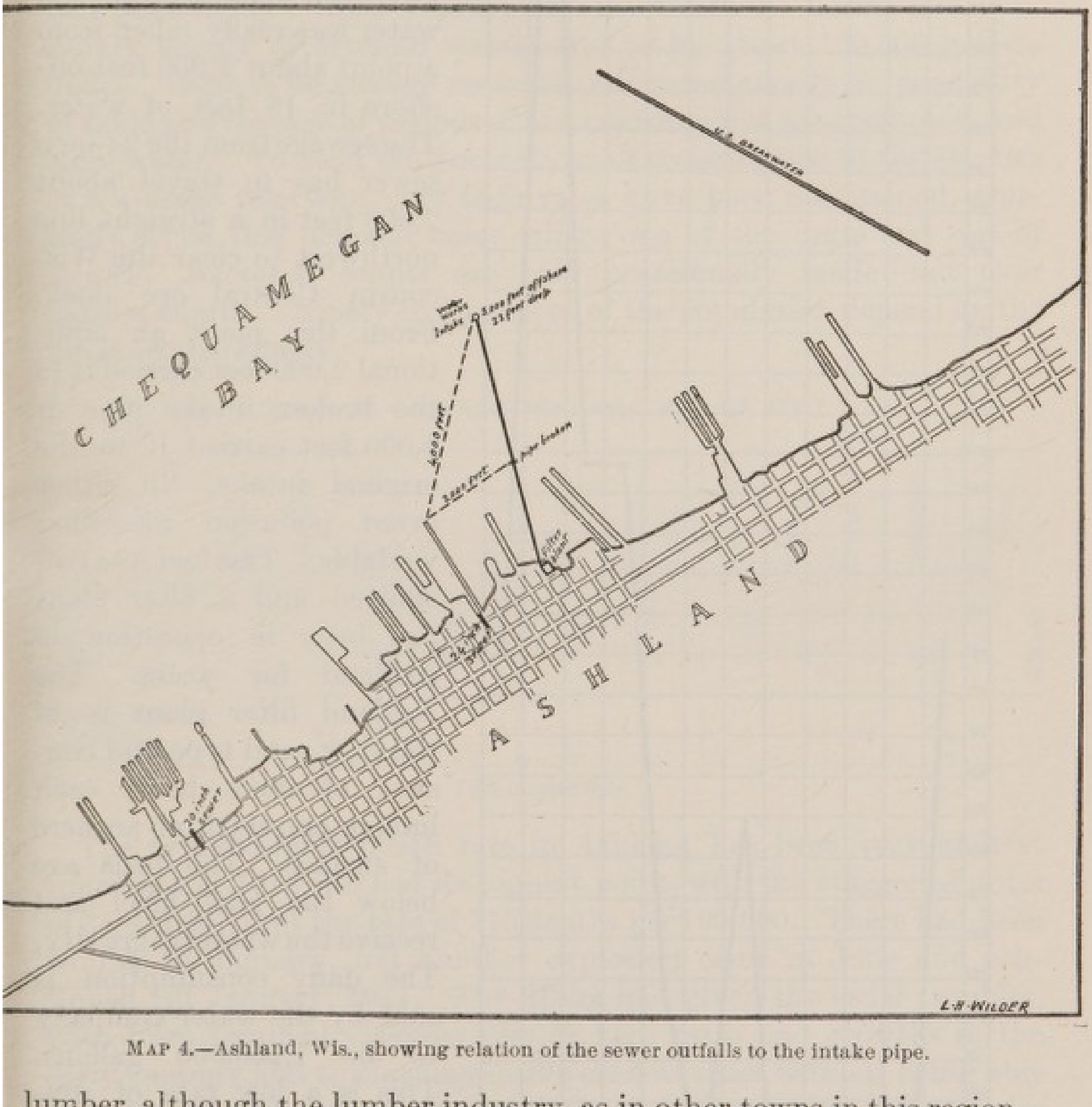
WASHBURN.

On the west shore of Chequamegon Bay, opposite Ashland, situated the town of Washburn with a population of about 3,800. Only 20 per cent of these have access to sewers, which discharge by one outlet into the bay.

The water supply is taken from the bay and delivered unfiltered. The daily consumption is about 400,000 gallons, and there is a reservoir affording storage for about three days' supply (1,200,000 gallons).

ASHLAND.

Ashland, Wis., has a population of about 11,500 and is situated on Chequamagon Bay. It owes its commercial importance to iron and



MAP 4.—Ashland, Wis., showing relation of the sewer outfalls to the intake pipe.

lumber, although the lumber industry, as in other towns in this region, has declined. Besides the lumber and ore docks there are several large coal docks.

There are about 7 miles of sewers in Ashland discharging by two outlets, one (20-inch) at the foot of Beaser Avenue, the other (24-inch) at the foot of Stuntz Avenue. About three-fifths of the population are tributary to these sewers, but about 5,000 people still depend upon privies.

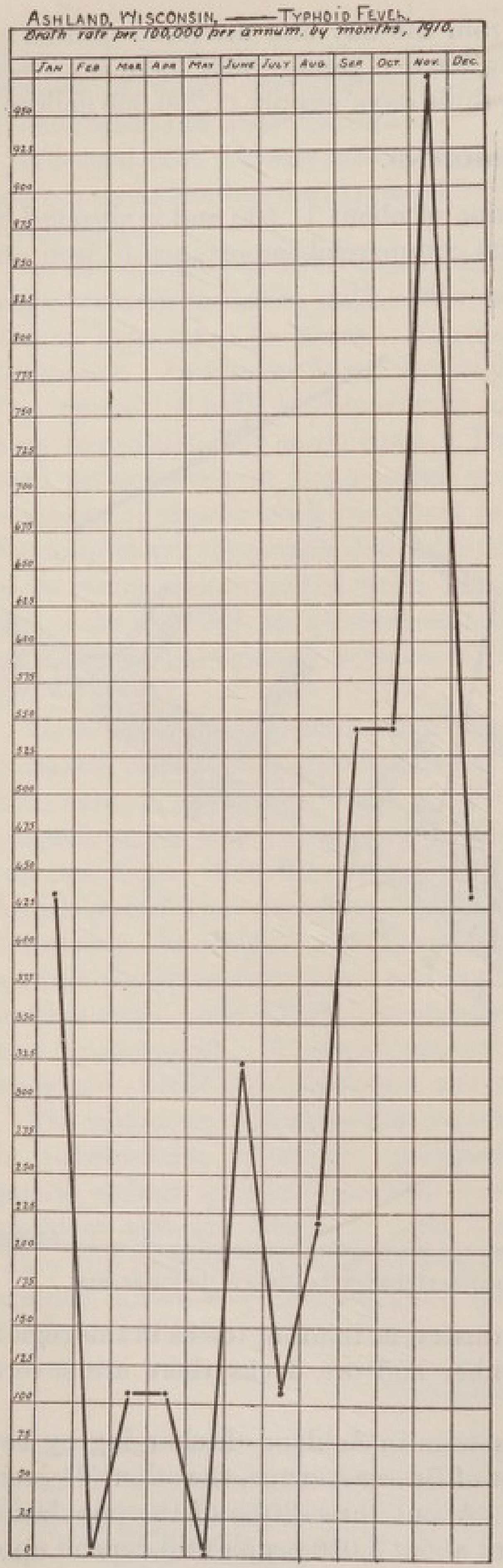


Chart 6.—The epidemic of 1910 in Ashland, Wis., was due primarily, in all probability, to polluted water and poor efficiency of the filter plant.

WATERWORKS.

The waterworks intake consists of a 24-inch pipe extending 5,000 feet northward from Twelfth Avenue East into the bay, terminating in a 22-foot depth. This pipe has been broken, and water was really taken from a point about 2,000 feet offshore in 18 feet of water. The sewage from the 24-inch sewer has to travel about 2,000 feet in a straight line northwest to clear the Wisconsin Central ore dock. From this point an additional 2,000 feet carried it to the broken intake pipe or 4,000 feet carried it to the original intake. In either event pollution was unavoidable. This fact was recognized and a filter plant has been in operation in Ashland for years. The Ashland filter plant is of the slow sand type and consists of three beds, each having one-sixth of an acre of surface. The beds are below the lake level and receive the water by gravity. The daily consumption is said by the water company to be 1,200,000 gallons. This is a low rate of consumption per capita for an American city, but even this would require the filters to be worked at the rate of 2,400,000 gallons per acre daily, continuously, without rest.

It goes without saying that much higher rates of

filtration are maintained at times. When the filters clog, at least one bed must be put out of commission and the rate for the other two correspondingly increased. With the high rates of filtration necessary in summer to meet the increased consumption, the filters clog more frequently and necessitate very frequent cleaning. Even worse than the high rates and frequent cleaning of the midsummer period is the result of cleaning in winter, because of lack of an extra unit the "green" filter must be put in operation immediately after cleaning, in spite of the fact that filters "ripen" slowly in cold weather. There is a subsidiary supply of artesian water, said to be about 150,000 gallons daily. There is no storage reservoir and consequently no possibility of taking advantage of periods of low consumption to accumulate and store water. To meet the fluctuations of consumption in the absence of a storage reservoir, very high rates have been maintained, especially when this demand came where one of the units was out of service. Bacterial counts are only occasionally made—not over twice a month. Ninety-five per cent of the population depend on the public water supply.

TABLE 20.—*Typhoid fever deaths, Ashland, Wis.*[1]

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total by years.
1908	2	......	......	......	1	......	......	......	......	1	1	3	0
1909	......	......	......	......	......	......	......	2	1	......	......	......	3
1910	4	......	1	1	......	3	1	2	5	5	9	4	35
1911	2	......	1	......	1	......	......	......	......	......	......	......	14
Total by months, 3½ years	8	0	2	1	2	3	1	4	6	6	10	7	....

[1] Six months only.

The typhoid-fever death rate in Ashland has been very high at times and in 1910 reached its highest point, with the staggering total of 35 deaths, or at the rate of 315 deaths per 100,000. There had been trouble in January, but another explosion came in June and continued till January, 1911. The filters had given the usual troubles, both from frequent cleaning due to high rates and growths in the early summer and to cleaning in the cold weather without being able to hold the unit out of service until the bed was ripe and safe for service.

Chart No. 6 shows the typhoid death rate per 100,000 per annum by months during 1910.

[1] Furnished by the State Board of Health of Wisconsin.

THE KEWEENAW PENINSULA.

The Keweenaw Peninsula, including the copper country, consists of the counties of Houghton and Keweenaw. There are several large communities in Houghton County, viz:

Calumet township, exclusive of Lawrence and Red Jacket	20,097
Laurium village	8,537
Red Jacket village	4,211
Hancock city	8,981
Houghton village	5,113

Keeweenaw County has no towns or villages of importance.

The sewage from these mining communities drains into Torch Lake, Portage Lake, or into the connecting waters between Portage Lake and Lake Superior. No sewage goes into Lake Superior direct, although the sewage from one sewer in Calumet Township is discharged after sand filtration into a creek tributary to Lake Superior.

The water supply is derived as follows:

	Population.	Water supply, source of—	Character of water.
Calumet Township	20,097	Lake Superior	Uncontaminated.
Hancock	8,981	do	Do.
Laurium	8,537	do	Do.
Houghton	5,113	Springs	Do.

Typhoid-fever death rates per 100,000 have been high at times in these communities; the following table was made from the available records of the Michigan State Board of Health.

TABLE 21.

Eight cities of northern Michigan with populations of from 8,000 to 15,000.

Typhoid-fever death rate per 100,000 population; average for 20 years: Escanaba, Menominee, Ironwood, Sault Ste. Marie, Marquette, Negaunee, Iron Mountain, Ishpeming—68.

Eight cities of southern Michigan, populations 8,000 to 15,000.

Typhoid fever death rate per 100,000 population; average for 20 years: Adrian, Alpena, Ann Arbor, Holland, Manistee, Traverse City, Benton Harbor, Owosso—28.1.

Typhoid-fever death rates per 100,000 per annum.

	Average 16 years.	1906	1907	1908	1909	1910
Calumet Township, exclusive of Lawrence and Red Jacket	30.4	5.6	43.8	16.9		
Hancock	30.1	28.4	13.3	62.3	62.5	48
Houghton			19.7	0		

Since 1907, Hancock has had a rate consistently high; the deaths were nearly all in August, September, and October. The water sup-

plies of these communities are probably uncontaminated, but high rates occasionally prevail because of other factors, especially from August to November. Many factors have been suggested as responsible for the unusually high rates which prevail at times in the mining country of northern Michigan. In many instances these high rates seem to be independent of water supply. Attention has been called to the fact that in newly settled communities there is likely to be careless disposal of human excreta. In these towns the percentage of foreigners is high and their ideas of personal hygiene are often crude. In this country there is a small rural population but a great crowding together of many persons in communities too small to have the hygienic public utilities of large cities. Such conditions favor a high rate due to contact and flies.

Hancock more than doubled its population in 10 years, and this fact in itself has an important bearing upon the increase in typhoid-fever rates in recent years.

In most of these northern peninsula towns the contaminated water supply was a potent factor in the high typhoid rate. In some other towns water from the public supply has not been a large factor, and this is true of the towns on the Keweenaw Peninsula. The rates for Hancock, Laurium, Calumet, and Houghton have not been as high as Escanaba or towns with polluted water supplies in the north, but their rates have been much higher than cities with good water supplies in the southern peninsula, largely because of the existence of factors which increase the rate due to contact.

MARQUETTE.[1]

Marquette had a population of 11,500 in 1910. Its sewage is discharged by seven outlets in to the harbor. (See map 5.) Three-fourths of the population are tributary to the sewers. The sewage travels from 3,000 to 4,000 feet from the sewer outfalls to the end of the breakwater and from this point a little more than 3,000 feet to the waterworks intake.

WATER SYSTEM.

The intake pipe of the Marquette waterworks extends 700 feet from shore and terminates in about 23 feet of water. Here as in other lake cities it was supposed that the current protected the intake and that the current was consistently from north to south, along the shore. The fallacy of this belief is shown by the explosive outbreaks and frequent finding of sewage contamination in the water. Samples were examined either at Ann Arbor or at the State board of health laboratory at Lansing, Mich.

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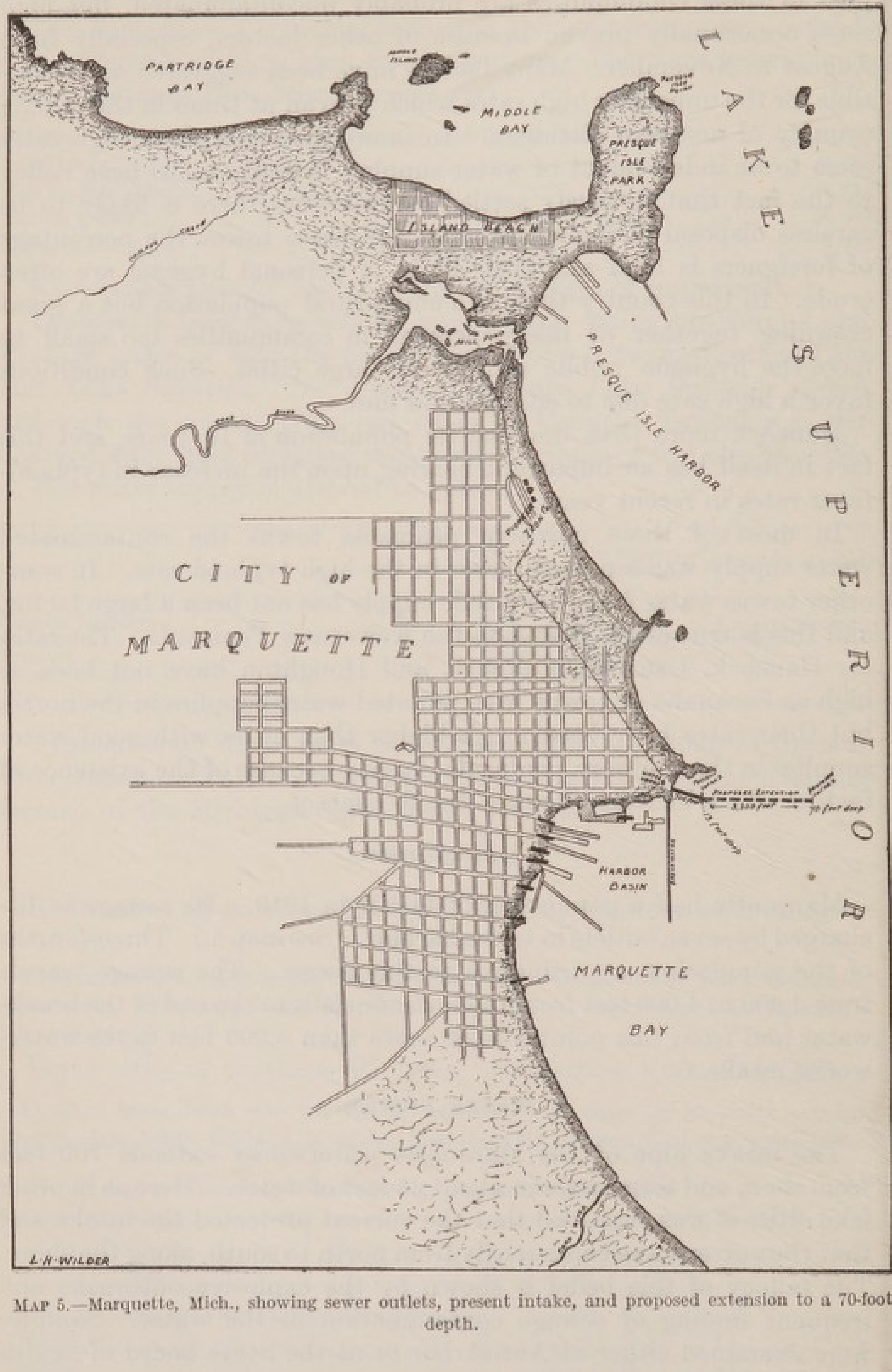
[1] In order to secure typhoid fever deaths by months the data were taken from the state records in Michigan, Wisconsin, and other states. These do not always coincide exactly with Census Bureau figures, but the discrepancy is generally slight.



MAP 5.—Marquette, Mich., showing sewer outlets, present intake, and proposed extension to a 70-foot depth.

Summary of tests of samples of water for five years.

12 months ending—	Samples reported good.	Samples slightly contaminated.	Samples reported unsafe.	Total samples.
March 1, 1906	11	1	....	12
March 1, 1907	6	1	....	7
March 1, 1908	9	4	2	15
March 1, 1909	9	4	2	15
March 1, 1910	3	3	4	10

Shortly after the installation of the plant of the Pioneer Iron Co. an odor and taste of creosote was noticeable in the public water supply. This caused much complaint, and an investigation was made in 1904 by Prof. Koenig, of Houghton, Mich. The investigation showed that the waste matter from the iron company's stills was responsible for the creosote "contamination" of the public water supply. He gave reasons showing why the creosote should be kept out of the water "not because it is directly injurious to health, but because it affects the imagination and therefore indirectly acts upon the gastric and other nerves which latter command or direct digestion." Not a word about the sewage pollution which was a direct menace to health. The professor concludes "The Pioneer works must be held to remove the tar. The well-being of the people is the highest law." In justice to the professor it must be said that he was employed to investigate creosote "contamination" and not sewage pollution or typhoid fever. In 1905 Mr. George H. Benzenberg and in 1906 Mr. Clarence Coleman, consulting engineers, were called upon for opinions in regard to the "contamination" of the public water supply by creosote. Both of these gentlemen after giving their opinion in regard to creosote called attention to the menace from sewage pollution and urged extension of the intake into deep water as a remedy.

Excessive typhoid fever rates have been recorded in Marquette for years. Chart No. 7 shows the typhoid fever death rate per 100,000 by years from 1900 to 1910. It will be noted that since 1903 the increase has been progressive, culminating in 1910 with a typhoid death rate of 99 per 100,000. In the past 10 years the rate was twice above 70. In 1907 the rate was 71.9 and in 1910, 99. A study of the seasonal prevalence shows that the marked rise in both these years was due to unusual prevalence in January, February, March, April, and May. Chart No. 8 shows the prevalence by months during 1907 and 1910. The typhoid fever death rate per 100,000 per annum is given by months, an average for the two years being struck. The outbreak in 1910 was explosive in character and reached its height in March. An analysis of the public water supply in February by the State board of health showed the water to be contaminated and the report further stated that the water should be boiled.

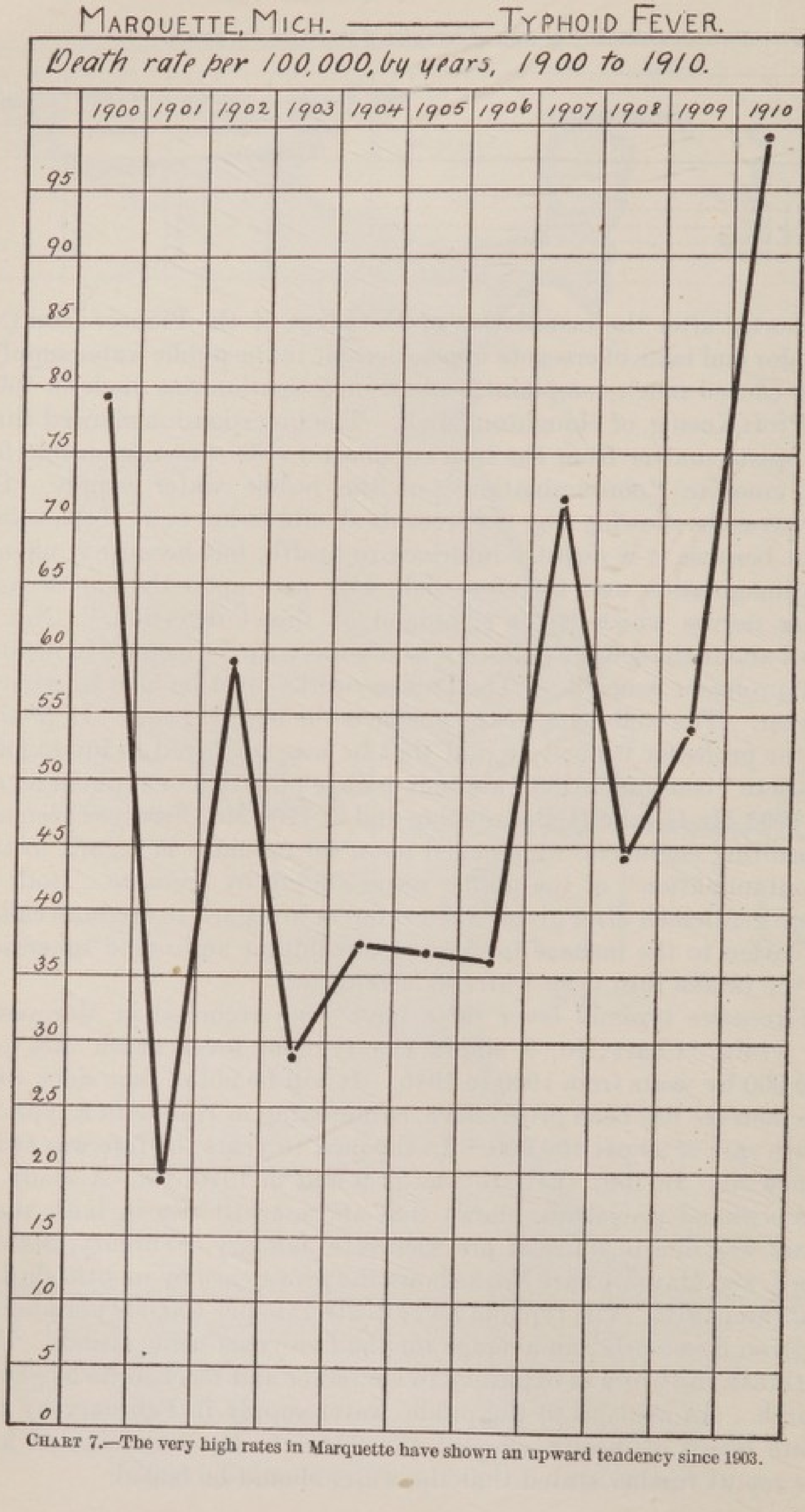


CHART 7.—The very high rates in Marquette have shown an upward tendency since 1903.

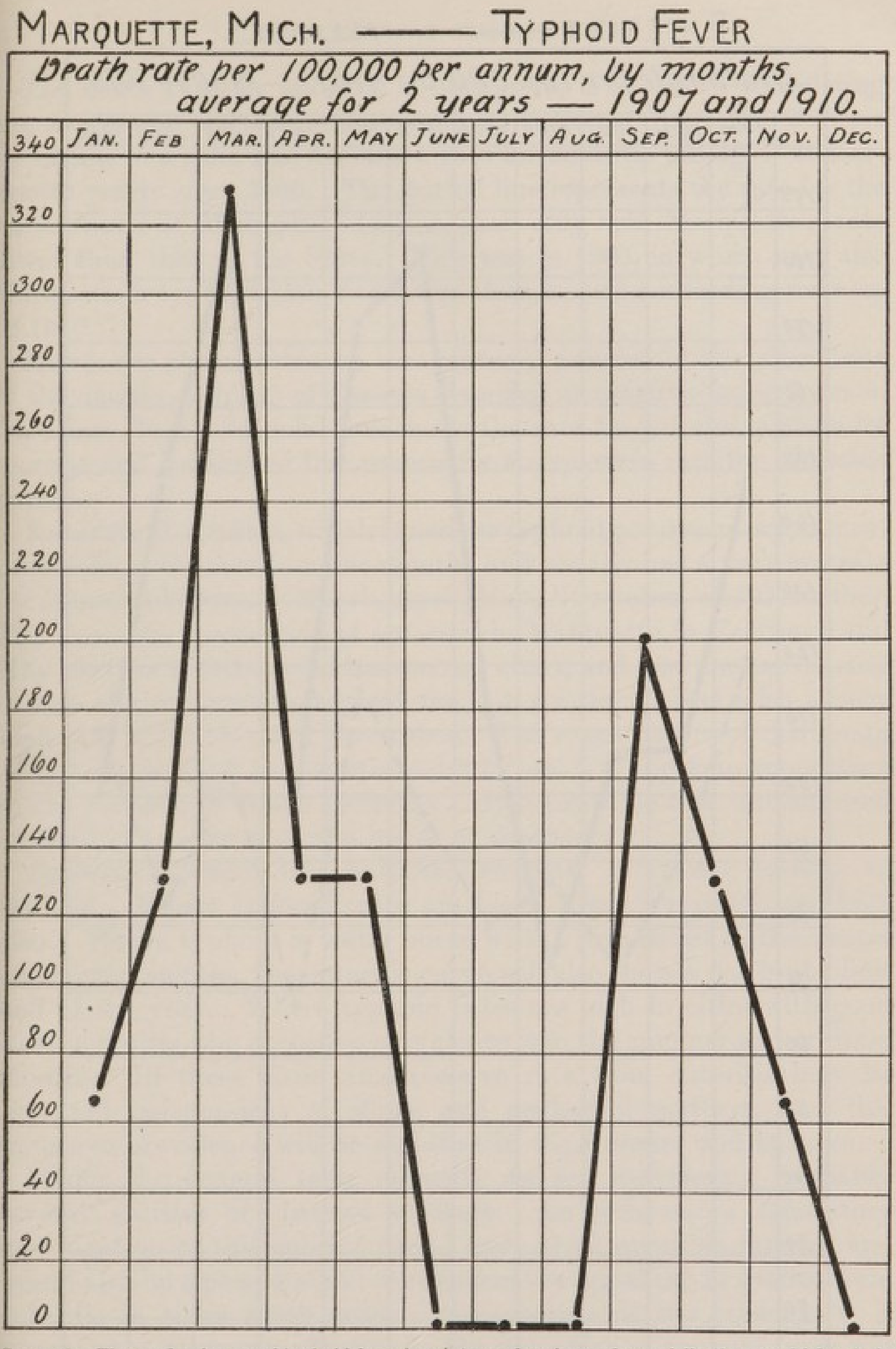


CHART 8.—The predominance of typhoid fever in winter and spring and especially the very high rate for March are very suggestive of water pollution.

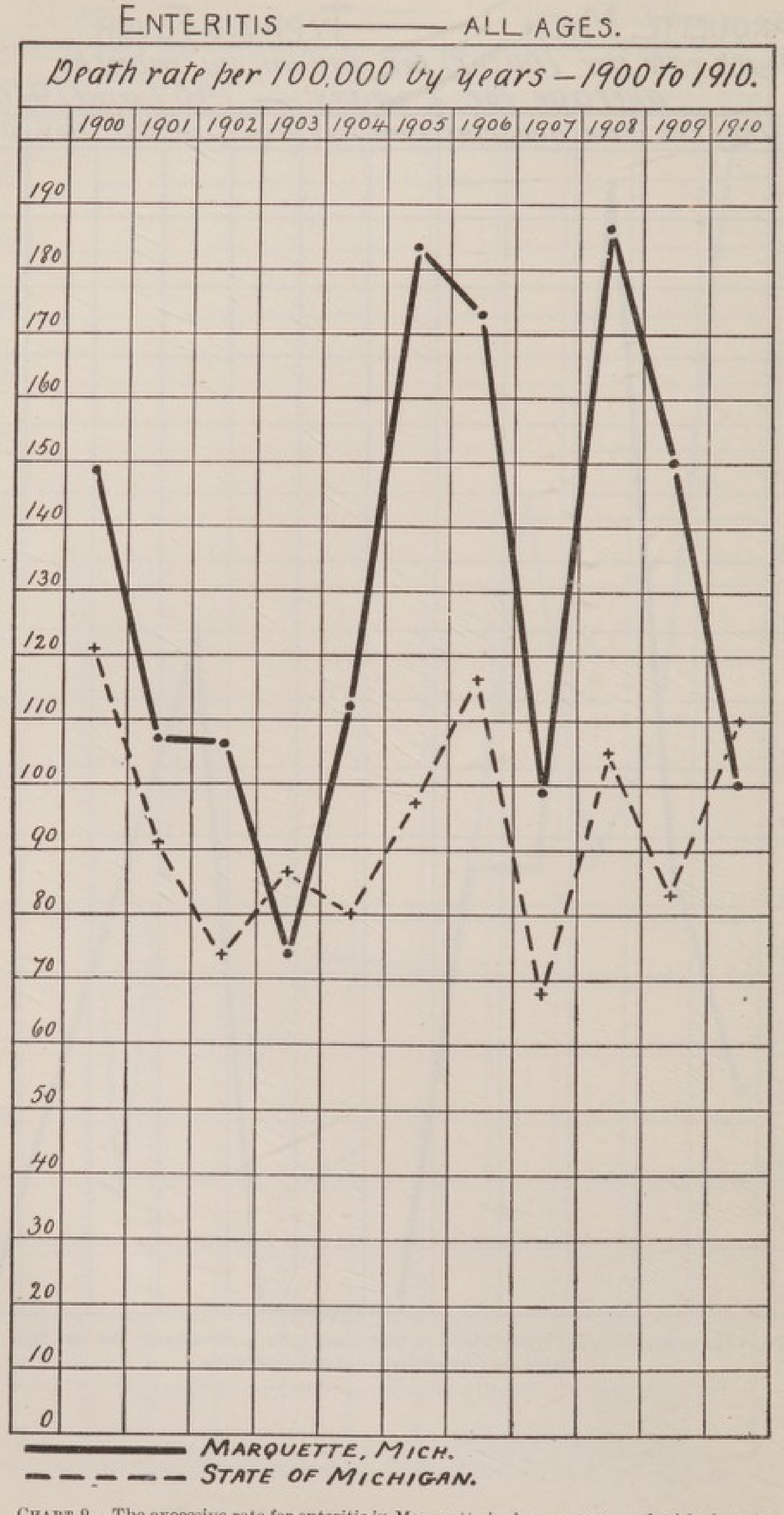


CHART 9.—The excessive rate for enteritis in Marquette is shown, compared with the rate for the entire State.

ENTERITIS AT MARQUETTE.

The death rate for enteritis in Marquette is excessive considering the size of the city and its economic condition. Chart No. 9 shows by means of a solid line the death rate for enteritis (all ages) in Marquette yearly since 1900. The dotted line represents the rate for the entire State of Michigan. In one year only was Marquette's rate lower than that of the State. This was in 1903, in which year also Marquette's typhoid rate was lower than in any succeeding year up to 1910.

Marquette shows evidence that water is a factor in the prevalence of the disease or group of diseases classified as enteritis under 2 years. On Chart No. 10 the solid line shows the rate for the entire State by months and the dotted line represents Marquette's rate for the same period.

Enteritis of children, which is neither typhoid nor dysentery, is most prevalent in the hot summer months and usually has a very low rate for January, February, March, April, May, November, and December. The excessive prevalence of enteritis in Marquette in February and May may be noted on the last-named chart, and also the persistence of this alleged enteritis beyond the hot weather period with a very high rate in October and November. The exact nature of this group of entities classified as enteritis under 2 years is of supreme importance in the problem of infant mortality. It is probable that undiagnosed typhoid is a factor and also bacillary dysentery.

Epidemiologically this so-called enteritis is closely related to typhoid. Where typhoid rates are high, those of enteritis are high also. Where typhoid is water borne with a prevalence in the winter and spring months, the enteritis curve will also show a rise in the first half of the year. Where typhoid rates are high in cities with good water supplies, the excessive prevalence is in the summer and autumn months. In these cities an excessive rate from enteritis may be expected independent of slums and neglectful mothers, and this excessive prevalence will be manifest in the summer and autumn.

Under the general term enteritis we are considering probably several entities of distinct etiology. An exhaustive laboratory investigation of this subject would have great scientific interest and would also be a practical aid in reducing the appalling mortality from enteritis in these small cities. Independent of the etiology, it is certain that measures effective in the reduction of typhoid fever will reduce the enteritis rate also.

After considering various projects for improving the quality of the water supply of Marquette, it has been decided to extend the intake to 3,300 feet from shore in 70 feet of water. After the 1910 outbreak it was realized that disaster might come at any time, and that tem-

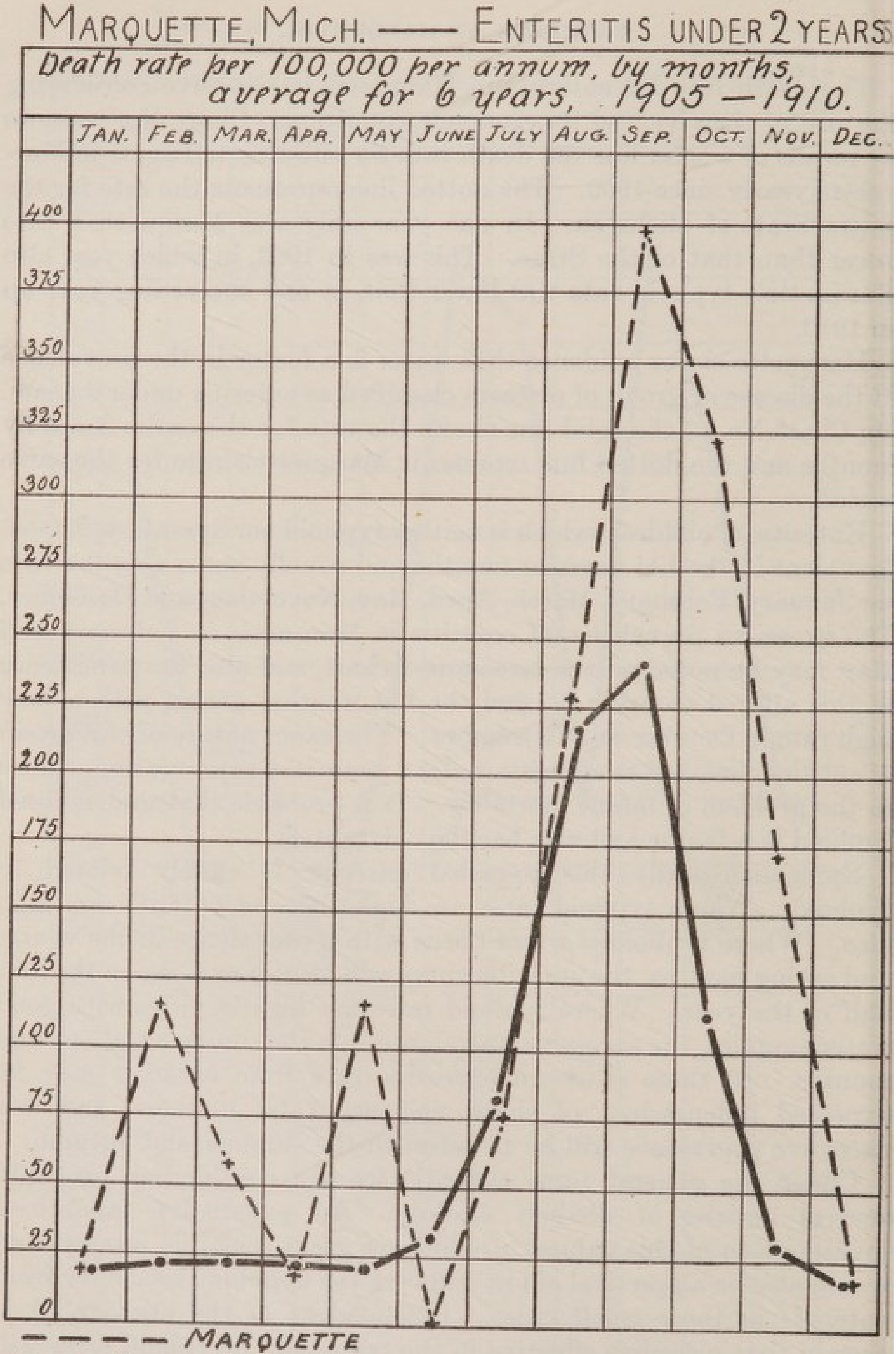
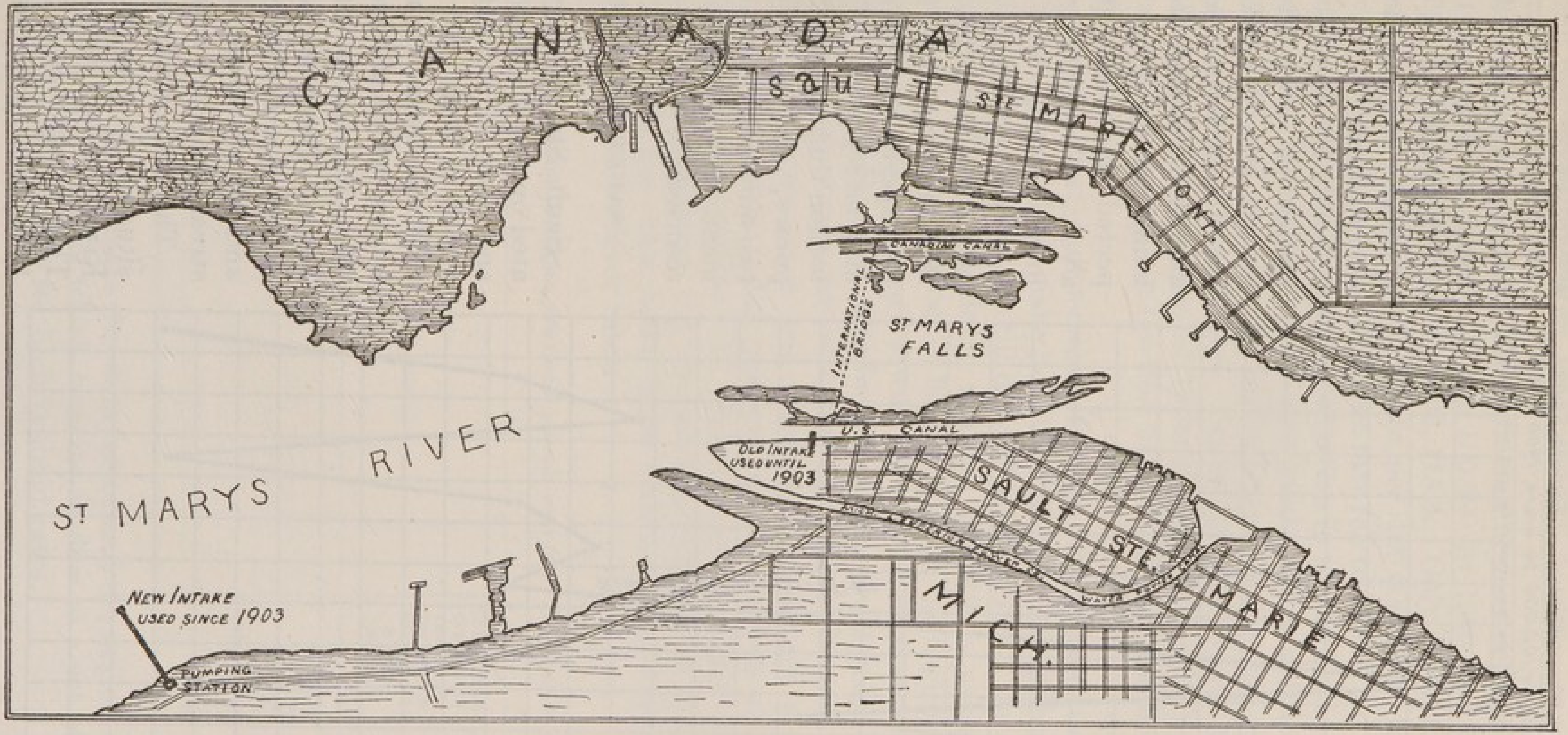


CHART 10.—The seasonal prevalence of enteritis of children is abnormal in Marquette. Note the pronounced peaks in February and May compared with the normal curve for the entire State.



MAP 6.—Sault Ste. Marie, Mich., showing location of old intake exposed to pollution in the canal and the new intake in the St. Marys River, which is comparatively safe.

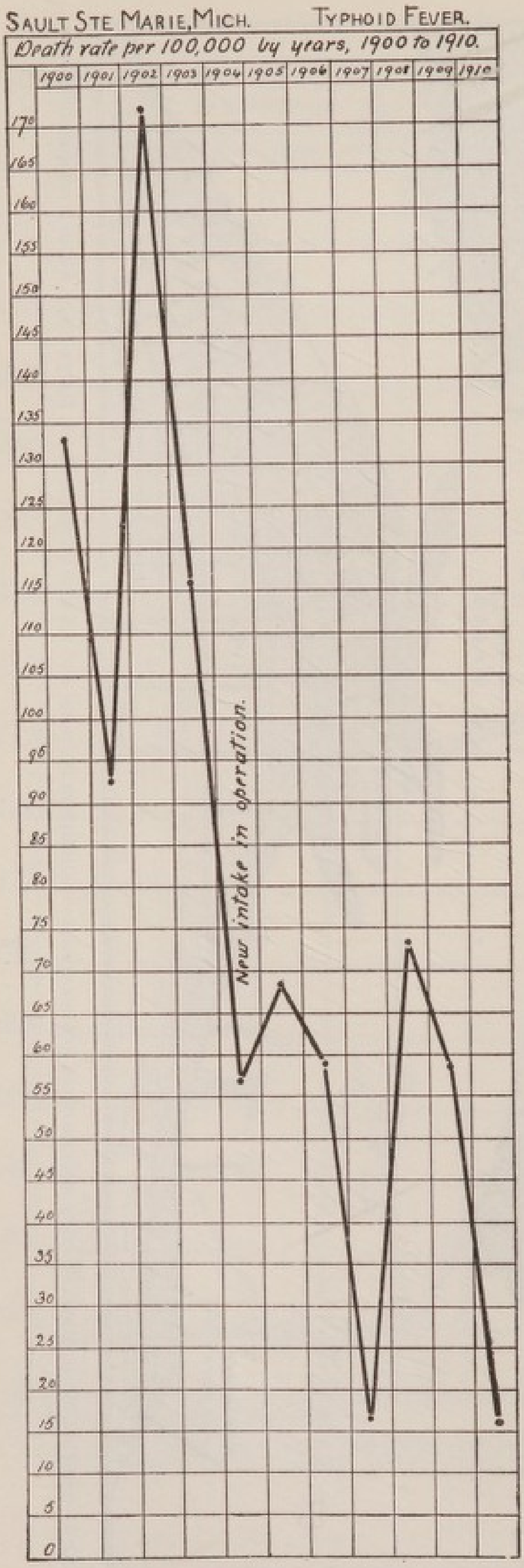


CHART 11.—The consistently lower rate for typhoid fever in Sault Ste. Marie since the installation of the new waterworks is notable.

porary protection was neces-sary pending the completio of the new intake. Accord ingly, on February 1, 1911 a hypochlorite plant was in stalled for treating the publi water supply.

North Marquette wil sooner or later discharg sewage into the lake nea the Picnic Rocks, and th amount of sewage from ex isting sewers may be ex pected to increase progres sively. The moving of th intake farther out in th lake will probably furnis safe water for a time, but Marquette's growth is rapi the experience of other citie may be repeated. The pro tection thus afforded is tem porary, and after one o two moves filtration or trea ment of the water will b resorted to.

SAULT STE. MARIE.

Sault Ste. Marie is situ ated on the St. Marys Rive and had a population o 12,615 in 1910.

It has about 20 miles o sewers which discharge th five outlets into the St. Mary River. There are no sew outlets near the water-work and all are situated down stream from the intake.

The waterworks intake situated in the St. Mary River 3 miles above the cit The intake pipe exten 1,600 feet from shore an there is 34 feet of wat over the crib.

TYPHOID FEVER AT SAULT STE. MARIE.

Sault Ste. Marie has had in the past very high rates from typhoid fever. The typhoid death rate per 100,000 in 1900 was 132.9; in 1901, 92.9; in 1902, 172.9; and in 1903, 115.9. Only twice in the past 11 years has the typhoid death rate per 100,000 been below 50, namely, in 1907 and in 1910, when the rate fell to 16.[1]

Chart No. 11 shows the marked reduction in the typhoid rate coincident with the installation of the new intake. The old intake was used until 1903 and was situated in the United States ship canal just west of the International Bridge. Since the new intake has been used the seasonal prevalence of typhoid fever in Sault Ste. Marie has changed and the rate in the first half of the year has been much lower than formerly.

It is probable that, independent of water supply, conditions exist in Sault Ste. Marie which make possible high rates for typhoid fever. Two-fifths of the population still depend upon privies. As an index of sanitary conditions the death rate for enteritis is valuable. In addition to the slum conditions of large cities and the neglect of working mothers in mill or factory towns, there is another set of factors which make possible a high rate for enteritis under 2 years of age in small cities. The steady prevalence of high enteritis rates in small cities which have no slums and where the percentage of working mothers is small indicates the presence of those factors which make high typhoid rates possible. In almost every instance very high typhoid rates accompany the excessive prevalence of enteritis in such cities. On the other hand, cities with a low rate for enteritis have also low typhoid fever rates.

TABLE 22.—*Seven Michigan cities with populations from 12,000 to 15,000.*

Cities.	Enteritis under 2 years death rate per 100,000 average for 6 years, 1905–1910.	Typhoid fever death rate per 100,000 average for 6 years, 1905–1910.
Escanaba	185.0	136.0
Alpena	162.6	46.7
Sault Ste. Marie	134.6	52.3
Ironwood	124.5	43.5
Manistee	48.0	20.8
Pontiac	44.0	24.5
Ann Arbor	18.6	22.1

In a word, if we eliminate the slum factor and the neglect of working mothers, the enteritis which remains is due to a set of factors which are also responsible for high typhoid rates.

[1] U. S. Census Bureau Reports give 23.7 for 1910.

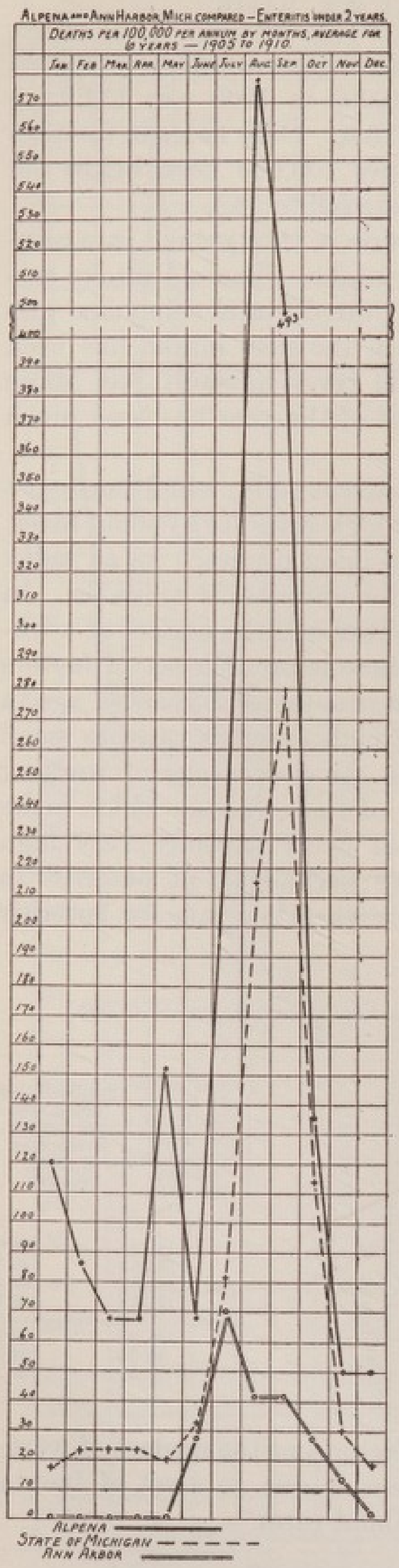


CHART 12.—Showing the difference in seasonal prevalence of enteritis in children in Alpena—a city with a polluted water supply—and Ann Arbor—a city with a good water supply.

If the water supply is a factor in tl typhoid prevalence, not only will tl typhoid rate be high in the wint months, but the enteritis rate will al be abnormally high from January June.

If the water supply is not a facto then the enteritis rate will be low i the first half of the year and high fro July to December.

Chart No. 12 shows the enterit curve by months in Alpena, with polluted public water supply, and i Ann Arbor, which has a safe publ water supply. The high rates f enteritis in Alpena prevail in the wint and spring months, especially in Fel ruary and May. The rate for An Arbor, as might be expected, is low i the winter and spring and has its ris in the summer and autumn months.

In a small city which is not a fa tory or "mill" town and whose wat supply is safe and which has an e cessive rate for enteritis under 2 year there must exist insanitary conditior which are responsible. The fact th these insanitary conditions influenc synchronously the rates for typhoi fever and enteritis can not be accepte to mean that they are the same dis ease. Just how much the element c mistaken diagnosis enters into th matter can only be determined by careful investigation of sick childre in one of these cities covering a lon period.

It may be accepted, however, tha the same factors are operative i transmitting the two diseases, an where high prevalence is confined t the second half of the year, coinci dent with a safe water supply, it ma be assumed that the factors whic favor transmission by flies and contac are most active.

Chart No. 13 shows the enteriti death rate per 100,000 per annum b

months in Sault Ste. Marie and Marquette, Mich. The very high death rate in Sault Ste. Marie is almost entirely due to the mortality in the months of July, August, September, October, and November. Such high rates in the summer and autumn indicate insanitary conditions which favor the spread of typhoid fever by contact and flies. The low rate in the first half of the year suggests that the water supply is safe. Marquette has a water supply subject to sewage pollution and the enteritis curve shows two marked rises, one in February and one in May, similar to the curve for Alpena shown on Chart No. 12.

As might be expected the seasonal prevalence chart (Chart No. 14) shows that in the past decade the high typhoid rate is due to excessive prevalence in August, September, October, and November. The dotted line on Chart No. 14, shows the rate for the past five years, and during this period the rate in the first half of the year is even lower than that for the entire decade. The excessive prevalence of typhoid fever in Sault Ste. Marie seems to be due to conditions which are operative in the greatest degree in the late summer and autumn.

CONCLUSIONS.

1. Imported cases from the iron ranges constitute nearly 50 per cent of Duluth's hospital typhoid, and their number indicates a very high prevalence in the iron mining districts. The nonresident cases have some effect upon the resident typhoid rates. The typhoid fever rate among residents is higher than it should be in a city like Duluth. The largest single factor in transmission seems to be contact. Such pollution as occasionally occurs at the waterworks intake must be dilute and can not cause explosive massive outbreaks unless a phenomenal growth of the city should take place. Duluth's water supply should

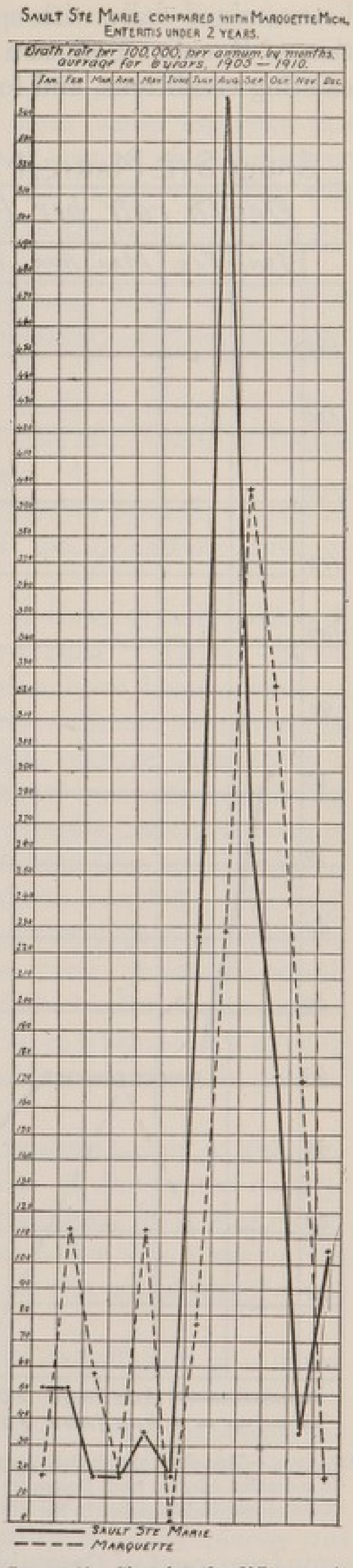


CHART 13.—Showing the difference in seasonal prevalence of enteritis of children between Sault Ste. Marie and Marquette.

be examined daily with special reference to the quantitative estimation of B. coli. Pollution of Duluth's water supply is possible under existing conditions, and for complete protection 365 days in the year

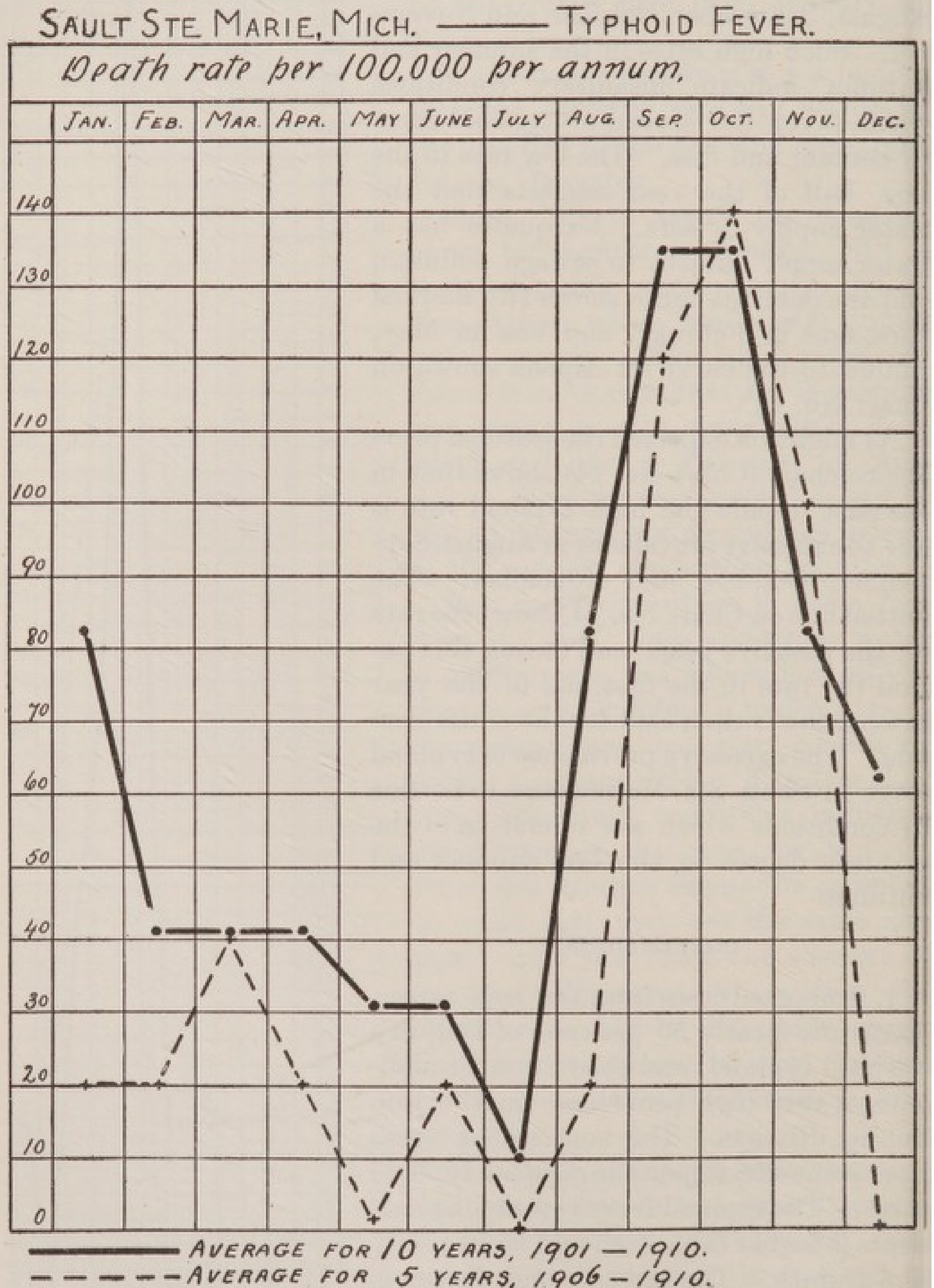


CHART 14.—This chart shows that the reduction in typhoid fever since 1905 is due in greatest measure to reduction effected from December to August. The rates for September, October, and November show no material reduction in the last five years.

some treatment of the public supply is necessary. In the absence of turbidity, hypochlorite treatment would probably fulfill every sani-

tary indication. Further experiments are necessary to demonstrate the efficiency and economy of using ultra-violet rays in water sterilization, but Duluth water is favorable for such experiments. The presence of cheap electric power and a clear water suggests the possibility of the economical employment of ozone as a sterilizing agent. It is doubtful if any method can be employed which will render Duluth's water safe at so low a cost as treatment with hypochlorite of lime.

2. Superior, Wis., has had excessive typhoid fever rates. The chief causes in recent years seem to be insanitary privies, contaminated wells, contact, and probably milk.

The water supply in Superior is safe. There is a modern filter plant under expert supervision, although the raw water is better than that furnished unfiltered in many cities.

Superior needs extension of this excellent water system, extension of the sewer system, and elimination of the insanitary outdoor privies and dangerous wells.

3. The raw water at Ashland's intake is at times grossly polluted. There is a filter plant, but it has been overworked. "Green" filters are put in service and the rates of filtration have been excessive. There has been lack of bacteriologic control as well, and examinations instead of being made daily were not made oftener than twice a month. The storage capacity for filtered water amounts to nothing, and consequently there is no reserve to meet fluctuations in consumption. There have been very high rates in Ashland for typhoid fever, and in 1910 the typhoid death rate per 100,000 was 315. The inefficiency of the filters was the probable cause of this explosive outbreak. Ashland needs new filter units, a storage reservoir for filtered water, a rate controller which is respected, and daily bacteriologic control of the water supply. The use of hypochlorite as a temporary expedient pending the necessary alterations in the filter plant would protect the public until the defects are corrected.

4. The typhoid fever prevalence in the mining towns of the Keweenaw Peninsula seems to be independent of the water supply.

5. Marquette has had very high rates for typhoid fever and enteritis. The seasonal prevalence suggests that water was a very great factor in these high rates. The pollution of the water supply was caused by Marquette's own sewage.

Temporary protection was afforded by the installation of a hypochlorite plant on February 1, 1911. It is the intention to extend the intake to 3,300 feet off shore in 70 feet of water. Daily bacteriologic examinations will show whether this will give a safe water at all times. Moving the intake farther out has never been attended with more than temporary success, and the history of other places will probably be repeated in Marquette, especially if the city continues to grow rapidly.

6. Sault Ste. Marie has had very high typhoid fever rates for many years. There has been a marked improvement since the new intake was put in service, and a change in the seasonal prevalence. The rate is still high, but is due to unusual prevalence in the summer and autumn months. At present the public water supply is probably not a factor.

The high enteritis rates show a similar seasonal distribution to that of typhoid fever, and excessive prevalence of both diseases is probably due to factors which are most active in warm weather. The sewage of Sault Ste. Marie is discharged into the St. Marys River below the waterworks intake. There are no cities or towns on the river between Sault Ste. Marie and Lake Huron. This sewage pollution after passing through the St. Marys River and a series of natural sedimentation basins before discharge into Lake Huron may be considered harmless at the present time.

III. LAKE MICHIGAN AND THE STRAITS OF MACKINAC.

LAKE MICHIGAN AS A SOURCE OF WATER SUPPLY.

Lake Michigan is 307 miles long and has a maximum width of about 118 miles. The maximum depth is 870 feet. The storage capacity is enormous, and its power to oxidize and purify organic matter can scarcely be overestimated. The effect of storage of Lake Michigan water is accentuated by the comparatively small outflow (an average of only 57,000 cubic feet per second through the Straits of Mackinac). For example, compared with Lake Huron, the area of water surface is nearly the same—over 22,000 square miles—and the maximum depth in Lake Michigan is about 100 feet deeper than that of Lake Huron. The outflow of Lake Huron at Port Huron is about 210,000 cubic feet per second, while the outflow from Lake Michigan is only about one-fourth as much. This means longer retention of polluted inflow from rivers and sewers and more opportunity for purification before discharge through the Straits at Mackinac. It would take Lake Michigan many years to empty itself at its present rate of outflow if all inflow were prevented. Under these circumstances the quality of Lake Michigan water must be good, provided we can get it far enough from the polluting inflow of rivers and sewers. Unfortunately, the zone of polluted water extends a considerable distance out into the lake from the water fronts of the cities and the mouths of the large rivers, and this zone of pollution has no constant boundaries because of currents due to wind and flood, but extends under unusual weather conditions far beyond the point which seems safe in quiet weather.

These facts make it extremely difficult, if not impossible, both from the engineering and economic standpoints, to obtain pure water near our large lake cities every day in the year by simply extending a pipe out into the lake, without filtration or treatment of the water.

THE NORTH COAST OF LAKE MICHIGAN.

From St. Ignace, on the Straits of Mackinac, to the entrance of Green Bay there is not a single city of importance. The city of Manistique is situated on this northern coast about 75 miles west of St. Ignace. The population in 1910 was 2,722. About 60 per cent of the population depend upon wells for their water supply. There is a public supply which comes by gravity from Indian River.

Seventy-five per cent of the population depends upon privies. There are about 7 miles of sewers discharging by four outlets—one into Lake Michigan and three into the Manistique River. There is no treatment of the sewage. The amount of pollution of Lake Michigan along this coast is at present a negligible quantity.

GREEN BAY.

Green Bay is separated from Lake Michigan by the peninsulas of Door County, Wis., and Delta County, Mich. The 30 miles between the extremities of these two peninsulas is partly closed by numerous islands. Green Bay, thus inclosed, acts as a sedimentation basin for the discharge of the Escanaba, the Peshtigo, the Oconto, the Menominee, and the Fox Rivers, and for the sewage and drainage of Escanaba, Menominee, Marinette, Green Bay, and many smaller communities.

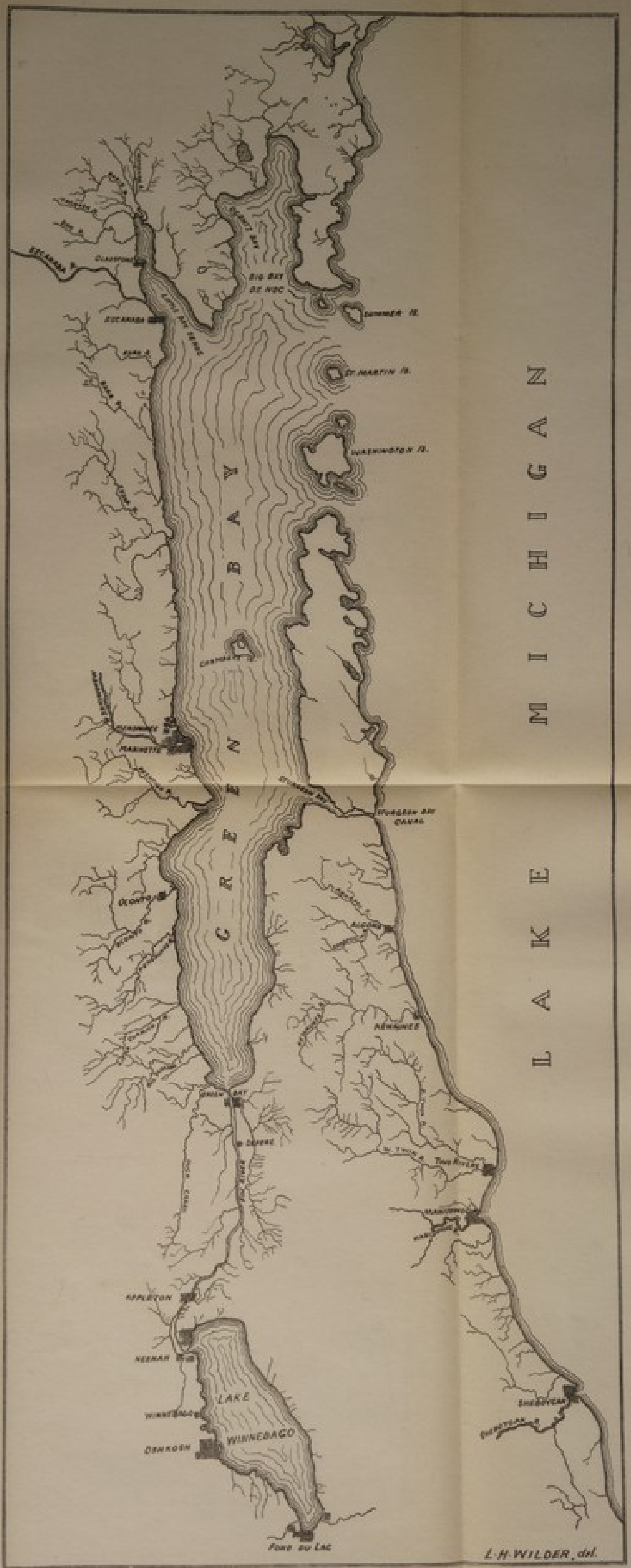
The amount of pollution taken care of by Green Bay is large, and the shore water of Lake Michigan south of Green Bay is much less polluted than if this natural sedimentation basin did not exist.

The southern end of Lake Michigan presents shore pollution in an aggravated form. Even excluding that portion of Chicago which sewers into the drainage canal, there is a large population from Waukegan to Michigan City sewering into the lake. The lake bottom slopes very gradually, and to reach a depth where wave action would not affect the intake would, in the cities between Evanston and Hammond, for example, necessitate going out a mile into the lake. While this would insure against the turbidity due to wave action, it would not protect against the sewage pollution, readily carried so short a distance as 1 mile by currents.

THE EASTERN SHORE OF LAKE MICHIGAN.

The amount of pollution of the water on the eastern shore is distinctly less than that of the western shore and the southern end of the lake. There are no large cities like Chicago or Milwaukee, and most of the rivers have a peculiar lake-like expansion at the mouth, which minimizes for a great part of the year the polluting effect of these rivers on Lake Michigan. The Big Manistee, the Little Manistee, the Big Sable, the Lincoln, the Pere Marquette, the Pentwater, the White, the Muskegon, and other smaller rivers all empty into small lakes which are separated from Lake Michigan by sand dunes and connected by a small channel. The United States Government has in many instances dredged these connecting channels, and the smaller lakes make excellent harbors.

The sewage pollution from Manistee, Ludington, Muskegon, Holland, and other cities is first received into these smaller lakes. These act as sedimentation basins, and for a great part of the year greatly



MAP 7.—Green Bay, an excellent sedimentation basin almost entirely inclosed. Showing also the cities in the Fox River drainage area, Fond du Lac Oshkosh Appleton, and Green Bay.

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reduce the sewage pollution which reaches Lake Michigan from these cities. In time of flood or after heavy rains this measure of protection is nullified, and the sewage is quickly carried to Lake Michigan through the harbor entrances by the swift current.

Concerning the other large rivers carrying sewage pollution to the lake, the Grand has no direct sewage contribution nearer than Grand Rapids, which is about 40 miles from the mouth. The same is true of the Kalamazoo, the towns near the mouth of the river being small and the effect of sewage from the larger cities like Kalamazoo being modified greatly by the long stream flow before reaching the lake.

The St. Joseph is somewhat different, and within 2 miles of its mouth receives the sewage of 15,000 people, which is carried quickly to the lake.

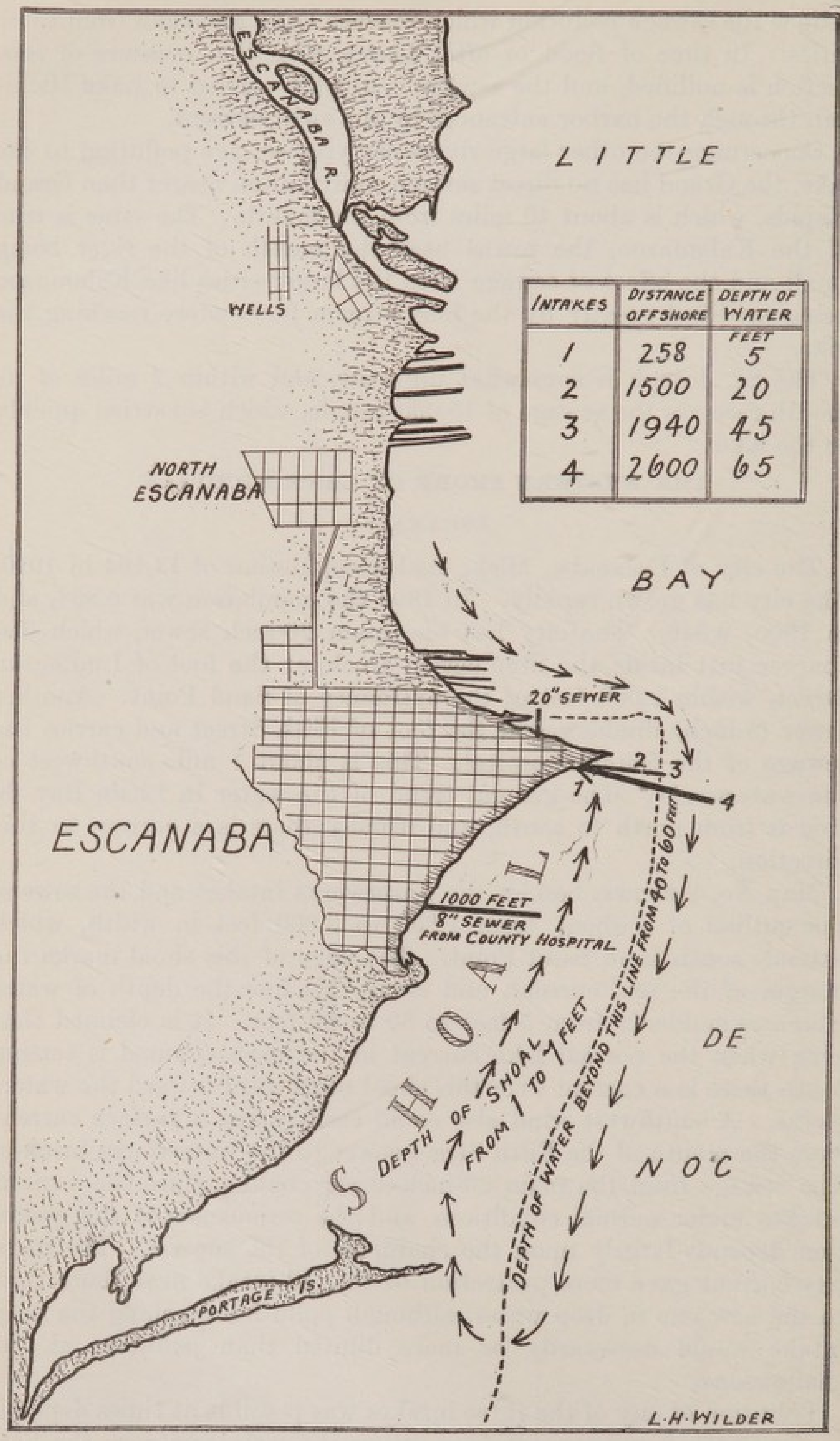
THE WESTERN SHORE OF LAKE MICHIGAN.

ESCANABA.

The city of Escanaba, Mich., had a population of 13,194 in 1910. The city has grown rapidly. In 1890 the population was 6,808, and in 1900, 9,549. The city has one main 20-inch sewer, which discharges just inside the Stephenson Dock, at the foot of Ludington Street, within 2,000 feet of the extremity of Sand Point. Another sewer (8-inch) discharges at the foot of Fifth Street and carries the sewage of the county hospital. This is about 1 mile southwest of the waterworks. The general trend of the water in Little Bay de Noc is from north to south, and usually there is a current in this direction.

Map No. 8 shows, besides the waterworks intakes and the sewers, the outline of a shoal, from 1,500 to 3,000 feet in width, which extends south from Sand Point. The edge of this shoal marks the margin of the real current, and along this line the depth of water increases suddenly from 5 feet to 50 or 60 feet. It is claimed that even when the normal lake current in the deep channel is setting south there is a current over this shoal northward toward the waterworks. A southwest wind also could easily cause a surface current from the mouth of the Fifth Street sewer to the waterworks intakes. The sewage from the main 20-inch sewer could pollute the various intakes under normal conditions, and the seriousness of this pollution depends largely upon the character of the sewage. The main bay current gave more protection to the old intake near shore than to the new one in deep water, although pollution reaching the deep intake would necessarily be more diluted than pollution at the shallow one.

Pollution of any of the three intakes was possible at times depending upon wind and current from either the main sewer or the hospital sewer.



MAP 8.—Escanaba, Mich., showing water works intakes and sewer outlets. Note the shoal and alleged reverse current over it, indicated by arrows.

WATER WORKS.

In 1886 the water works was installed by a private company. The water was taken from an intake 1,500 feet offshore at the edge of the shoal in about 20 feet of water. In addition there was an "emergency" intake about 250 feet offshore in 5 feet of water. Intestinal disease was common, usually called "winter cholera" in this section, and the company was induced to extend the intake 440 feet farther.

The present intake is 2,600 feet offshore in 65 feet of water.

In November, 1909, a filtration plant was installed. It is a mechanical or "rapid sand" type, and consists of 8 units, each unit being 20 by 12 feet, with a capacity of 600,000 gallons daily. Alum is used as a coagulant. Toward the end of 1910 the plant was not satisfactory; local gravel had been used in the beds and the results were poor. In January, 1911, the beds were built over with new sand and gravel brought from some distance. During January, February, and March results were poor, but the plant seems to be giving better results at present (October, 1911).

TYPHOID FEVER.

Chart No. 15 shows the typhoid fever death rate per 100,000 by years since 1900.

Escanaba has been notorious for having the highest typhoid rates of any city in the registration area. The rate was high in 1900, but in the next three years it was considerably lower. In 1904 the explosive outbreak of March, April, and May brought the yearly rate up to 351.4 per 100,000. For the six years from 1904 to 1909, the average typhoid death rate per 100,000 was 203.1. In November, 1909, the filter plant was installed and, although its operation was far from satisfactory, the rate fell in 1910 to 61. Chart No. 16 shows the typhoid-fever death rate per 100,000 per annum by months—average for 10 years, 1901–10. The prevalence in March, April, and May is very striking.

ENTERITIS UNDER 2 YEARS.

Enteritis among persons under 2 years of age is usually a disease of summer and autumn. In cities with good water supplies this is almost invariably the case. This high mortality among infants from enteritis is usually greatest in those cities which have slums or which have a large percentage of working mothers with consequent child neglect. There is another group of cities which have almost invariably high death rates for enteritis under 2 years, namely, those with a high typhoid-fever rate. In these cities the enteritis

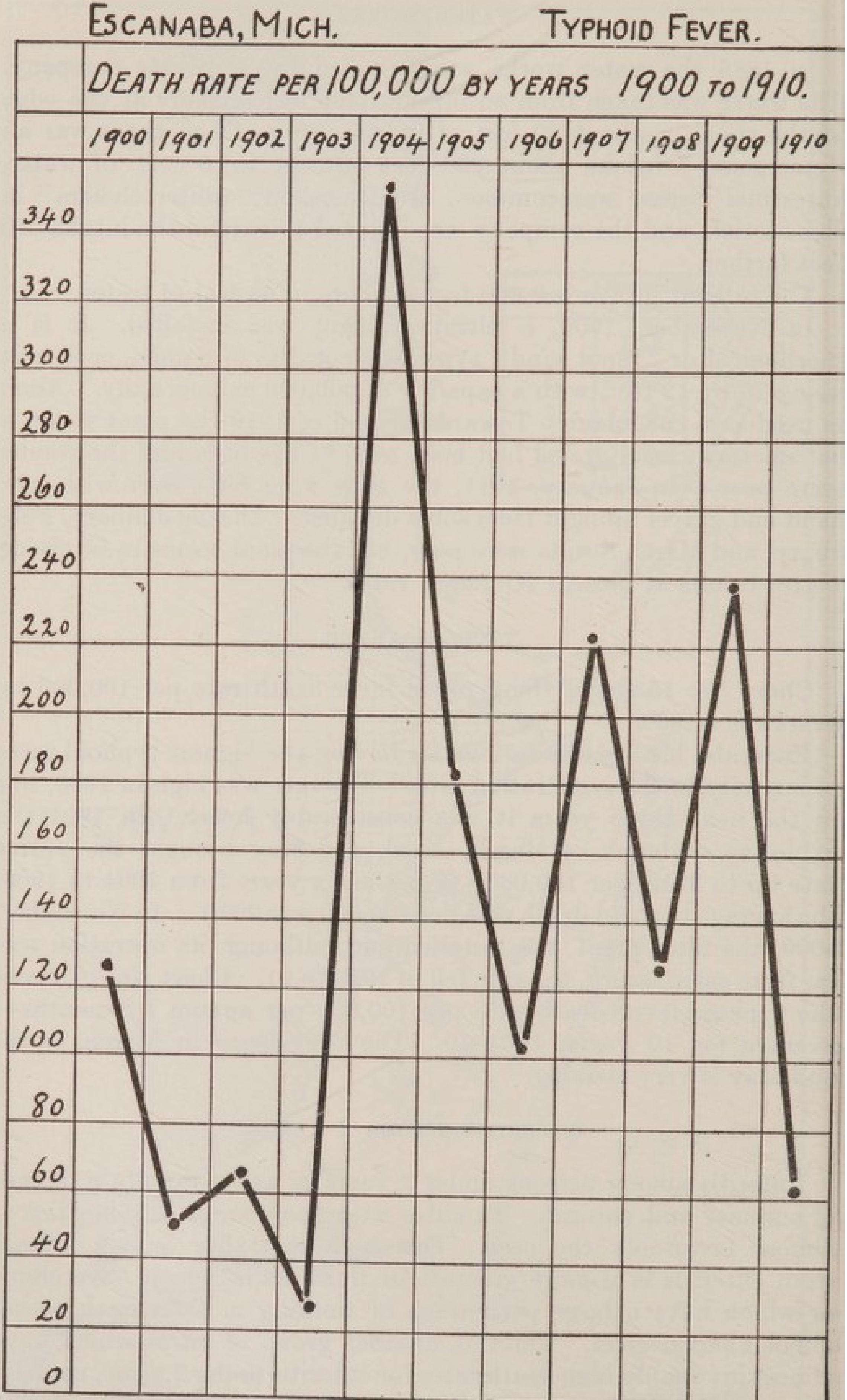


CHART 15.—Escanaba, Mich., had the highest typhoid fever rates among the registration cities from 1904 to 1909.

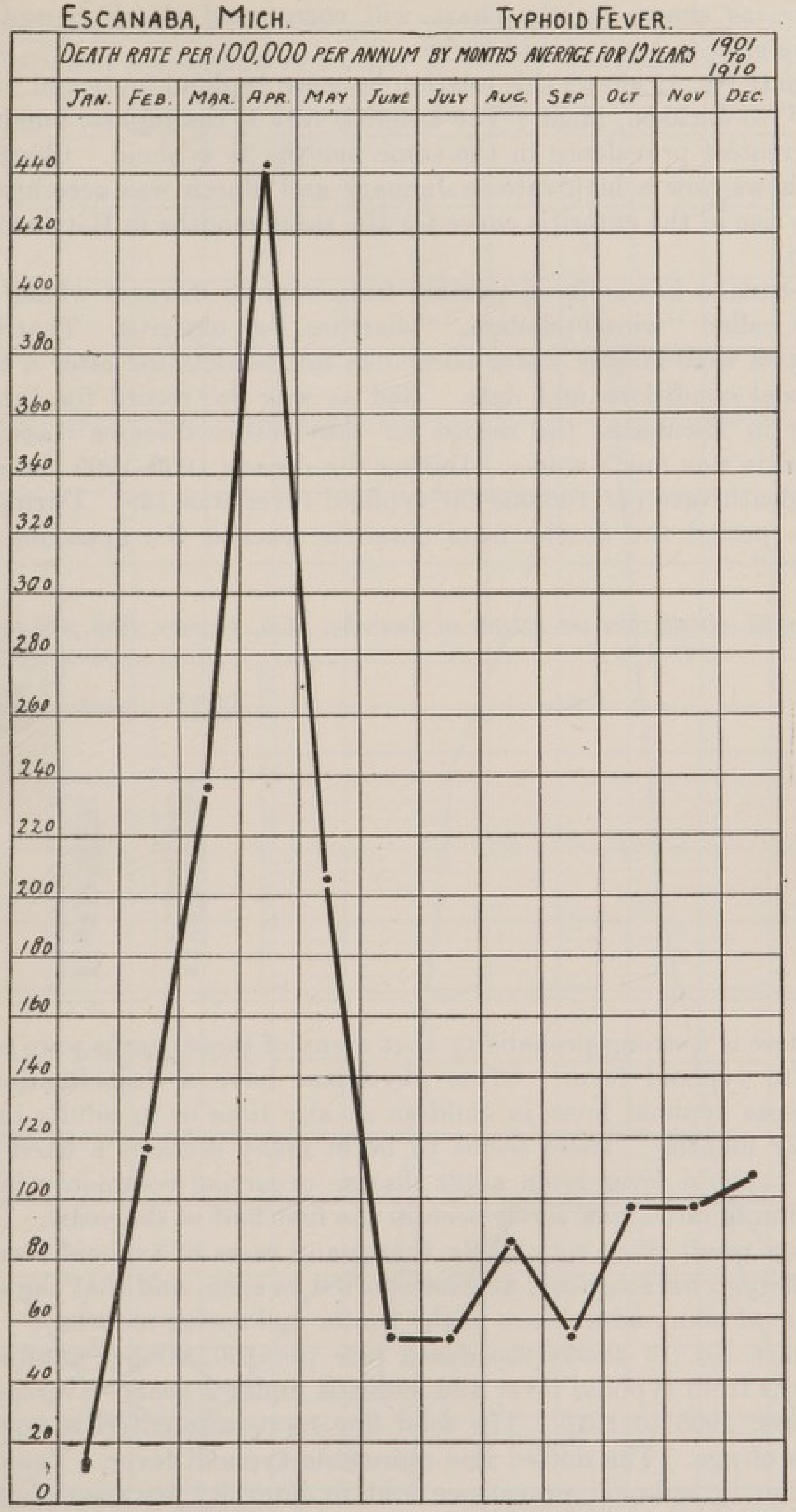


CHART 16.—The great majority of typhoid fever cases in Escanaba occurred in the winter and spring months.

curve, as shown on the chart, will correspond closely in seasonal prevalence to the typhoid curve.

Chart No. 17 shows this relation between typhoid fever and "enteritis" in Jackson, Mich. The enteritis rate is the higher, but it has its greatest prevalence in the same months as typhoid. Chart No. 18 shows how a high rate in January and March was accompanied by a rise in the enteritis curve for the same months in Battle Creek, Mich.

Escanaba has suffered terribly from various diseases which have been called "winter cholera," "diarrhea," or enteritis. That these diseases were largely water borne can not be doubted after a study of local conditions and data. Bad as was the record for typhoid fever in Escanaba, the record for these other diseases classed as enteritis was much worse. During the decade 1900–1909 the average death rate per 100,000 for typhoid fever was 149. During the same period the deaths from enteritis reached the appalling rate of 213.7.

TABLE 23.—*Death rates per 100,000 in Escanaba, Mich., by years, from 1900 to 1911.*

Years.	Typhoid fever.	Enteritis.	Total typhoid and enteritis.
1900	125.7	282.8	408.5
1901	50.3	140.9	191.2
1902	67.8	174.4	242.2
1903	28.0	140.1	168.1
1904	351.4	225.3	576.7
1905	182.8	417.9	600.7
1906	101.1	261.1	362.2
1907	220.2	130.5	350.7
1908	126.5	268.8	395.3
1909	237.0	96.0	333.0
1910	61.5	123.0	184.5
1911	46.0	100.0	146.0

There is a strong probability that many of these deaths were really due to typhoid fever. Often physicians have a disinclination to diagnose typhoid fever in children at any time or in adults in the winter months. There seems to be in many sections a fixed idea that typhoid fever is an adult disease occurring commonly in the autumn months, and rarely seen in the first half of the year.

As a result, it is very likely that many cases of typhoid fever in children go unrecognized and unreported as such, and that the same is true of many adult cases in the winter and spring months.

Chart No. 19 shows the death rate per 100,000 per annum by months from typhoid fever and enteritis under 2 years—average for 6 years, 1905 to 1910. The solid line represents enteritis under 2 years of age. The dotted line represents typhoid fever The close relation in seasonal prevalence and in intensity between the two diseases is at once apparent. Only a thorough investigation cover-

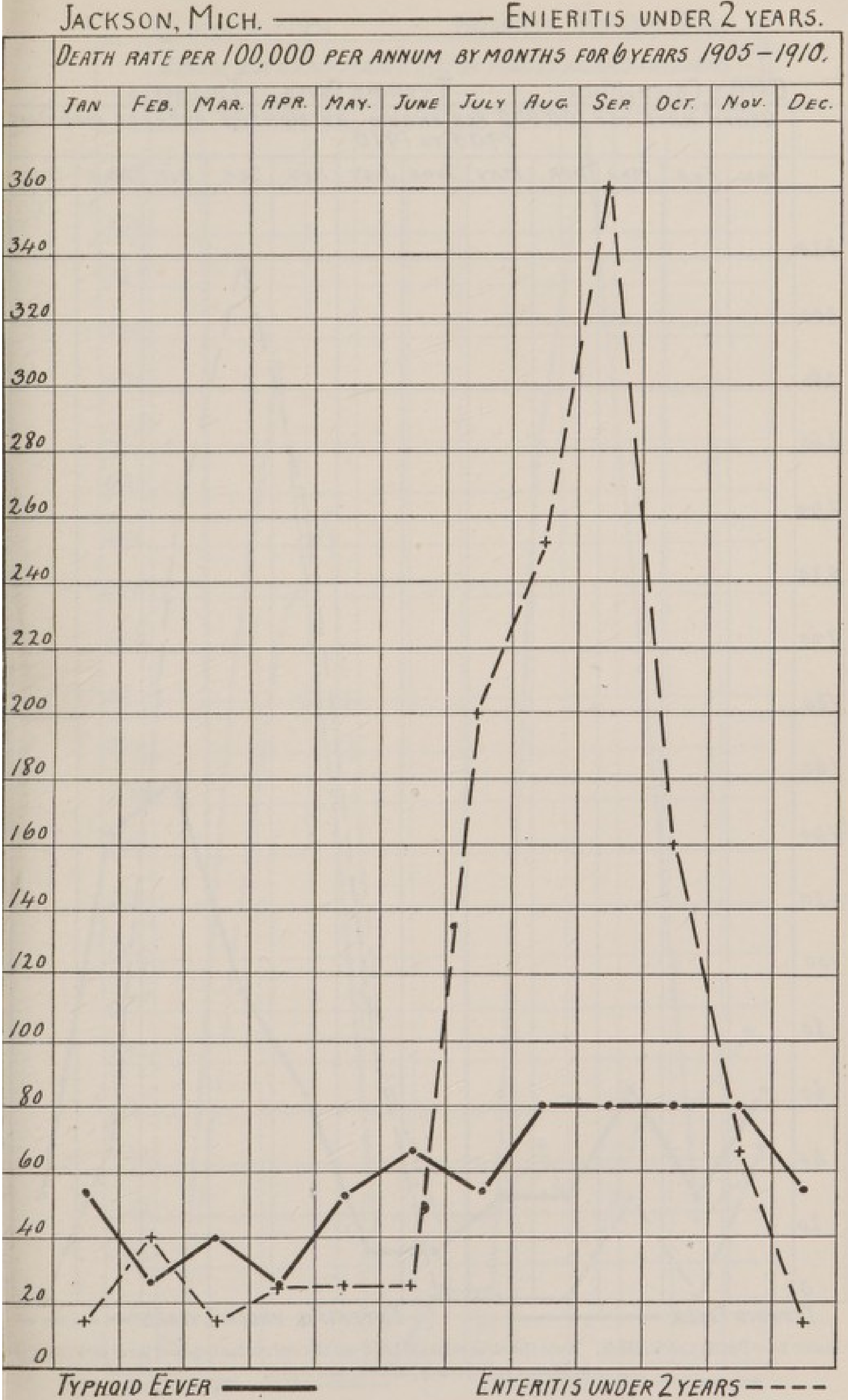


CHART 17.—Jackson, Mich., has asafe watersupply. This does not prevent high enteritis rates in summer, but insures low rates for both typhoid and enteritis in winter and spring months.

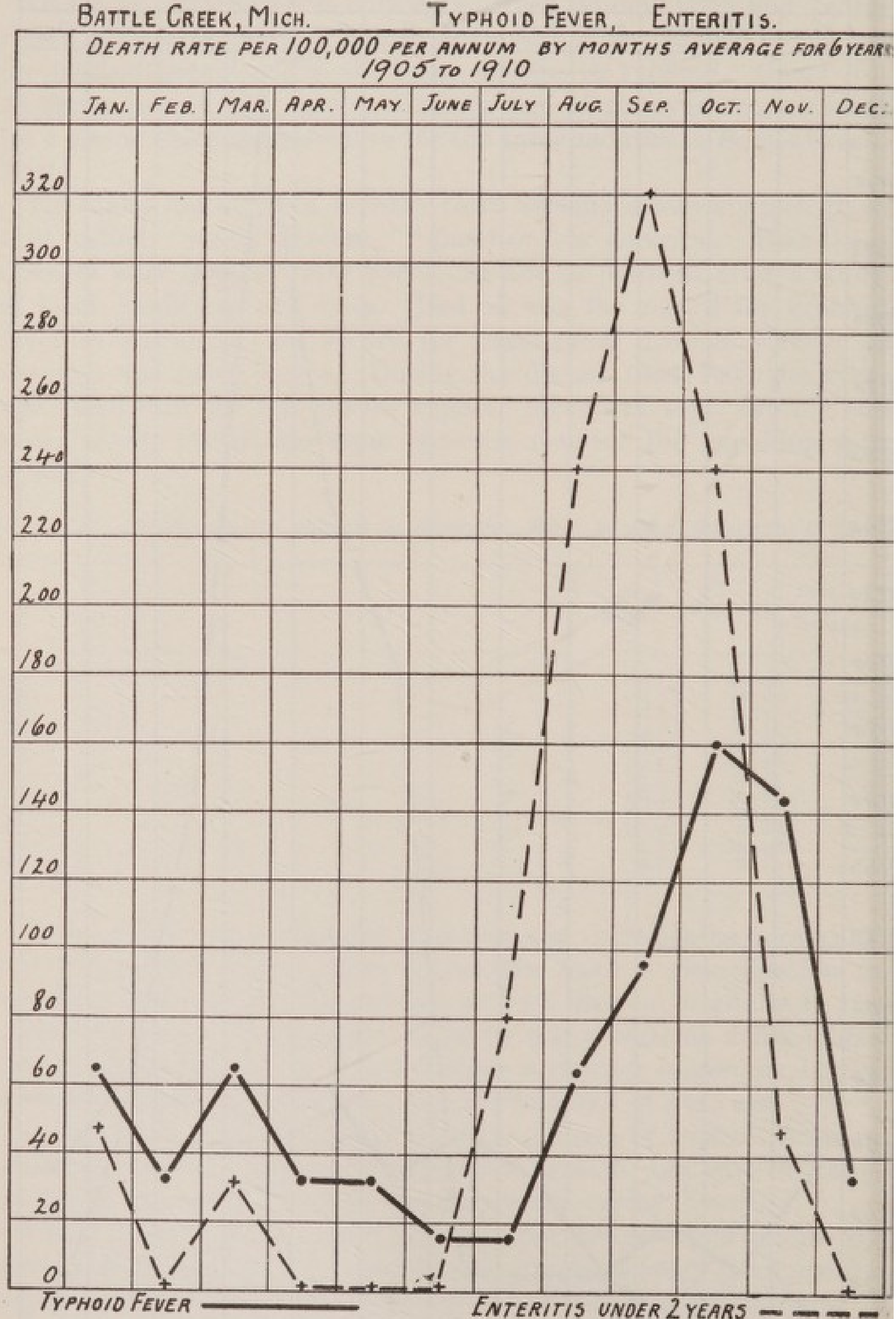


CHART 18.—Battle Creek, Mich. Note the close relation between the curves for typhoid fever and enteritis in January, February, March, and April.

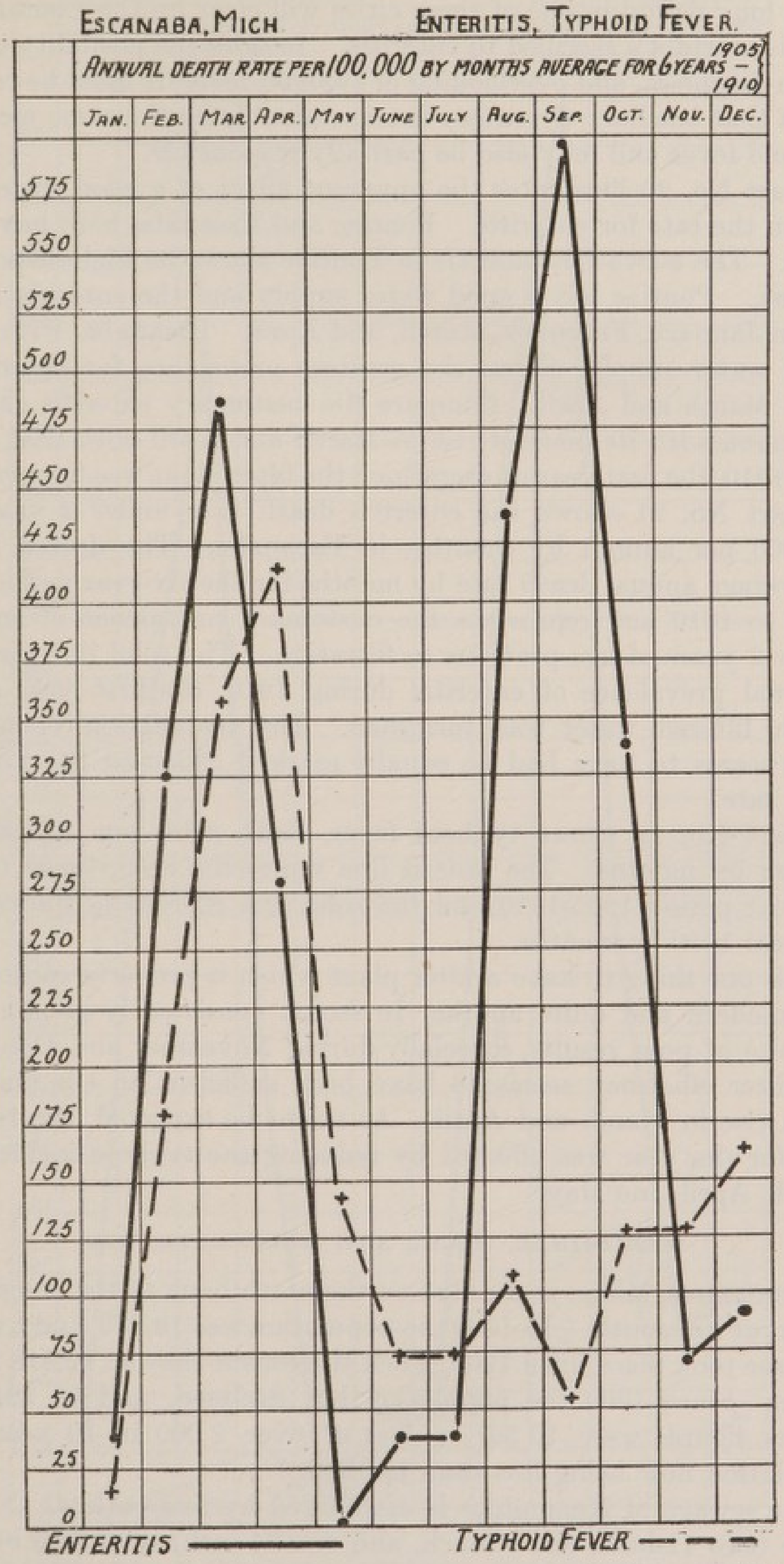


CHART 19.—Escanaba, Mich., showing close relation between typhoid fever and enteritis in January, February, March, and April.

ing a long period in one of these cities will clear up the exact nature of this mortality ascribed to enteritis. Besides the posibility of mistaken diagnosis, and overlooking of typhoid fever, it must be remembered that bacillary dysentery is transmissible by the same means as typhoid fever and may also be partially responsible.

Chart No. 20 illustrates the apparent effect of a good water supply on the rate for enteritis. Pontiac and Escanaba both have high rates. The curve for enteritis in Pontiac shows its highest point in August. Pontiac has a good water supply and the enteritis rate is low in January, February, March, and April. Escanaba, with a polluted water supply, shows the greatest prevalence for enteritis to be in March and April. Compare the customary enteritis curve in Escanaba with its marked rise in March and April with that of the year 1910, the first year during which the filter plant was in operation.

Chart No. 21 shows the enteritis death rate under 2 years per 100,000 per annum by months, in Escanaba. The dotted line is an average annual death rate by months for the six-year period from 1905 to 1910 and represents the customary prevalence of enteritis under 2 years of age previous to filtration. The solid line gives the seasonal prevalence of enteritis during 1910, the first year during which filtered water was furnished. The installation of a filter plant seems to have had an equally marked effect on the typhoid-fever rate.

Chart No. 22 shows typhoid fever death rates per 100,000 per annum by months. The dotted line represents an average for the six-year period 1905-1910 and the solid line represents the rate for the year 1910 by months.

It is one thing to have a filter plant which is properly constructed and modern and quite another to secure consistently good results. In spite of poor results, especially during November and December, the filter efficiency seems to have been sufficient to eliminate the usual rise in March and April. As might be expected, the reduced rate for the year was effected by reducing the typhoid incidence in March, April, and May.

MENOMINEE, MICH., AND MARINETTE, WIS.

Menominee, Mich., is situated on the north bank of the Menominee River, at its mouth. In 1890 the population was 10,630, and a steady increase took place until 1900, when the census showed 12,818 inhabitants. Since 1900 the population has declined, and in 1910 the census figures were 10,507, a loss of over 2,000 in 10 years, the population now being less than in 1890.

The sewage of Menominee is discharged by five outlets. Four of these (two 12-inch, one 18-inch, and one 24-inch) discharge into the Menominee River. One 12-inch sewer discharges into the bay about 4,000 feet northwest of the waterworks intake.

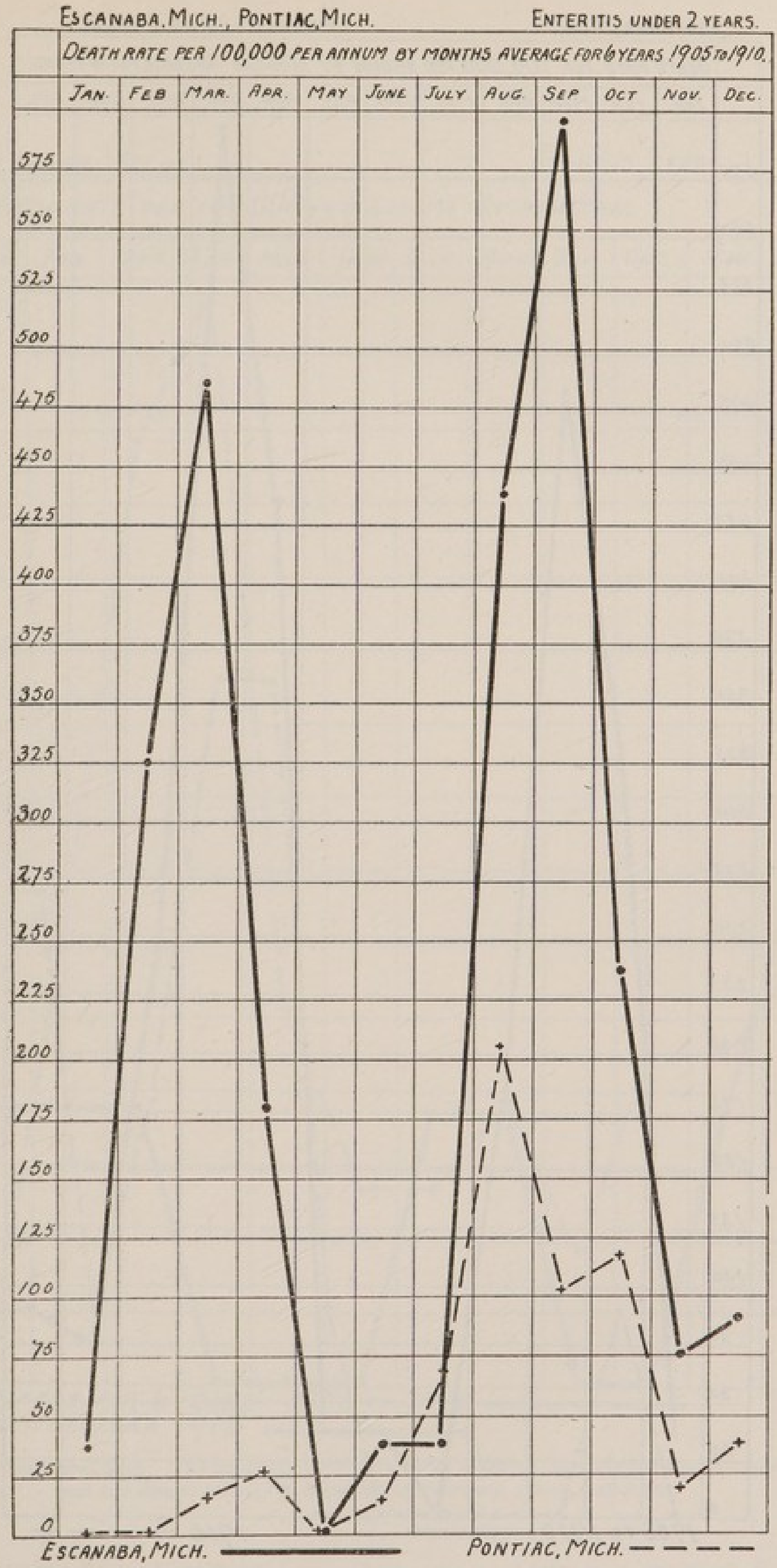


CHART 20.—Escanaba, Mich., compared with Pontiac, Mich.; enteritis under two years. Pontiac has a good water supply, while Escanaba's is grossly polluted.

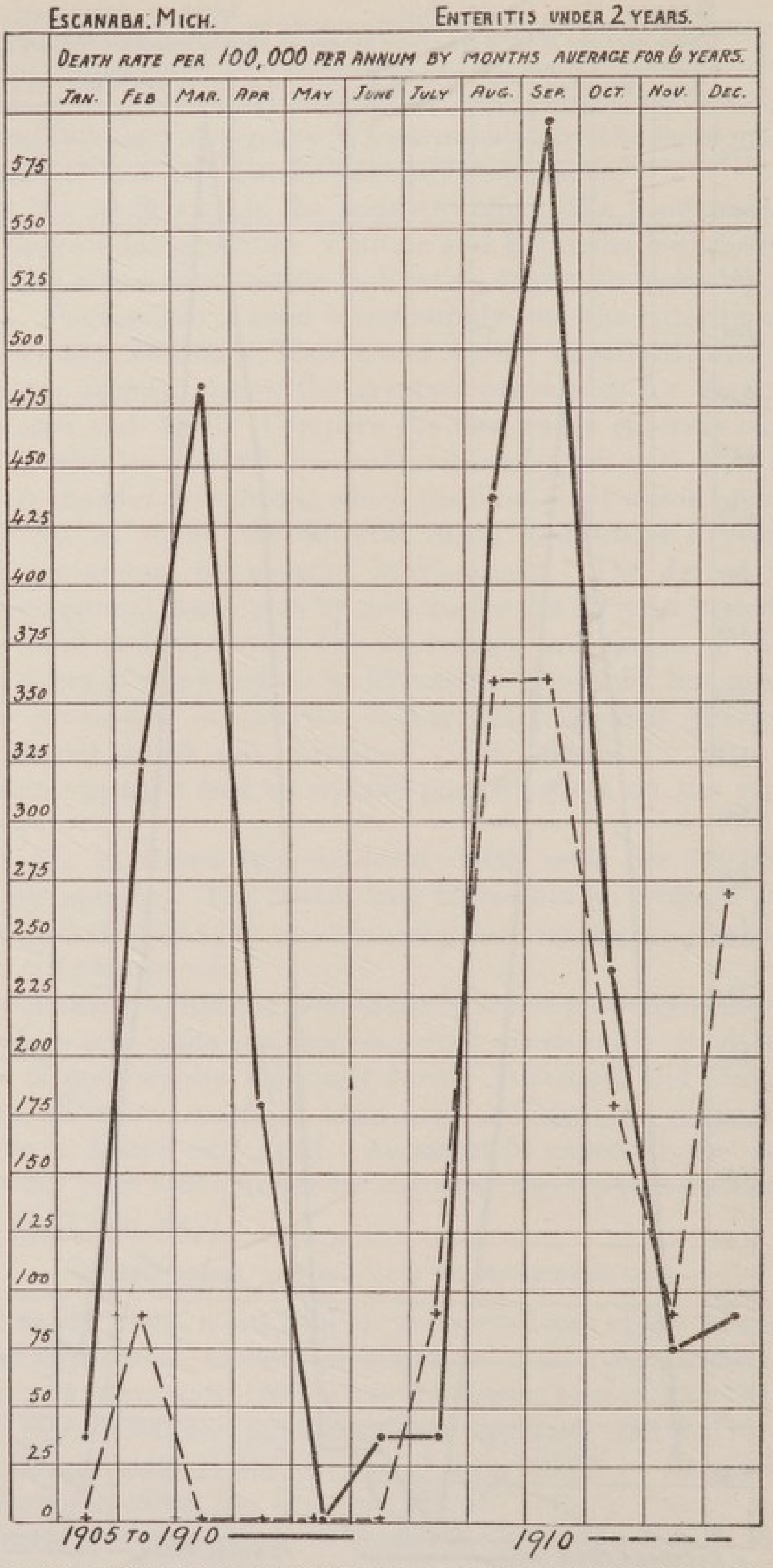


CHART 21.—Escanaba, Mich., enteritis under two years. The great reduction in enteritis following the installation of the filter plant was due in greatest measure to the reduction effected in February, March, and April.

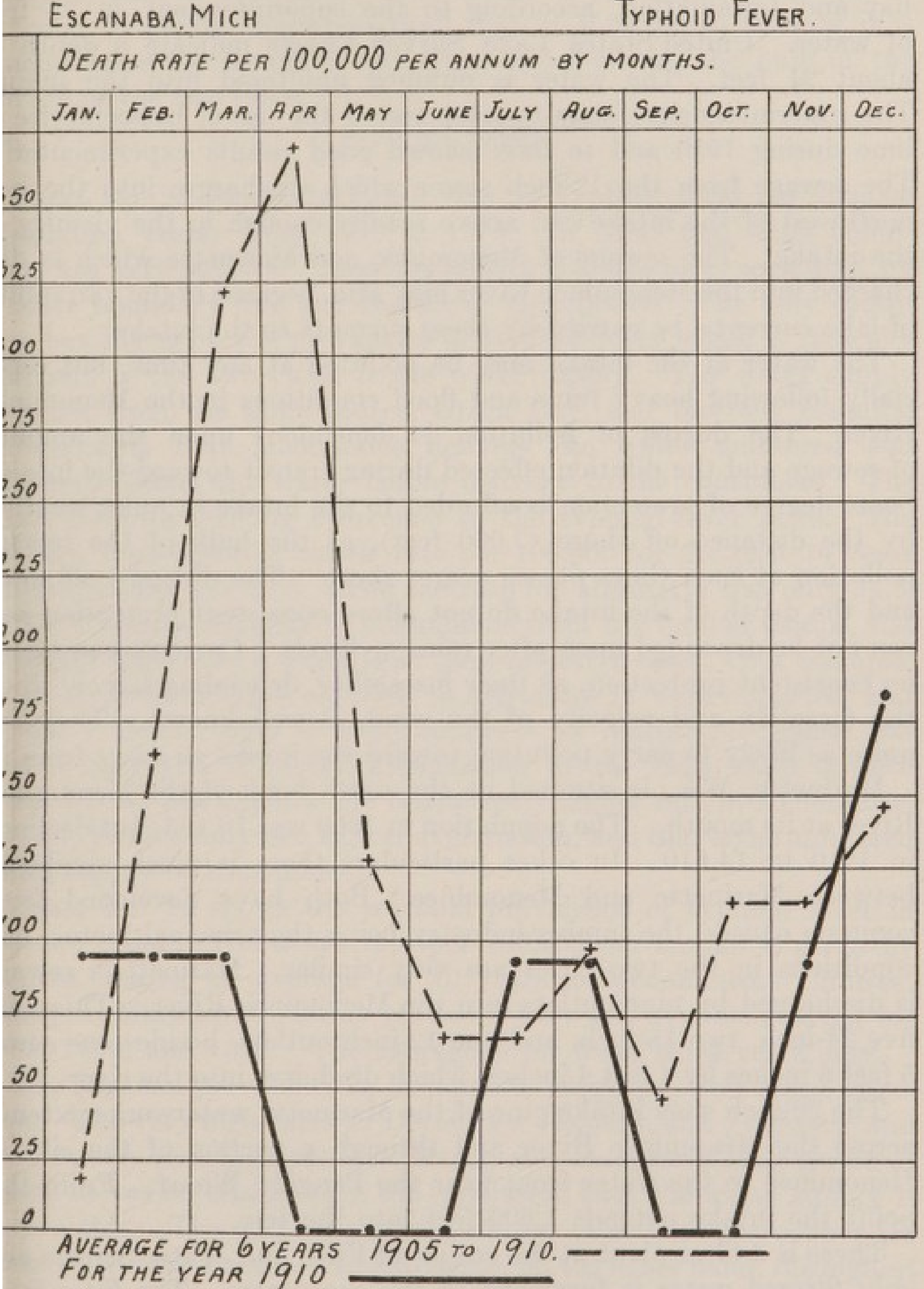


CHART 22.—Escanaba, Mich. The reduction in typhoid fever following the installation of the filter plant was due almost entirely to reduction in February, March, and April.

WATERWORKS.

The Menominee waterworks consist of an intake pipe and pum ing station, the intake pipe (16-inch) extending 2,000 feet into t bay and terminating, according to the superintendent, in 23 fe of water. United States Lake Survey Charts indicate a depth about 21 feet. The water is pumped unfiltered into the main The superintendent claims to have tested the use of hypochlorite lime during 1910 and to have shown good results experimentall The sewage from the 12-inch sewer which discharges into the b northwest of the intake can arrive readily enough in the vicinity the intake. The sewage of Menominee and Marinette which is di charged into the Menominee River may also, because of the variabili of lake currents, be carried by these currents to the intake.

The water at the intake may be polluted at any time, but esp cially following heavy rains and flood conditions in the Menomin River. The degree of pollution is dependent upon the amou of sewage and the dilution effected during transit toward the intak Some degree of protection is afforded to the intake in quiet weath by the distance off shore (2,000 feet), as the bulk of the sewa pollution at such times passes nearer shore. The distance off sho and the depth of the intake do not afford consistent protection an can not be depended upon after rains or floods. Currents can affo no consistent protection, as their instability, depending largely up the direction and velocity of the wind, is well known. They a quite as likely to carry pollution toward the intake as away from i

Marinette, Wis., is situated on the south bank of the Menomin River at its mouth. The population in 1900 was 16,195, but decline in 1910 to 14,610. In other particulars there is much similari between Marinette and Menominee. Both have developed fro common causes, the lumber industry being the principal factor, an conditions in the two cities are very similar. Marinette's sewag is discharged by nine outlets into the Menominee River. There a five 24-inch, two 18-inch, and one 12-inch outlets, besides one sew 5 feet 6 inches by 4 feet 4 inches, which discharge into the river.

The 20-inch steel intake pipe of the Marinette waterworks exten across the Menominee River and through a portion of the city Menominee to the water front near the Pengilly Wharf. From th point the intake extends 1,600 feet into the bay.

There is a filter plant at the corner of Fifth and Water Streets an only filtered water is furnished to the consumers. The filter is the mechanical or "rapid" sand type and consists of 10 units, eac capable of filtering 500,000 gallons daily. An average of 1.8 grai per gallon of alum is used as a coagulant. Frequent bacteriolog examination of the water is made, and the filter efficiency seems t

good. The filter efficiency of the Marinette plant is vital, as pol-tion at the intake is unavoidable at times. The same general condi-ons described in connection with Menominee's waterworks intake ply to that of Marinette. The intake of the Marinette supply is posed to greater pollution than that of Menominee because it is uch nearer the mouth of the river, which carries the bulk of the wage of the two cities.

TYPHOID FEVER.

Chart No. 23 shows the death rate for typhoid fever per 100,000 pulation yearly from 1900 to 1910. In these two cities condi-ons are very similar. They are practically one city, separated by State boundary line and the River Menominee. The only condi-on bearing upon the prevalence of typhoid fever which is radically fferent in the two cities is the water supply. The water supply taken from the same source, Green Bay, and the only essential fference is that Menominee delivers the water unfiltered and arinette filters the water before delivery to the consumers. The art shows a striking difference in the typhoid-fever rates. The erage typhoid-fever death rate per 100,000 for the past 10 years Menominee was 68.6, while the rate for Marinette was only 34.5. here are cases brought to Menominee from the lumber camps, but arinette suffers even worse from these imported cases. For example, 1910 out of 26 cases reported in Marinette 11 were imported, and the 7 deaths only 3 were residents of Marinette. These im-rted cases give a partial explanation of the high rates in both ties but do not explain the consistently higher rate in Menominee. fact, there is only one logical explanation, and that is the unfiltered ater supply of Menominee.

Chart No. 24 shows the seasonal prevalence of typhoid fever in e two cities. The death rate per 100,000 per annum is given by onths, taking an average for 10 years in Menominee. Unfortu tely, in Marinette monthly statistics were not available except for 08, 1909, and 1910. The average is for these three years only.

The seasonal prevalence in Menominee suggests water-borne infec-on. The very high rates in December, January, and February, and e scarcely less high rates in March and May, for a long period of ars, leaves no escape from the conclusion that the water supply is sponsible. The only months with lower rates than September are ne, July, and August. In Marinette, on the other hand, the highest te was in September.

ENTERITIS.

In the group of diseases classified under enteritis the influence of ater in these two cities is less marked.

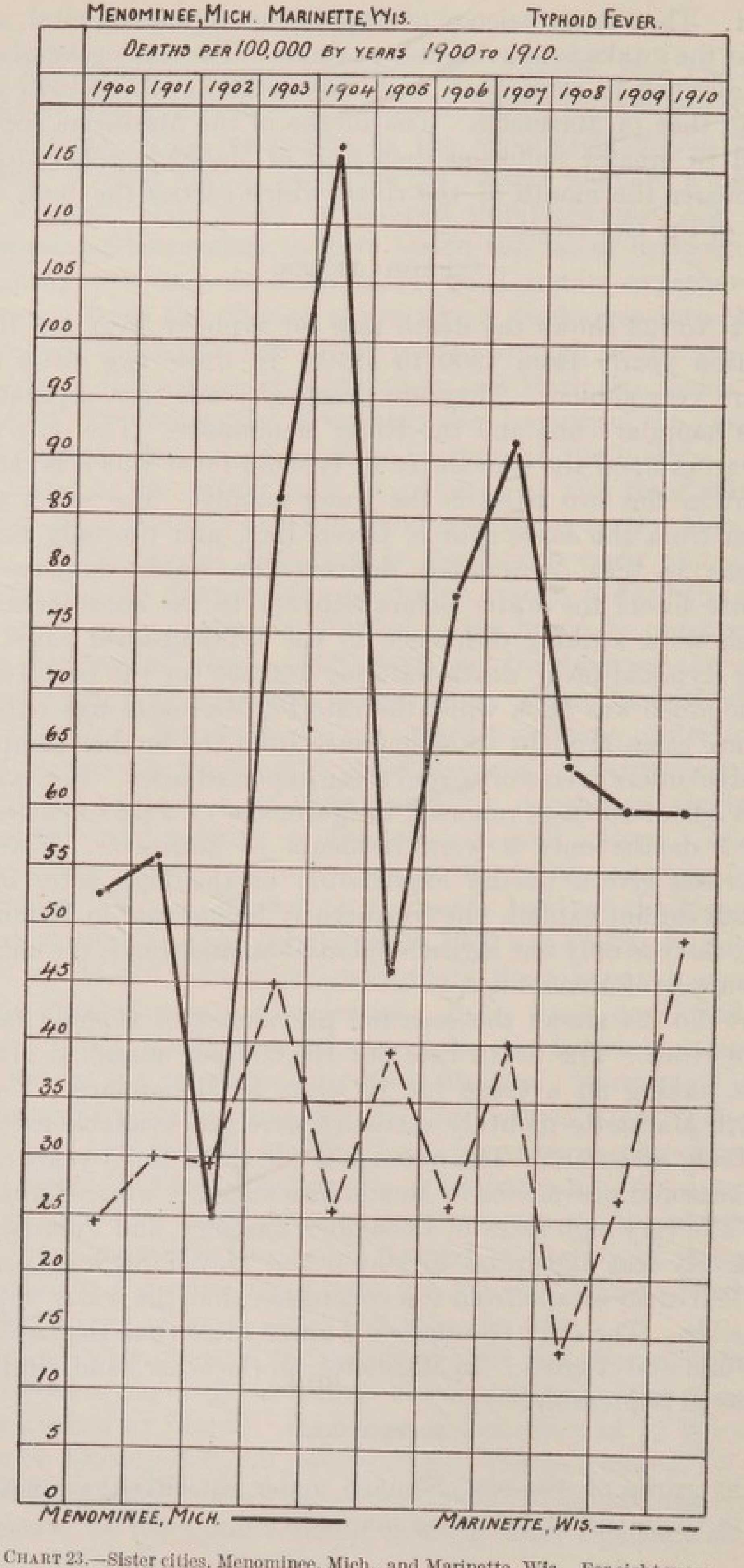


CHART 23.—Sister cities, Menominee, Mich., and Marinette, Wis. For eight years Marinette has had a lower typhoid rate consistently each year. Marinette has a filtered water supply; Menominee has a polluted, unfiltered supply.

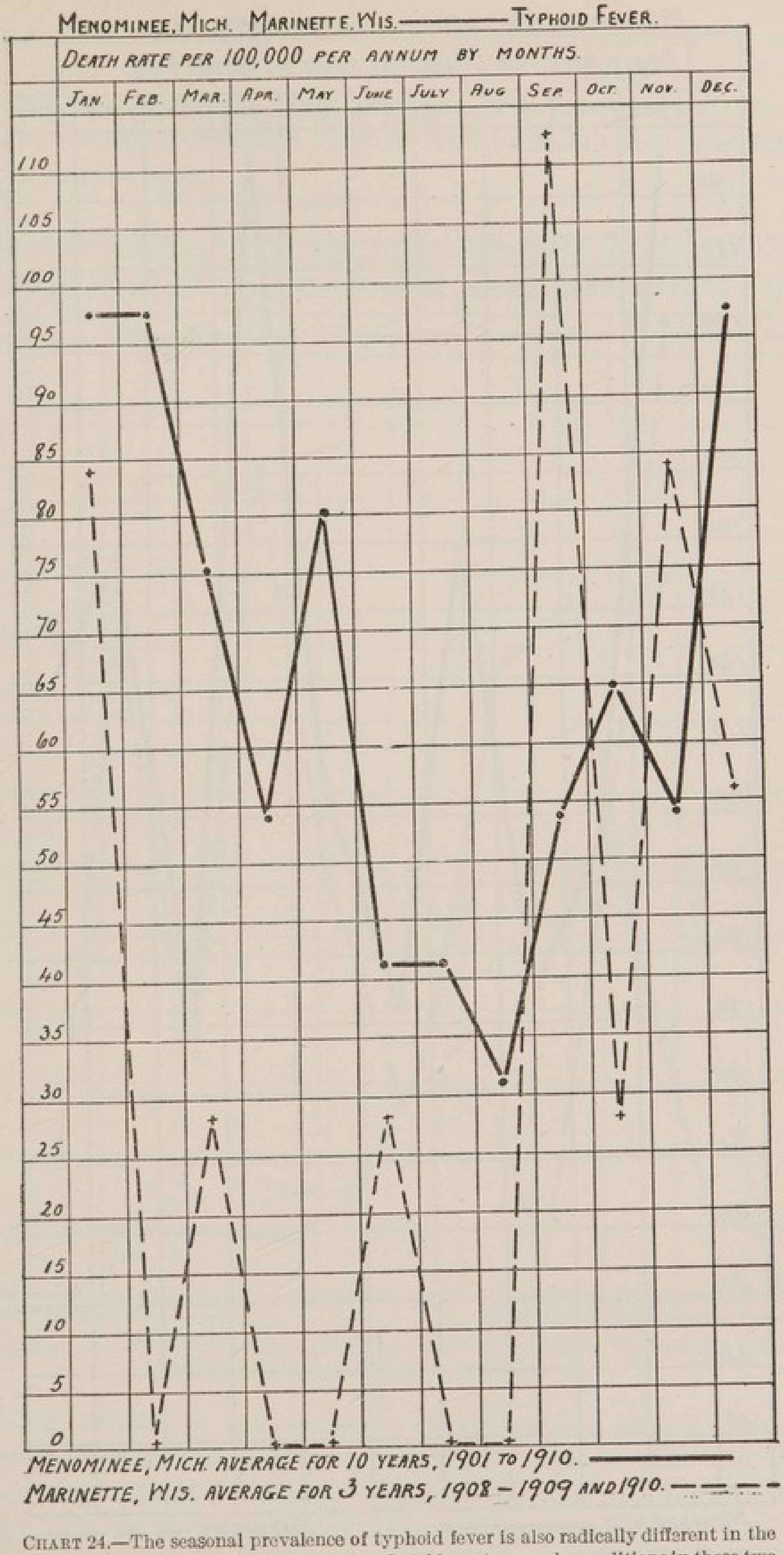


CHART 24.—The seasonal prevalence of typhoid fever is also radically different in the two cities, Menominee and Marinette. Outside water supply conditions in these two cities are very similar.

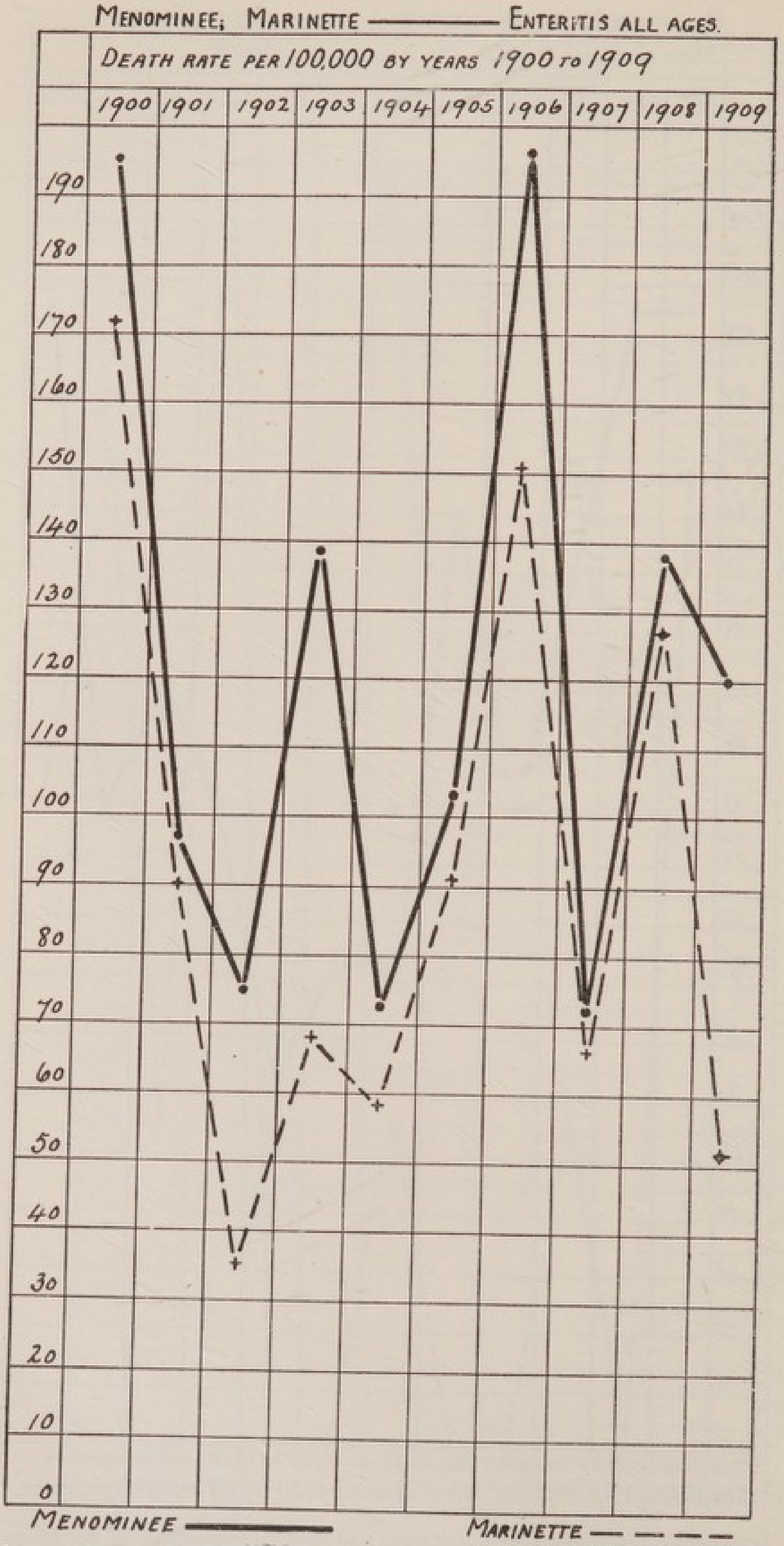


CHART 25.—Enteritis is also consistently higher in Menominee than in Marinette.

Chart No. 25 shows that the rate for Marinette, however, is con-
sistently lower than that of Menominee, and in every year of the
decade this was manifest. The average death rate per 100,000 per
annum for the 10-year period 1900 to 1909 in Menominee was 120.6,
and in Marinette 91.2.

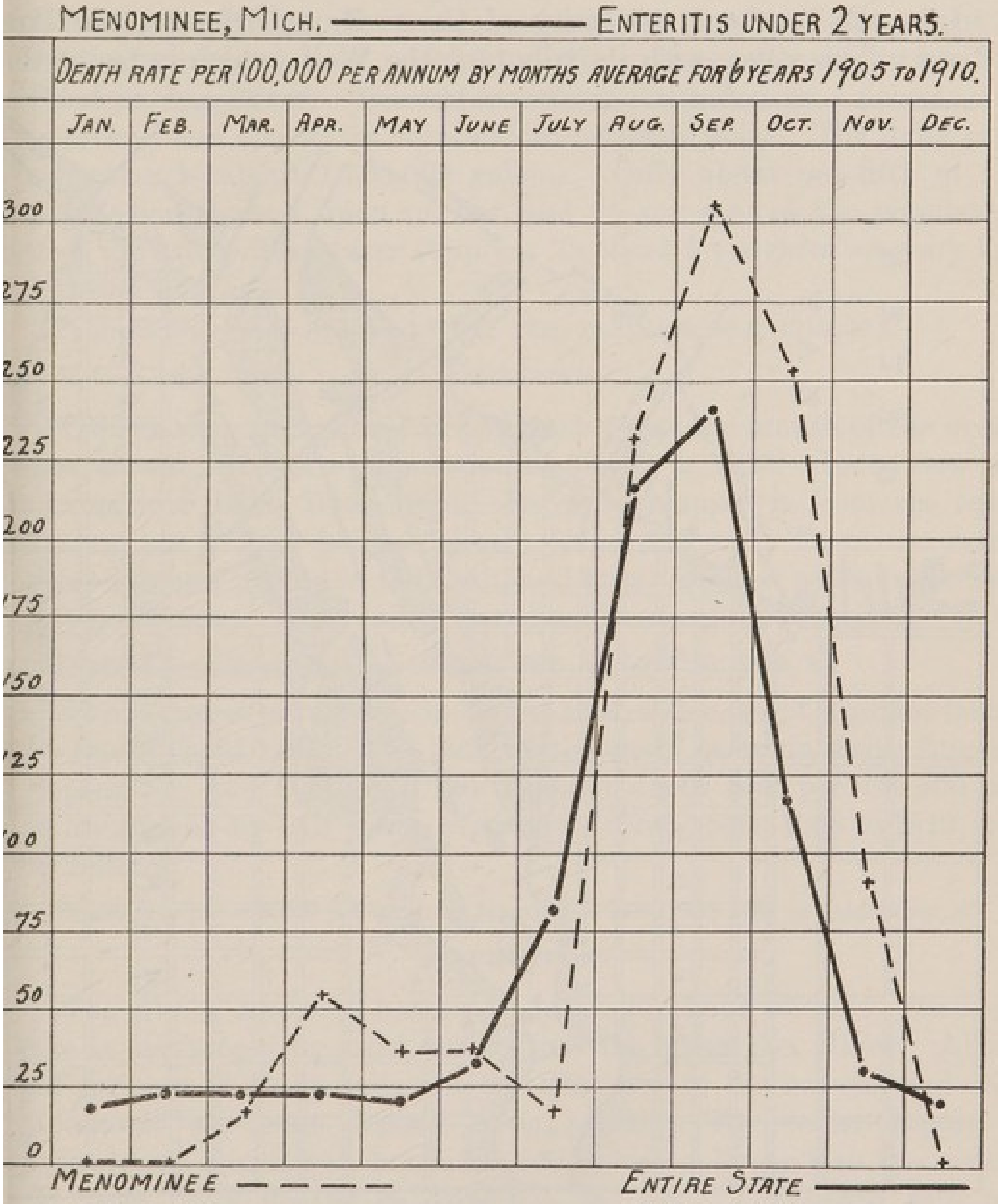


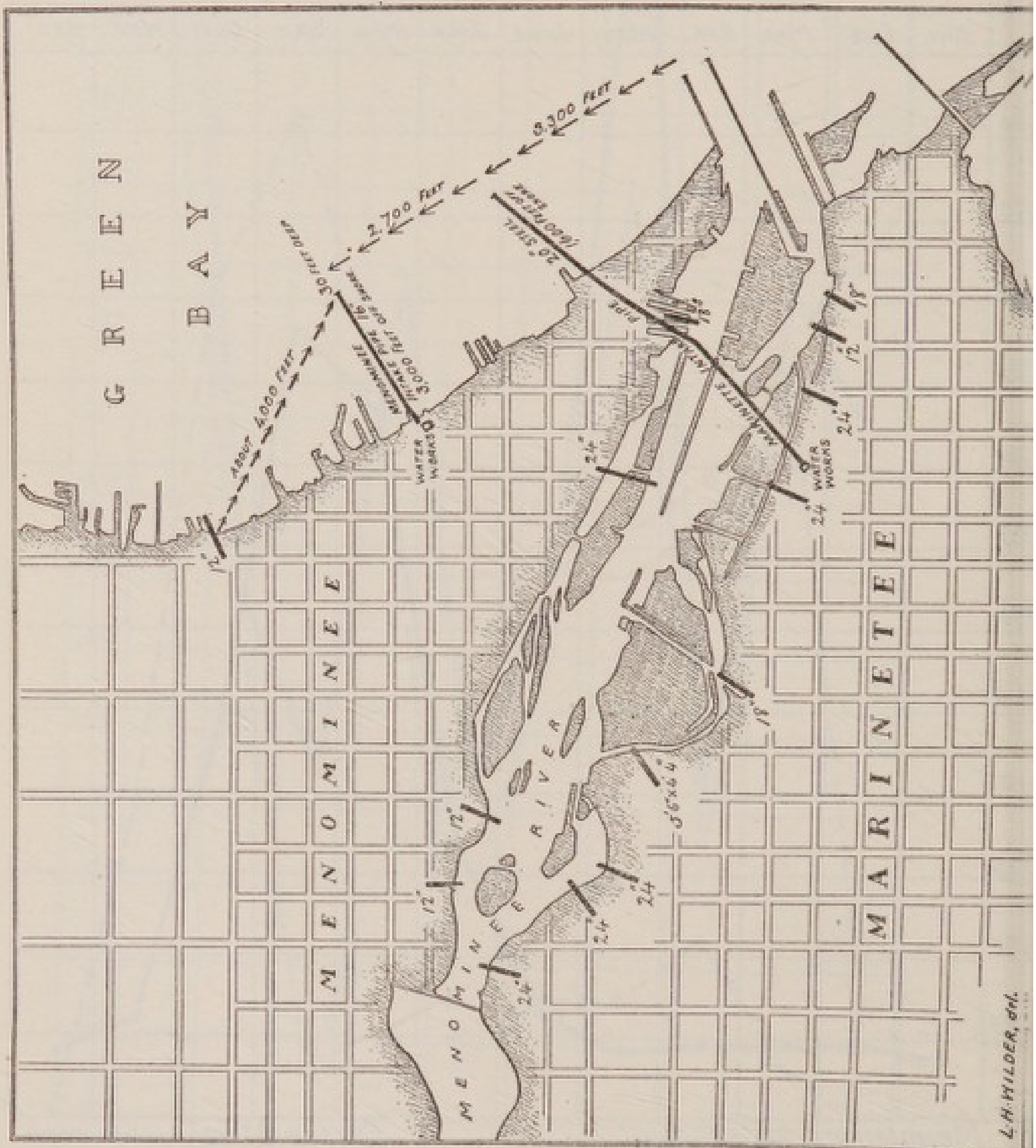
CHART 26.—Menominee, Mich. The rate for enteritis in April is more than double that of the State of Michigan, taking the average for six years.

Chart No. 26 shows the seasonal prevalence of enteritis under
two years in Menominee, Mich., by months, compared with the rate
for the entire State of Michigan. This shows that the bulk of the
enteritis occurs in the months of August, September, and October.
April, however, has a rate of 52, while the State rate for April is only

23, indicating that water is a factor, although not the greatest facto Enteritis would not be eliminated by the installation of a safe wat supply, but such a measure would effect a reduction probably equ to the difference between the rates for Menominee and Marinett

THE FOX RIVER DRAINAGE AREA.

Into the southern extremity of Green Bay discharges the Fo River. This river, with its tributary the Wolf (which is really tl



MAP 9.—Menominee, Mich., and Marinette, Wis., showing waterworks intakes and sewer outlets.

larger river) and Lake Winnebago, receives the sewage and drainag of several cities and a populous watershed. There are more tha 300,000 persons in the drainage area, including the cities of Oshkosh Green Bay, Fond du Lac, and Appleton. This system of waterway terminating in the Fox River is necessarily polluted by the larg

population, but fortunately the cities and towns have water supplies derived from deep wells, which are safe and apparently adequate, or furnish river or lake water only after filtration. (See map 7.)

FOND DU LAC.

Fond du Lac is situated upon Lake Winnebago at the mouth of the Fond du Lac River. Its population is about 19,000. It has about 31 miles of sanitary sewers, which by eight or nine outlets empty into the Fond du Lac River. The waterworks is controlled by a private corporation, and the water comes from artesian wells. The daily consumption is about 1,500,000 gallons. Only about one-fifth of the population depend upon privies, and 95 per cent of the population uses the safe public water supply. Typhoid fever rates are very low in Fond du Lac.

Typhoid fever death rate per 100,000: 1908, 10.8; 1909, 10.8; 1910, 10.8.

OSHKOSH.

Oshkosh is situated on Lake Winnebago at the mouth of the upper Fox River. It had a population of 33,062 in 1910. Its sewers discharge into Lake Winnebago. Its water supply is from the same source, but filtered before delivery to consumers. There are many cesspools and privies in Oshkosh, and many shallow wells in the outlying districts. The typhoid rate has been as follows:

Typhoid fever death rate per 100,000: 1908, 39; 1909, 20; 1910, 33.

The seasonal prevalence indicates that water is not a prime factor in the typhoid rate. The bulk of the cases occur in July, August, September, and October. The typhoid death rate per 100,000 per annum given by half years, average for three years, 1908 to 1910, was as follows:

Death rate per 100,000 per annum: January to June, 18; July to December, 60.

APPLETON.

The city of Appleton has a population of about 18,000. The sewage is discharged by eight outlets into the lower Fox River. About 80 per cent of the population are tributary to the sewers, and only about 20 per cent depend upon privies. The water supply is from lower Fox River, but is filtered before delivery into the mains. Typhoid fever deaths in Appleton are few.. The death rate per 100,000 for typhoid fever, average for the past three years was only 12.9.

Typhoid fever death rate per 100,000: 1908, 5.5; 1909, 5.5; 1910, 27.5; average rate, 12.9.

GREEN BAY.

The city of Green Bay has a population of 25,236. It is situated at the southern extremity of Green Bay at the mouth of lower Fox River. Its sewage is discharged by numerous outlets into East River

and Fox River. Its water supply is derived from artesian wells. There are 10 of these wells, and the daily pumpage is 11,000,000 gallons. In 1910 it was expected to increase the pumpage capacity to 21,000,000 gallons by installation of a new 10,000,000-gallon pump. The wells are true artesian wells, and the water may be considered safe.

Typhoid fever in Green Bay has been prevalent, though the rates are not excessive compared with other cities. The typhoid fever death rate per 100,000 for the past three years in Green Bay was as follows:

Death rate per 100,000, typhoid fever: 1908, 31.6; 1909, 23.4; 1910, 26.6; average rate, 27.2.

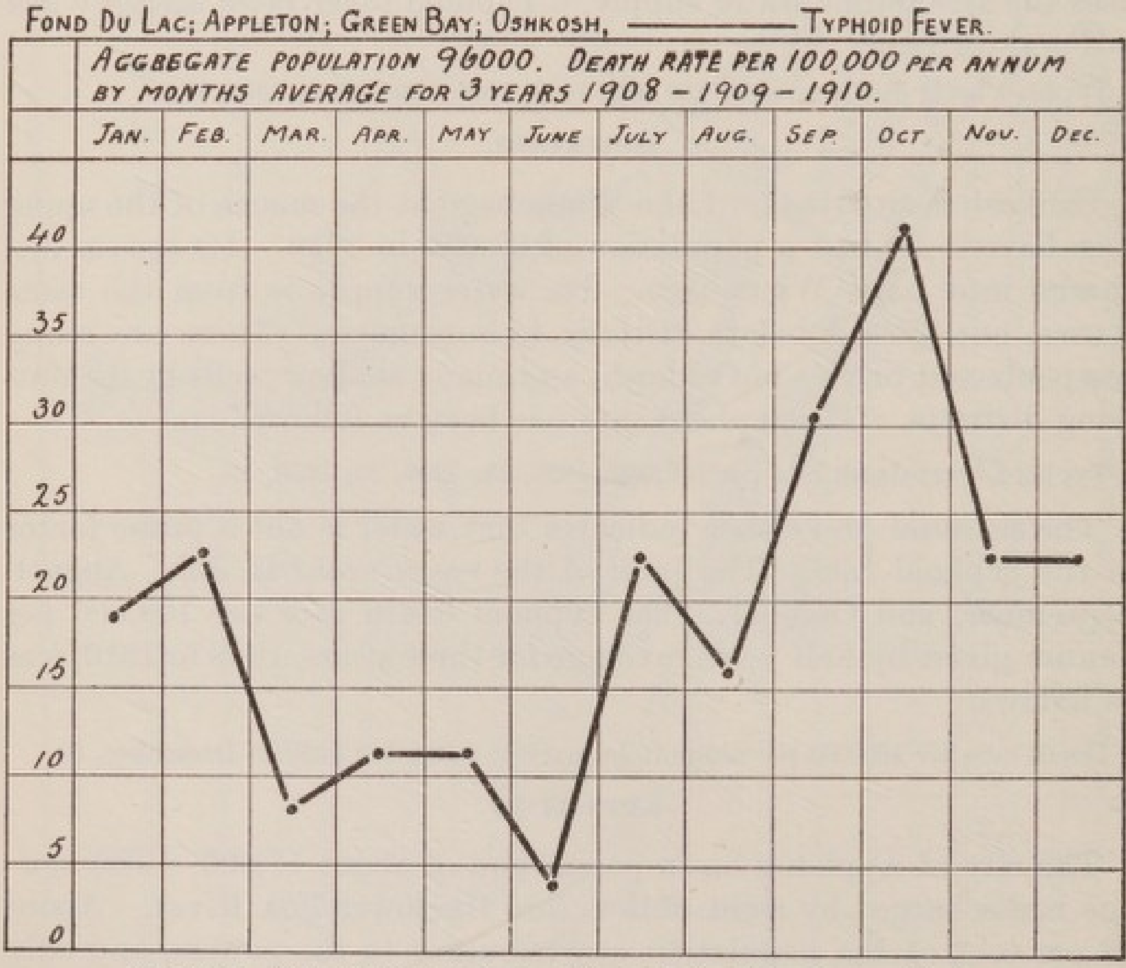


CHART 27.—Typhoid fever rates in the cities of the Fox River Darinage Basin.

This gives an average for the three years of 27.2, considerably lower than Oshkosh, but much higher than either Fond du Lac or Appleton. In all four of these cities the public water supplies must be considered safe. The difference in typhoid rates is due to other factors.

Typhoid fever death rate per 100,000, average for three years, 1908, 1909, 1910: Fond du Lac, 10. 8; Appleton, 12.9; Green Bay, 27.2; Oshkosh, 30.6.

The seasonal prevalence of typhoid fever and the distribution of cases in these four cities indicates that the public water supplies have had little, if any, part in the transmission of typhoid fever. Chart

No. 27 shows the prevalence by months. The rise in January and February is due entirely to deaths in Oshkosh and Green Bay. It is significant that privies and cesspools and private wells are more common in these two cities than in the cities of Fond du Lac and Appleton. In the city of Fond du Lac, with few privies and a safe public water supply from artesian wells used by 95 per cent of the people, not a single death from typhoid fever occurred in the three years 1908, 1909, 1910 in the first half of the year.

MANITOWOC.

The city of Manitowoc is situated on the west shore of Lake Michigan at the mouth of the Manitowoc River. The population in 1910 was 13,027. Manitowoc's sewage is discharged as follows:

One 8-inch outlet into river; three 10-inch, into river; one 15-inch, into river; one 20-inch, into river; one 24-inch, into river; one 15-inch, into lake 3,600 feet north of river's mouth; one 18-inch, into lake 1 mile south of river's mouth.

The water supply of Manitowoc is taken from wells sunk on the shore of Lake Michigan about 4,000 feet south of the mouth of the river. There is a natural filtration of the water in the gravel and sand layers—whether the supply is ground water intercepted on its way to the lake or lake water filtering back into the wells. There is every reason to believe that the Manitowoc water supply is safe. Typhoid fever has had a very low rate in Manitowoc. The typhoid-fever death rate per 100,000 per annum for the past three years was as follows:

Death rate per 100,000, typhoid fever: 1908, 16; 1909, 8; 1910, 8.

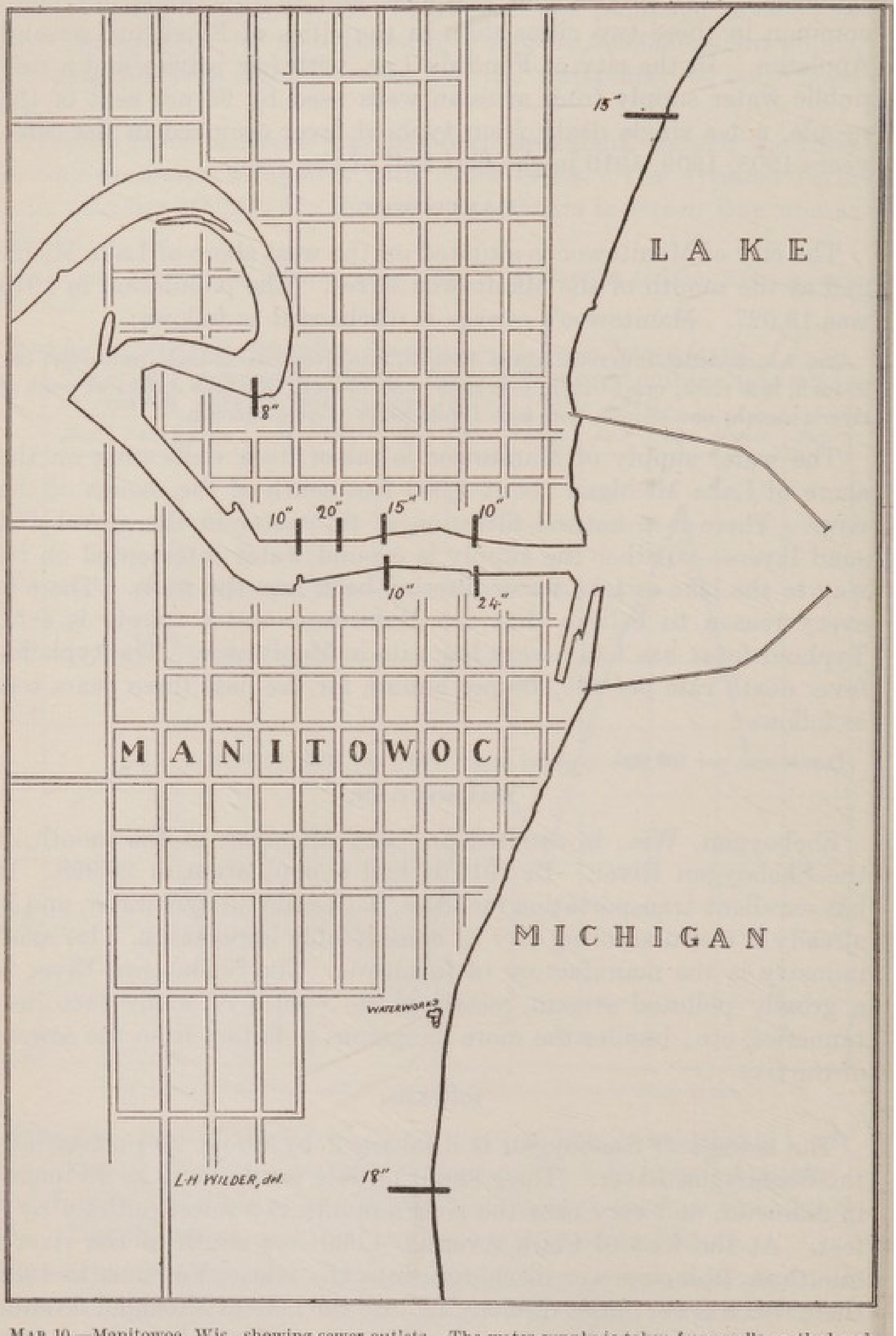
SHEBOYGAN.

Sheboygan, Wis., is situated on Lake Michigan at the mouth of the Sheboygan River. In 1910 it had a population of 26,398. It has excellent transportation facilities, both railroad and water, and is already a manufacturing city of considerable importance. Its chief industry is the manufacture of furniture. The Sheboygan River is a grossly polluted stream, receiving the wastes of many factories, tanneries, etc., besides the more dangerous pollution from the sewers of the city.

SEWERS.

The sewage of Sheboygan is discharged by about 20 outlets into the Sheboygan River. These sewer outlets are from 12 to 48 inches in diameter, and very near the river's mouth is a sewer outlet 4 by 5 feet. At the foot of Ciara Avenue, 4,000 feet south of the river's mouth, a 48-inch sewer discharges into the lake. Previous to 1908 there was a sewer outlet discharging into the lake at Michigan Avenue and another at Niagara Avenue. The sewage from these districts is now discharged into the river.

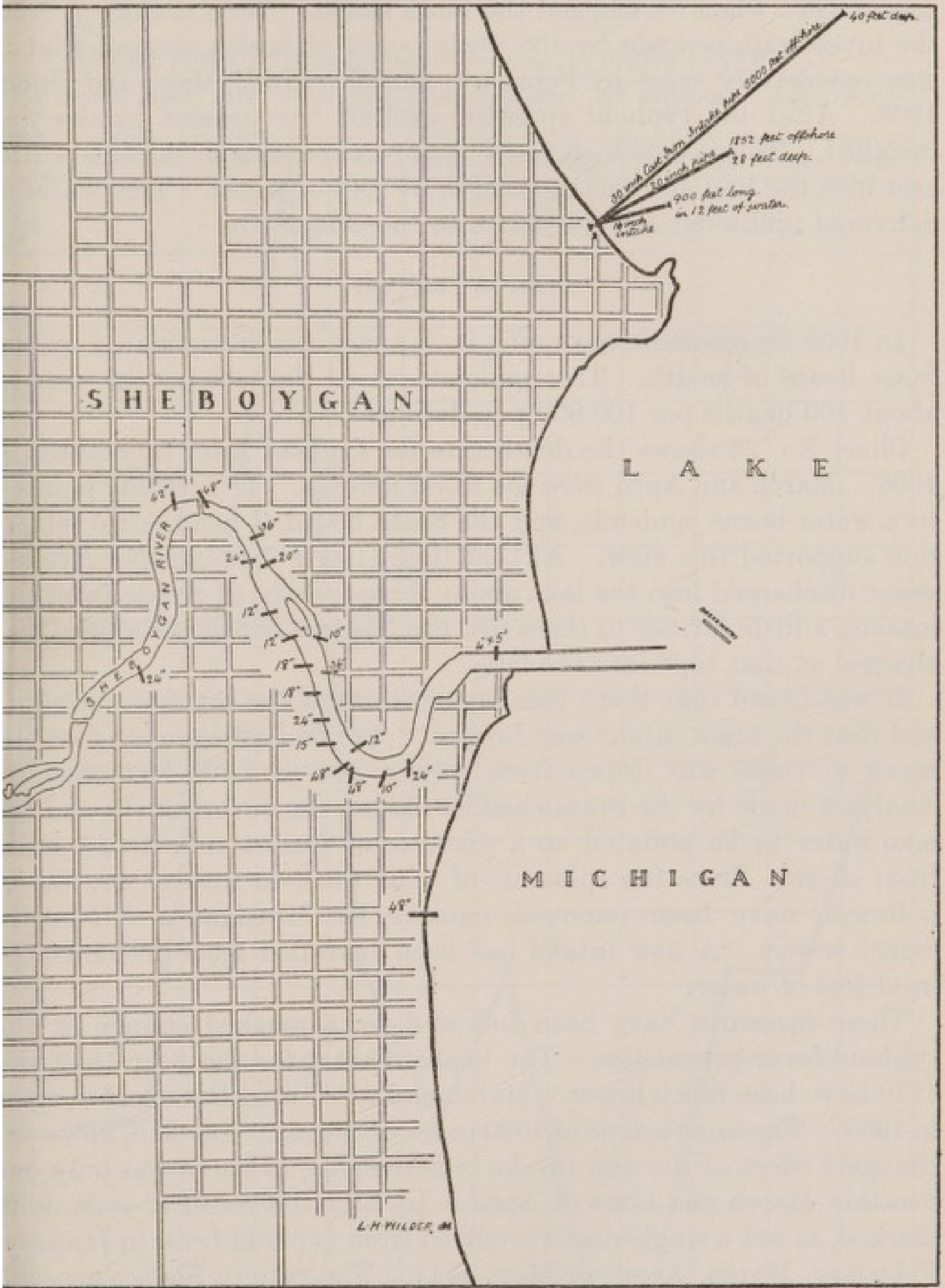
1. U. S. Census Bureau reports give 15.3 for 1910.



MAP 10.—Manitowoc, Wis., showing sewer outlets. The water supply is taken from wells on the beach.

WATER SUPPLY.

The Sheboygan water supply is drawn from Lake Michigan and delivered without treatment or filtration. There is a standpipe[1]



Map 11.—Sheboygan, Wis., showing sewer outlets and waterworks intakes.

with a capacity of a little more than 328,000 gallons, but this is too small to have any purifying effect as a storage reservoir, containing only about 2½ hours' supply.

[1] Standpipe collapsed Jan. 15, 1912, due to the action of ice.

Previous to the epidemic of 1905 the water was drawn from the lake from two intakes. First, the main intake, 1,852 feet off shore in 28 feet of water; and, second, the emergency intake, 900 feet off shore in 12 feet of water. The emergency intake was not supposed to be used except when ice clogged the main intake. As a matter of fact the investigation made by the State board of health showed that it was extensively used in February, March, April, May, and June, 1908. After the typhoid epidemic of 1908 the present intake was installed. This is a 30-inch cast-iron pipe extending 5,000 feet northeast into the bay and terminating in 47 feet of water. This water is delivered unfiltered and untreated to the consumers.

TYPHOID FEVER.

In 1908 an epidemic beginning in January was investigated by the State board of health. This epidemic raised the rate for the year to about 100 deaths per 100,000 population.

Chart No. 28 shows the death rate for typhoid fever by months in 1908. March and April were the worst months. Everything pointed to a water-borne epidemic, and the State board of health's investigation supported this view. At that time (1908) the Michigan Avenue sewer discharged into the lake about three-fourths of a mile from the intake; a little farther to the south the Niagara Street sewer also discharged at that time into the lake.

It was found that there was frequent use of the emergency intake and that the main intake was broken, 1,400 feet offshore, so that the water at times was drawn from points 900 to 1,400 feet offshore. Analyses made by the State chemist during the outbreak showed the lake water to be polluted to a distance of from 1 mile to 1½ miles from shore. Since the epidemic of 1908 the two nearest sources of pollution have been removed, namely, the Michigan and Niagara Street sewers. A new intake has been installed 5,000 feet offshore in 47 feet of water.

These measures have been followed by a marked change in the typhoid-fever prevalence. The typhoid rates for the year 1909 and 1910 have been much lower. March and April were the worst months in 1908. The same is true of 1909 in lesser degree. In 1910, however, the good effect of the new intake is noticeable, as there was only one death in March and none in April. In 1911 the result is even more marked, as not a single death occurred from typhoid fever in January, February, March, April, or May, 1911. The rate in Sheboygan will probably remain high after the public water supply is eliminated as a factor because of other factors. There are a great many shallow wells and insanitary yard privies. The diverting of sewage from the lake front north of the river's mouth was a very good sanitary measure, as was also the extension of the intake to the 47-foot depth.

By these measures a good raw water is secured for the filtration treatment which is necessary. The mere extension of the intake 000 feet can not be expected to furnish a safe water at all times. It ll protect Sheboygan most of the time, and ought to prevent explo-

ART 28.—Sheboygan, Wis., showing the explosive outbreak of typhoid fever in March and April, 1908.

ve massive outbreaks for many years unless Sheboygan's growth is ery rapid. But due to extraordinary conditions, serious pollution ay occur at any time, and a dilute or transient pollution may be sponsible for cases, a though it will be difficult to trace these cases

to the water supply. The only way in which accurate conclusio[ns] as to the protection afforded by such intakes can be formed is [by] making a daily examination with a careful quantitative estimati[on] of the B. coli for a period of at least one year. It is unfortunate th[at] wherever there is reason to believe that the water at the intake is [in] general of good quality B. coli estimations are only made at ra[re] intervals.

MILWAUKEE.

The city of Milwaukee had a population of 373,857 in 1910. [Its] growth has been very rapid, the gain in 10 years being over 88,0[00]. Its splendid harbor and transportation facilities, coupled with [its] substantial business houses and manufacturing concerns, make M[il]waukee a city of great industrial and commercial importance. [For] these reasons good sanitary conditions in Milwaukee are an int[er]state necessity, and bad conditions can not be considered of lo[cal] significance only.

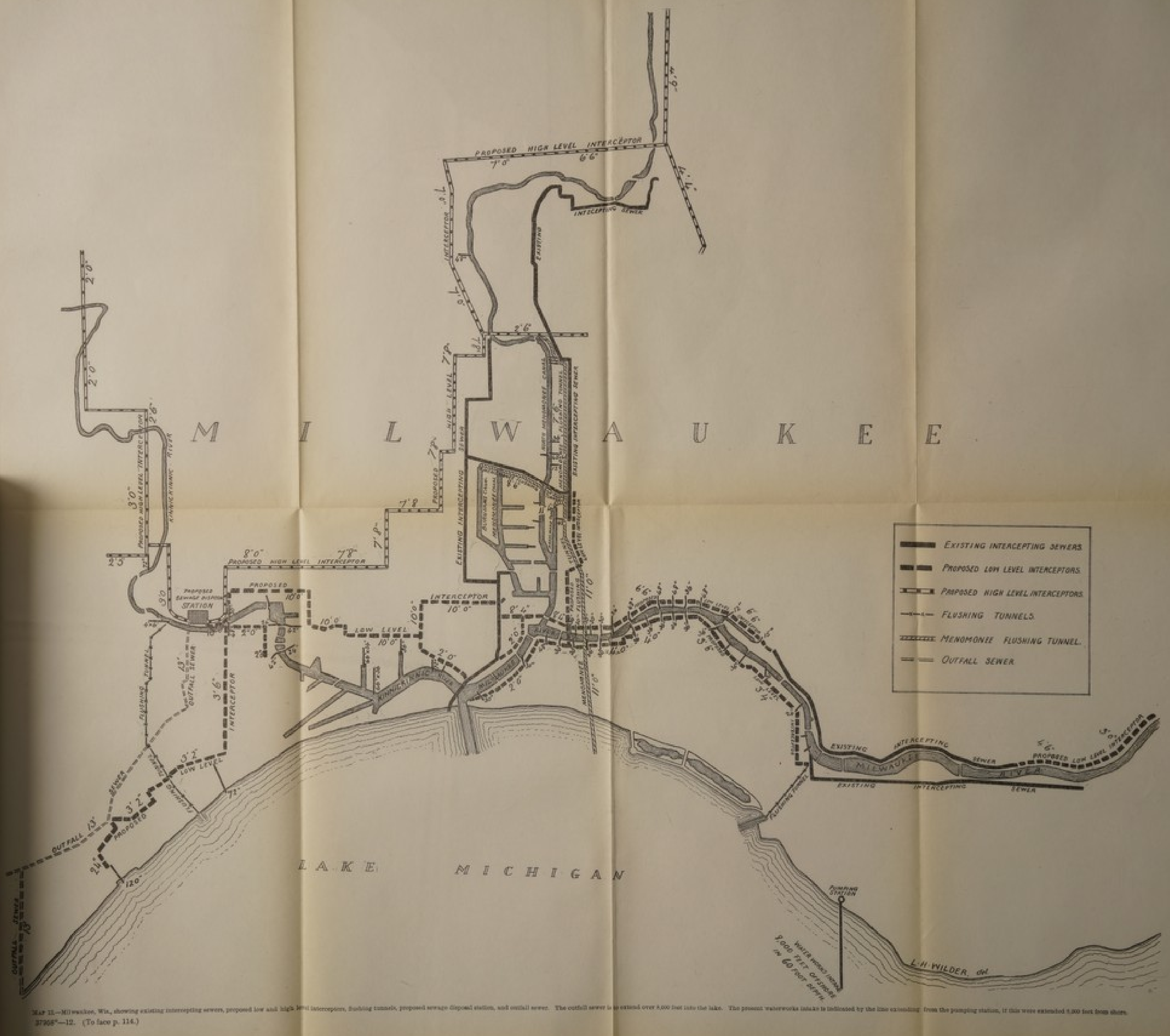
SEWERAGE SYSTEM.

At present the entire sewage of Milwaukee is discharged into [the] Milwaukee, Kinnickinnick, and Menominee Rivers, and into [the] Menominee Valley intercepting sewer. The confluence of these th[ree] rivers forms the inner harbor and there are several miles of doc[ks]. Canals have been constructed with dead ends to increase water fro[nt] and dockage, especially on the Menominee. As a result, the ve[ry] small stream flow is received at Milwaukee into a network of cana[ls] and practically all current velocity is lost. Under these conditio[ns] the rivers receiving the daily discharge of the city's sewers beca[me] unspeakably foul. To correct these conditions in the almost sta[g]nant rivers, flushing tunnels were constructed for the Milwaukee an[d] Kinnickinnick Rivers, and a system of intercepting sewers to keep [the] sewage out of the Menominee River and canals, this latter syst[em] discharging into the lake just south of the harbor.

These measures gave considerable relief from the foul odors whi[ch] formerly were such a nuisance, but probably increased the danger [to] the waterworks intake by projecting the fresh sewage more quick[ly] into the lake and cutting off the septic action formerly exercised [by] the rivers upon the sewage.

Map No. 12 shows the existing sewer outlets, the flushing tunne[ls], the existing interceptors, and the sewage pumping station. It a[lso] shows the proposed Menominee flushing tunnel and the propos[ed] intercepting sewers which will eventually receive and carry the ent[ire] sewage of Milwaukee to the proposed sewage disposal station. T[he] map also shows the proposed outfall sewer and the waterworks inta[ke].

In September, 1909, the Milwaukee common council appointed [a] commission of three expert engineers to make a study of the situati[on] and submit recommendations for improvement of the condition of t[he]



MAP 13.—Milwaukee, Wis., showing existing intercepting sewers, proposed low and high level interceptors, flushing tunnels, proposed sewage disposal station, and outfall sewer. The outfall sewer is to extend over 8,000 feet into the lake. The present waterworks intake is indicated by the line extending from the pumping station, if this were extended 5,000 feet from shore.

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rivers, protection of the water supply, and a satisfactory solution of the sewage disposal problem. The commission consisted of Messrs. John W. Alvord, George C. Whipple, and Harrison P. Eddy. These gentlemen made an exhaustive study of local conditions and made a complete report of conditions, with the remedies to be applied for their correction.

They recommended a sewage disposal plant on the Kinnickinnick River near the present flushing station; all sewage to be brought to this station by a system of high and low level interceptors. The high level interceptor will carry the sewage to the works by gravity; the low level sewage necessarily will be pumped to the sedimentation tanks.

The works are to consist of grit chambers, screens, baffled sedimentation tanks, and a disinfection plant. There is also provision for further purification when necessary by percolating filters, although the commission considered that the building of these additional works might be deferred for years. The outfall sewer from the disposal works is to be 13 feet in diameter and to extend 1 mile out into the lake, where it divides into two divergent branches 60 inches in diameter. This provides for a further extension of 3,000 feet from the point of bifurcation. Each of the two 60-inch terminals have openings 150 feet apart through which the effluent is discharged at a depth of from 30 to 35 feet. For sludge disposal the commission recommended the disposal in the lake 15 miles from shore by a special steamer built for the purpose. The commission also recommended that a water filtration plant be constructed at once, although they did not interpret their instructions to demand details for the plant.

WATER SUPPLY.

Milwaukee up to 1875 depended upon surface wells, and the rates for typhoid fever were very high. In 1875 a lake intake was installed 2,100 feet offshore in 18 feet of water. This proved a great improvement over the wells but the elimination of wells was not effected at once; in fact, it was a matter of years. From 1874 to 1895 this intake was used. In 1895 a new intake was installed which has been used up to the present. This consists of a tunnel extending out 3,146 feet to a crib from which two 60-inch mains extend 5,000 feet farther out into the lake terminating in two submerged cribs in 60 feet of water. The inflow to the cribs is about 15 feet above the bottom, and about 45 feet below the lake surface.

POSSIBILITY OF SEWAGE POLLUTION AT MILWAUKEE S WATER WORKS INTAKE.

No sewage is discharged into the lake north of the harbor entrance. The flushing operations in the Milwaukee and Kinnickinnic Rivers project millions of gallons of fresh sewage daily through the harbor

entrance to the lake. The Menominee Valley interceptor is discharged just south of the harbor entrance, and exceeds 50,000,000 gallons of fresh sewage daily. The distance from the harbor entrance to the intake is about 3⅓ miles. Currents in Lake Michigan according to Maj. Judson, a recognized authority, are very unstable and irregular. He says:

In my opinion the currents of Lake Michigan are so irregular in character that nothing would be gained worth the cost if attempt were made to obtain and classify further data of a general nature. If it is a question of protecting the water supply of any particular locality, in any event special study would have to be made, inasmuch as the lake currents, variable as they are, are much influenced by local conditions.

We do know, and perhaps it is enough for the purposes of this commission, that occasionally currents of considerable velocity, say several miles per hour, may be expected to arrive from almost any direction at any point reasonably near either shore of the lake. It is therefore apparent that in the general case if the waters of the lake are polluted by the discharge into it of large quantities of sewage, then practicable localities in the lake, even 20 to 30 miles distant from the point of entrance of the sewage, are not safe places from which to derive water for domestic use.[1]

The "prevailing" currents carry the sewage south away from the intake, but currents in an opposite direction are quite likely to occur. Accordingly, currents may be expected at times from southwest to northeast paralleling the bend in the shore line which forms Milwaukee Bay and in the exact direction of a line drawn from the harbor mouth to the intake. The possibility of sewage pollution at the intake is evident. The degree of pollution would depend upon certain factors, among which are the amount of sewage discharged, the time of transit from the point of discharge to the intake, and the amount of dilution effected.

The amount of sewage discharged daily is large, estimated at 61,000,000 gallons. The time of transit would depend upon the distance and the velocity of the current. The amount of dilution would also depend upon the current, which, if direct and rapid, would greatly hinder dilution. It is unnecessary to theorize upon the possibility of sewage contamination of Milwaukee's intake. This sewage contamination actually occurs, as shown by bacteriologic examinations made by Dr. Ruhland, city bacteriologist.

The following table gives the results of Dr. Ruhland's examination of water during October, November, and December, 1910:

[1] First report of the Lake Michigan Water Commission, 1909.

1910	Number of bacteria per c. c. gelatin.	Fermentation test.	Source.
ct. 1	3,000	Positive	Raw.
1	260	....do	Tap.
3	2,200	....do	Raw.
3	470	....do	Tap.
4	1,000	....do	Raw.
4	1,500	....do	Tap.
5	1,250	....do	Raw.
5	95	....do	Tap.
6	3,500	....do	Raw.
6	55	Negative	Tap.
7	825	Positive	Raw.
7	50	Negative	Tap.
8	1,200	Positive	Raw.
8	95	Negative	Tap.
10	1,250	Positive	Raw.
10	350	Negative	Tap.
11	500	Positive	Raw.
11	62	Negative	Tap.
12	900	Positive	Raw.
12	125	Positive (10 c. c.)	Tap.
13	870	Positive	Raw.
13	210	Negative	Tap.
14	345	Positive	Raw.
14	180	Negative	Tap.
15	....	....do	Raw.
15	345	Positive	Tap.
17	5,900	....do	Raw.
17	700	Positive (10 c. c.)	Tap.
18	800	Positive	Raw.
18	220	Positive (10 c. c.)	Tap.
19	1,200	Positive	Raw.
19	710	Positive (10 c. c.)	Tap.
20	1,215	Positive	Raw.
20	1,300	Positive (10 c. c.)	Tap.
21	680	Positive	Raw.
21	675	....do	Tap.
22	1,950	....do	Raw.
22	500	....do	Tap.
24	2,750	....do	Raw.
24	410	....do	Tap.
25	1,025	....do	Raw.
25	300	....do	Tap.
26	350	....do	Raw.
26	70	Negative	Tap.
27	300	Positive	Raw.
27	53	Negative	Tap.
28	210	Positive	Raw.
28	80	Negative	Tap.
31	....	Positive	Raw.
31	....	Negative	Tap.
ov. 2	1,750	Positive	Raw.
2	130	Positive (10 c. c.)	Tap.
3	17	Negative	Do.
4	28	....do	Do.
5	25	....do	Do.
7	15	....do	Do.
9	2,102	Positive	Raw.
9	19	Negative	Tap.
10	10	....do	Do.
11	27	....do	Do.
12	550	....do	Do.
14	72	....do	Do.
16	25	....do	Do.
17	17	....do	Do.
18	38	....do	Do.
21	17	....do	Do.
22	14	....do	Do.
23	14	....do	Do.
25	....	....do	Do.
28	164	....do	Do.
29	....	....do	Do.
30	....	....do	Do.
ec. 2	37	....do	Do.
3	47	....do	Do.
5	79	....do	Do.
7	....	....do	Do.
8	60	....do	Do.
9	28	....do	Do.
10	34	....do	Do.
12	....	(1)	Do.

[1] Chlorimation stopped.

1910	Number of bacteria per c. c. gelatin.	Fermentation test.	Sourc
Dec. 14	97	Positive (40 per cent gas.)	Tap.
16	89	Negative	Do.
17	97	Positive (40 per cent gas).	Do.
20	67	Negative	Do.
21	79	.....do	Do.
22	103	Positive (40 per cent gas).	Do.
23		.....do	Do.
27	152	Positive (35 per cent gas).	Do.
28	95	Negative	Do.
29	87	.....do	Do.
30	879	.....do	Do.

In the above table raw water signifies the untreated water durin the period when hypochlorite of lime was used. The hypochlori was used from June 21 to December 12. Consequently, up to Decem ber 12 the tap water was water treated with hypochlorite. Positiv for the fermentation test means positive in 1 c. c. samples unle otherwise stated.

These tables show almost constant pollution of the water suppl From January 1 to June 30, 1911, Dr. Ruhland has reported 40 p cent of the samples as positive for the *B. coli* test, and since June the percentage of positives has been higher.

TYPHOID FEVER IN MILWAUKEE.

During the period from 1870 to 1875 the water supply was large taken from shallow wells, and very high typhoid-fever rates prevaile in Milwaukee. In 1875 the first lake intake was put in service an a remarkable coincident drop is noticeable in the typhoid rat (See Chart No. 29.) The elimination of the dangerous wells was n accomplished promptly, in fact many still exist, and while the typho rate was much lower than it was prior to 1875, it remained high unt 1894, with an average above 30 deaths per 100,000.

It was decided to move the intake farther out into the lake, an in 1895 the present intake was installed, 8,000 feet from shore in 6 feet of water.

This was productive of good results for several reasons. First, substituted a safe water supply for one very greatly menaced, if n polluted, by the increasing amount of city sewage; second, it offere to the citizens a supply which they considered safe, and thus facil tated the elimination of the shallow wells; third, confidence in th new supply caused thousands of new house connections enabling th householders to replace their insanitary yard privies by modern flus closets.

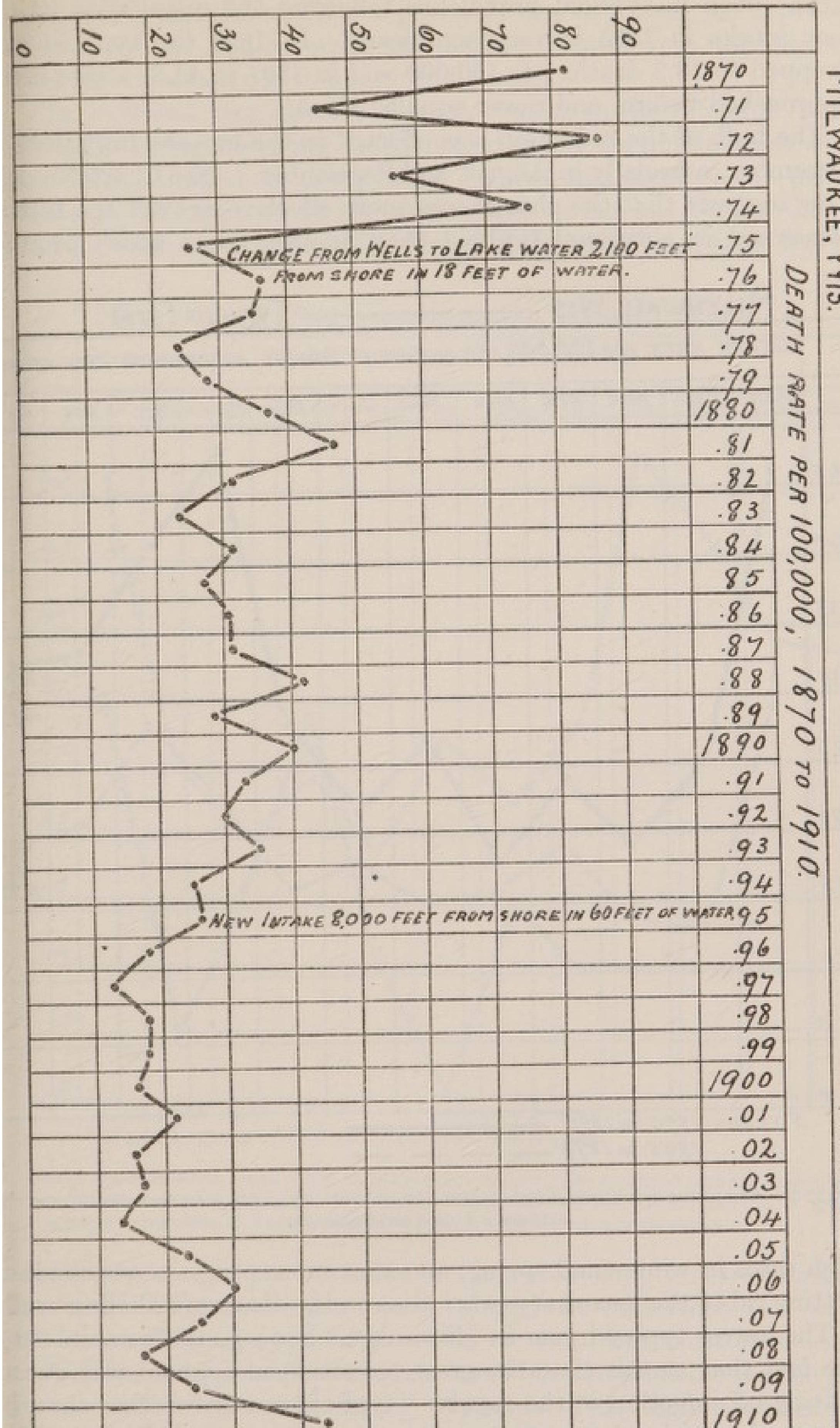


CHART 29.—Milwaukee, Wis., typhoid fever death rate by years since 1870.

The drop in typhoid prevalence following the installation of th new intake in 1895 is very significant. In 1896 the typhoid ra dropped to 18.2 deaths per 100,000 and in 1897 to 11.8, a rate nev approached before, and never equaled since

The bulk of the reduction was effected in the months from July December, especially in August and September. (See Chart No. 3 This suggests that the change was more effective against the facto concerned in autumnal typhoid than against those which produ

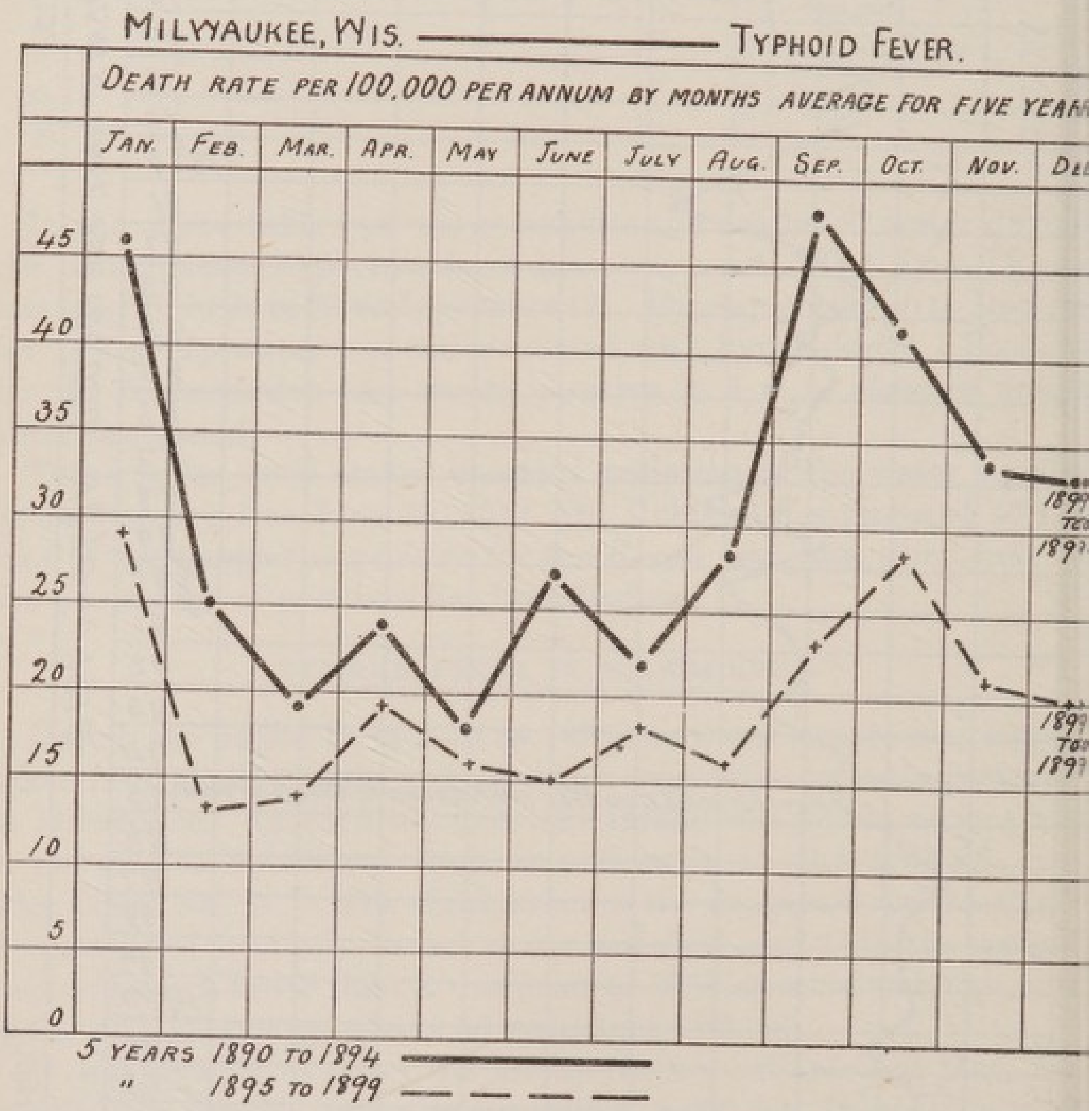


CHART 30.—Comparing quinquennial periods 1890-1894 and 1895-1899. The reduction effected was mo evident in August and September.

high rates in winter and spring, and that more progress was made i getting rid of the insanitary privy than in the closing of shallow well

The lowest typhoid year in Milwaukee's history, 1897, accentuat the fact that at this time the great reduction in typhoid was due t cutting off infection in the regular "typhoid season" rather than b any marked reduction in the winter and spring typhoid. (See Char No. 31.) There still remained an undue prevalence in the winte

and spring months which was probably due to water. It is probable that the many shallow wells which still persisted were responsible for this high mortality in January and April.

In 1899 and 1900 there was improvement in the rates for the first half of the year following the increased use of the public water supply and abandonment of many wells. From this time to the present, however, the typhoid in the winter and spring has become increasingly prominent in spite of the fact that the number of wells has been

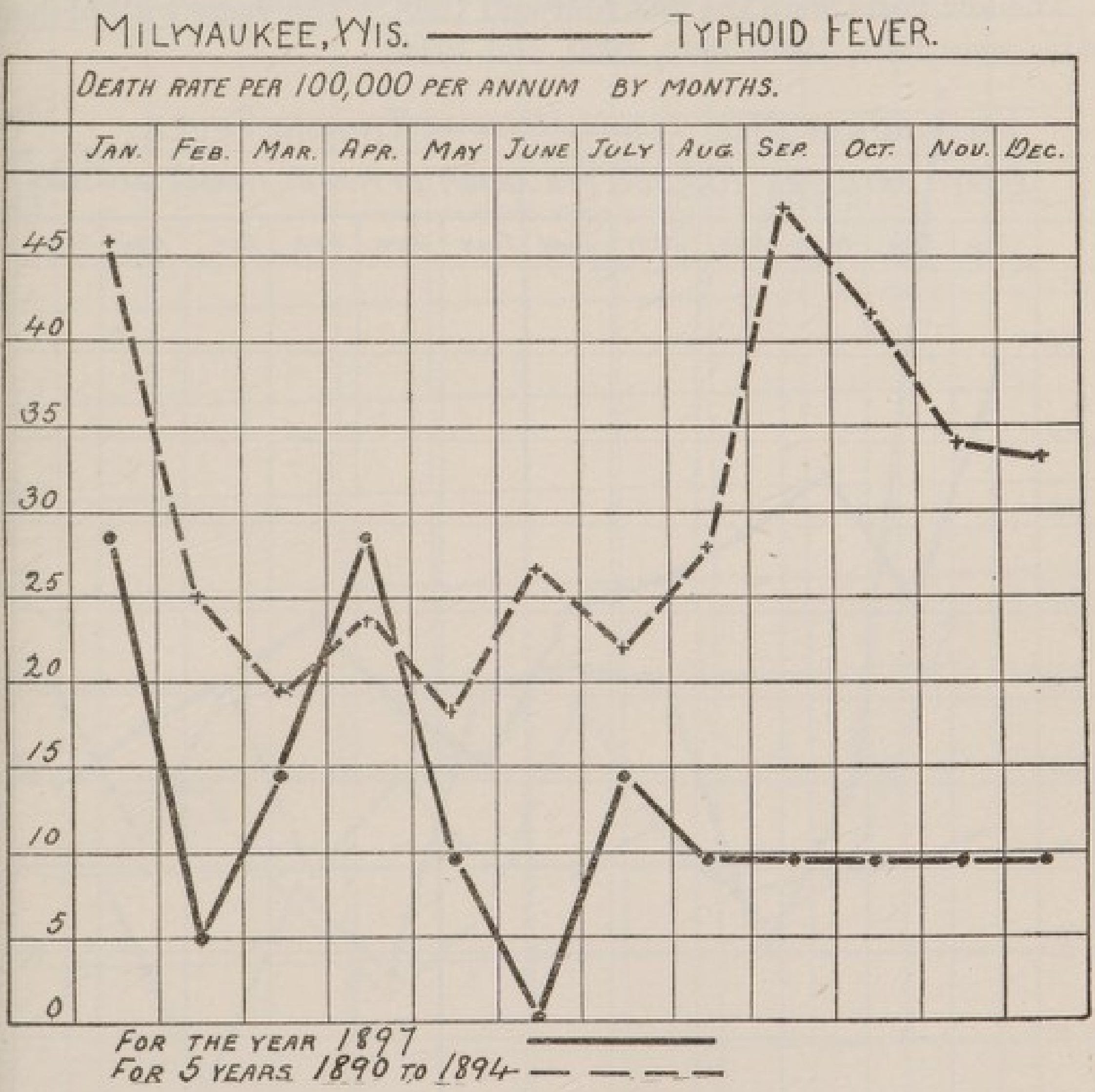


CHART 31.—The lowest typhoid year in Milwaukee's history (1897) compared with the quinquennial period previous to installing the new intake. The great reduction effected was due in greatest measure to reduction in August, September, October November, and December.

steadily decreased and the use of the public supply correspondingly increased. The wells may have played an important role in the winter and spring typhoid previous to 1900, but with their steady reduction, some other factor must have been responsible for the great increase of winter and spring typhoid. This high prevalence in January, February, March, April, and May is not an unusual occurrence in any single year, but from 1903 to 1910 the winter and spring

typhoid rates exceeded those of the second half of the year in every year except 1908, and this condition grew progressively worse as the population and sewage discharge increased until in 1910 it culminated with a death rate of 61 per 100,000 for the first half of the year. (See Chart No. 32.) In the decade ending in 1910 there were five years with low, and five with distinctly higher typhoid-fever rates.

Typhoid death rate per 100,000: 1901, 21.7; 1902, 15.1; 1903, 16.8; 1904, 13.6; 1908, 16.8; 1905, 22.9; 1906, 30.5; 1907, 25.7; 1909, 23.4; 1910, 43.

The low years were the first four and 1908. The years with higher rates were 1905, 1906, 1907, 1909, and 1910.

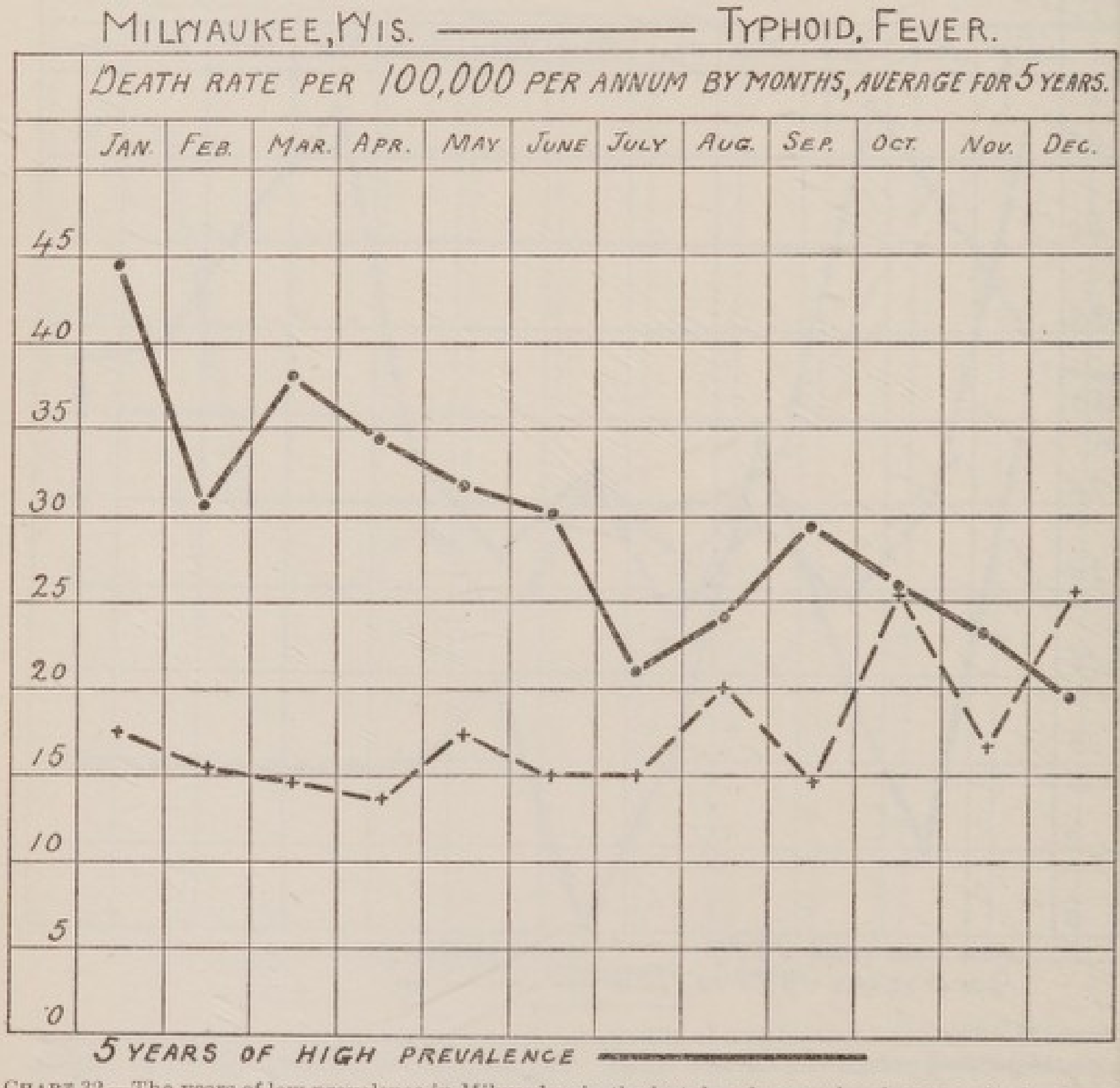


CHART 32.—The years of low prevalence in Milwaukee in the last decade were low because of reduction in the typhoid rates for the first half of the year.

Chart No. 33 shows that the high rates in 1905, 1906, 1907, 1909, and 1910 were due almost entirely to excessive prevalence from January to June, and that the low rates for 1901, 1902, 1903, 1904, and 1908 were made possible by reduction of the typhoid during the first half of the year. (These years with high rates in the first half of the year are all in the last half of the decade.) The increase in the rate from January to June since 1902 has been progressive and

oincident with the increase in the amount of sewage up to 1908. n this latter year the rate was low for both halves of the year, but n 1909 the rate from January to June was 24, and in 1910 the rate eached 61.

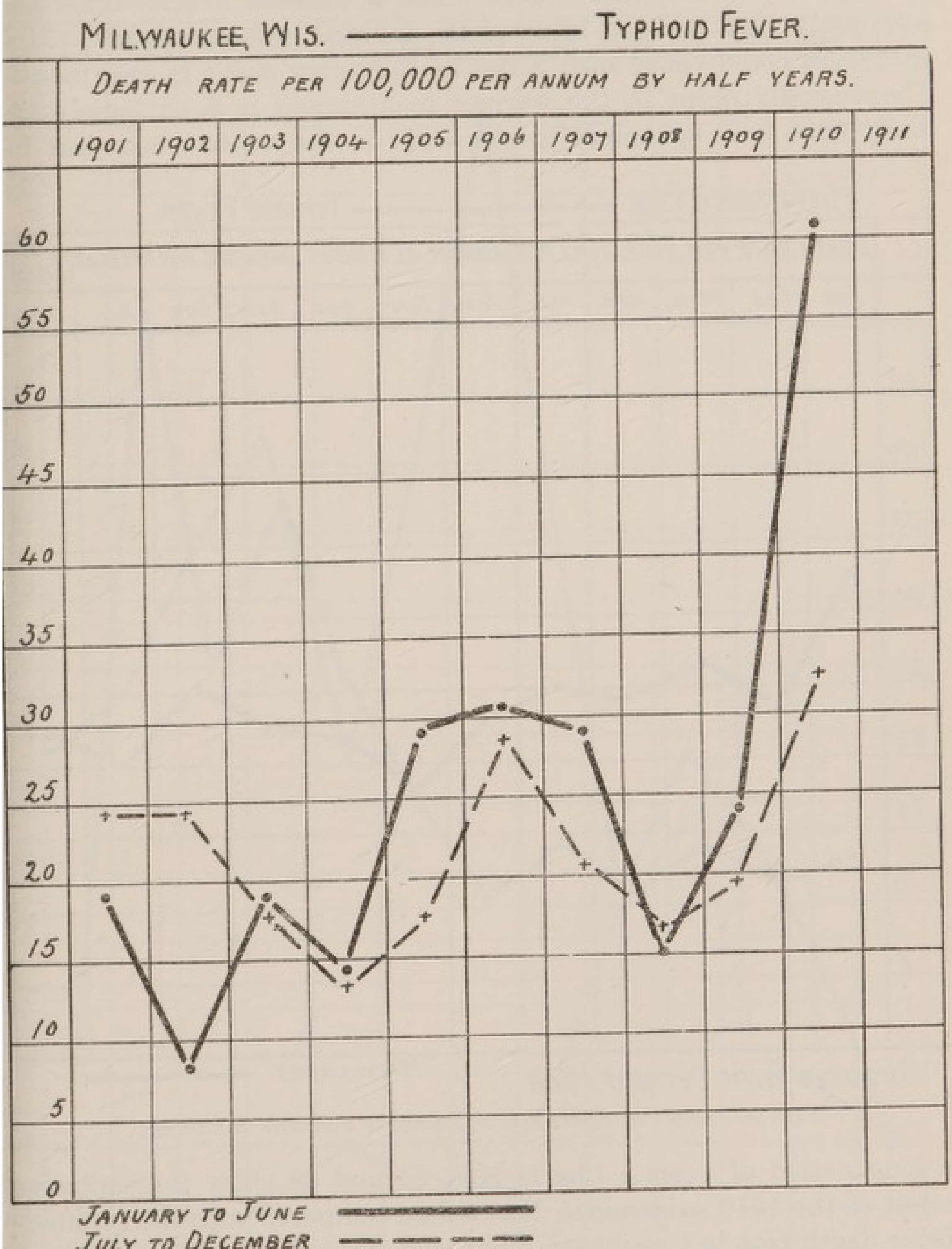


CHART 33.—There is a fairly close relation between the curves for the two halves of the year, but in 1910 the rise for the winter and spring months (solid line) is very much greater than that of the second half of the year.

Chart No. 34 shows the typhoid rate in Milwaukee compared with Detroit, Mich. Detroit has a water supply which can not be said to be safe, but which luckily in the past decade escaped gross pollution.

Detroit's typhoid curve resembles that of cities with safe wa supplies. The contrast with Milwaukee's curve is striking. " apex of the Detroit curve in September is usual in cities with s water supplies. Milwaukee, with the highest points in January a March, presents a typhoid curve which is unusual in such cities a commonly met with in cities with polluted water supplies. M epidemics could cause such a rise as they may occur in any mon They usually occur in the warmer months, and it is extremely u likely that milk epidemics would occur in the winter each year

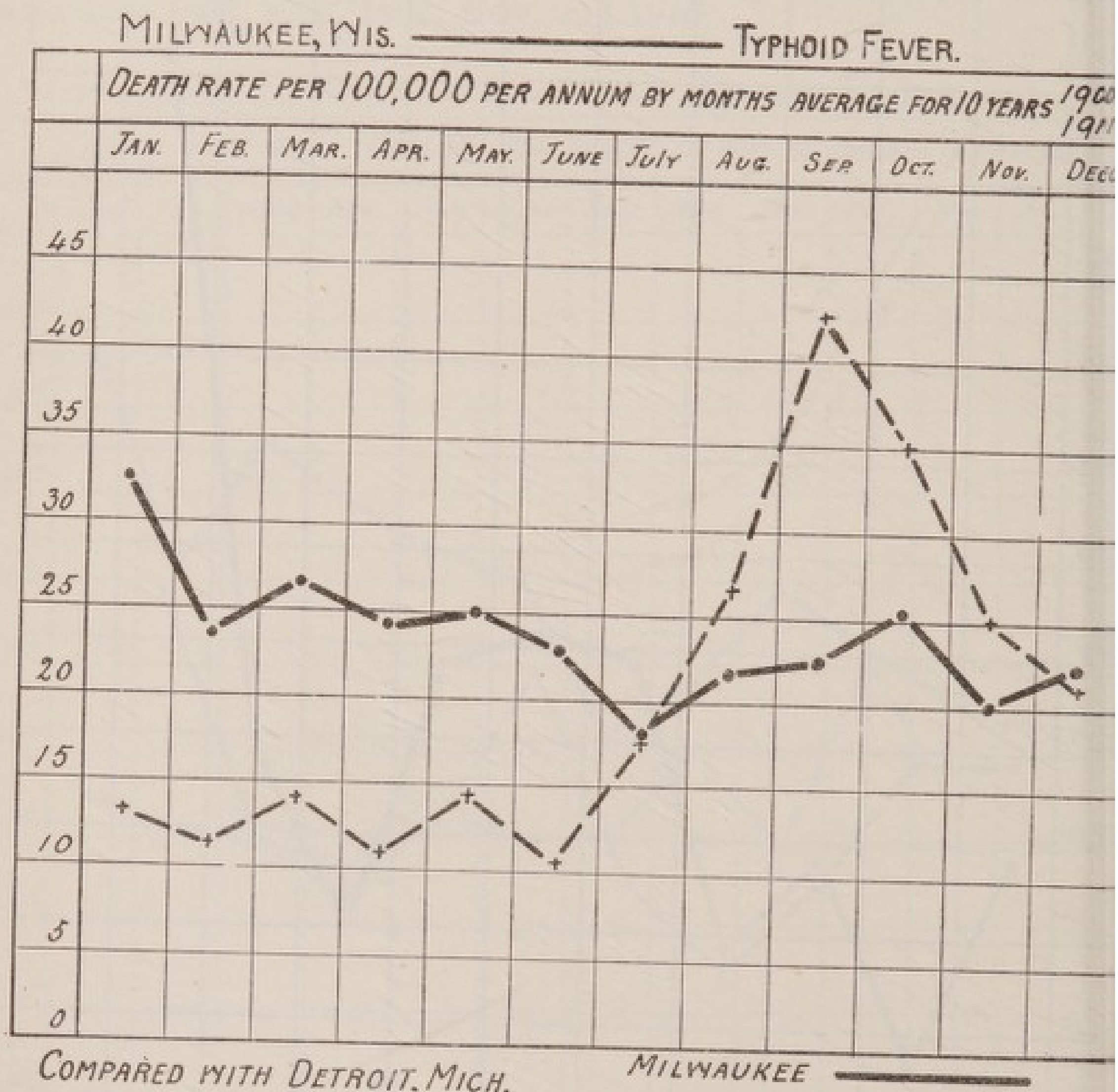
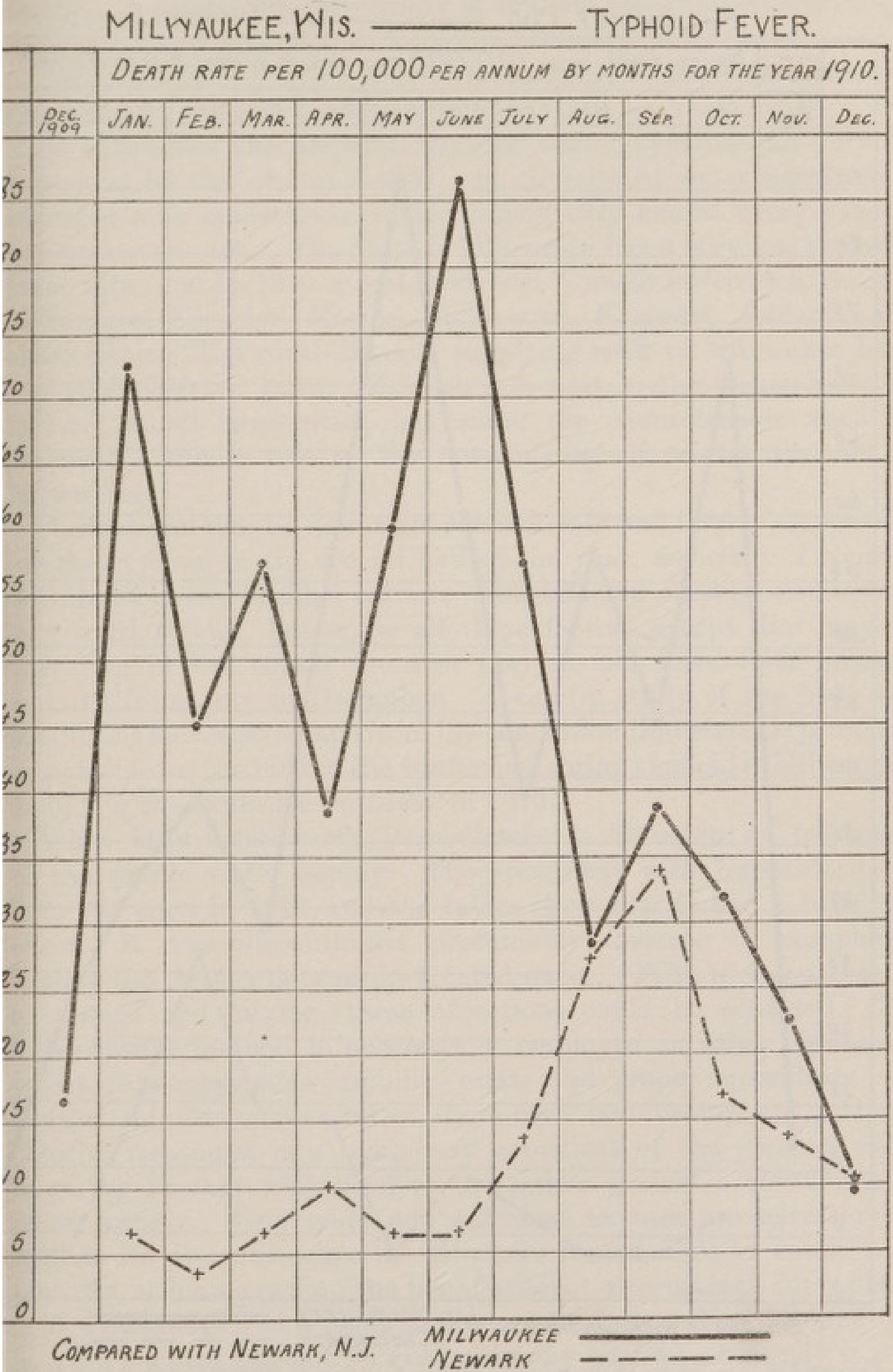


CHART 34.—Comparing typhoid fever, by months, in Milwaukee with Detroit.

a long period of years. Charts Nos. 35 and 36 show the explosive onset of the 1910 epidemic in Milwaukee compared with the typhoid fever death rate in Cincinnati, Ohio, and Newark, N. J., cities which have safe public water supplies.

Investigation by the Milwaukee board of health disclosed that the distribution of cases in the explosive outbreak of 1910 was general, as would be expected in a water outbreak, affecting poor and wealthy sections indiscriminately and showing absence of local areas or



ART 35.—Comparing Milwaukee with Newark, N. J., seasonal prevalence, 1910. Newark has a safe water supply.

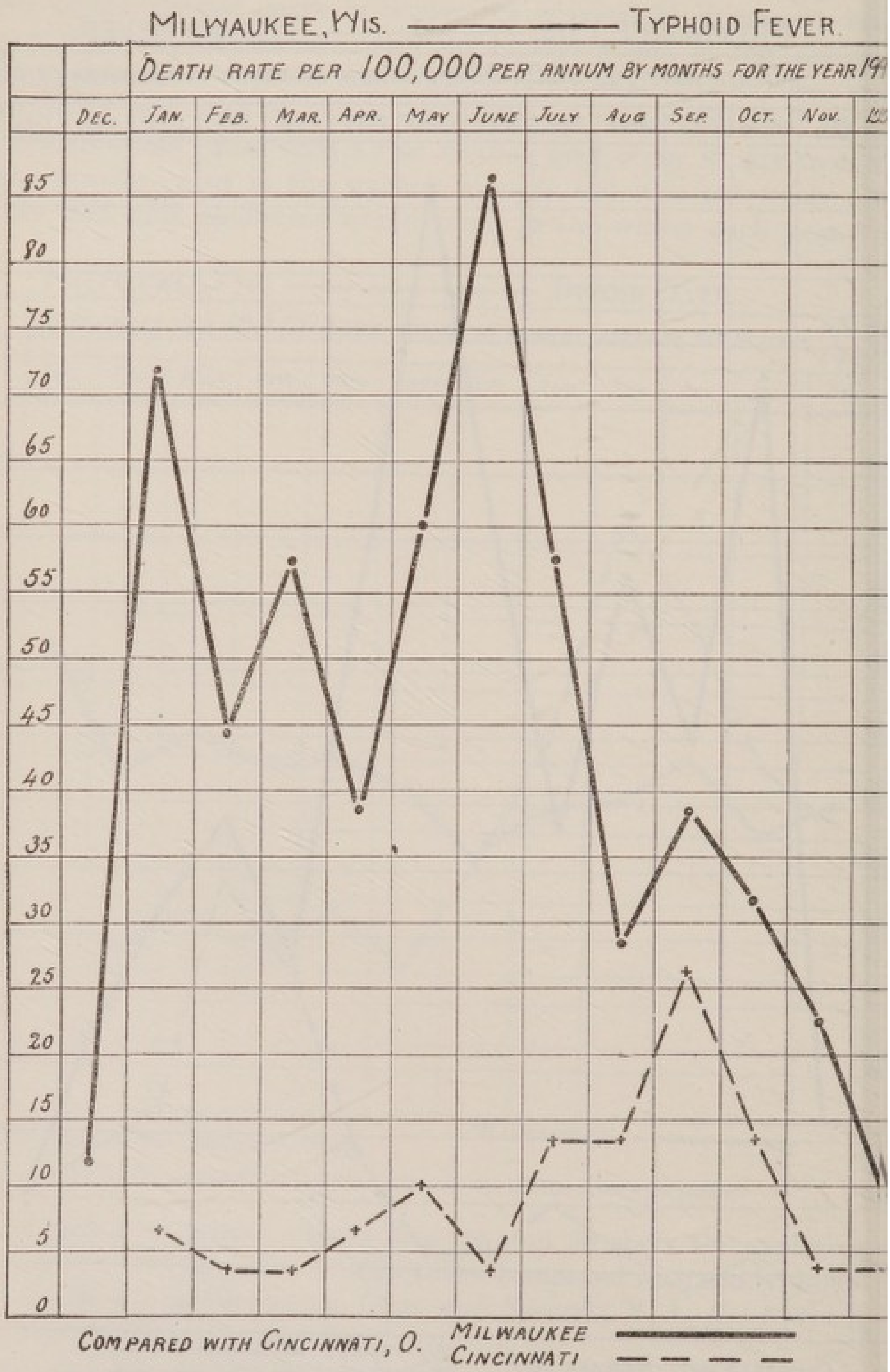


CHART 36.—Comparing the seasonal prevalence of typhoid fever in Milwaukee with that of Cincinn
1910. Cincinnati has a safe water supply.

"foci" of infection. The data gathered did not show a preponderance of cases in children or other fact that would suggest milk as a prime factor. A careful intensive study of typhoid cases and epidemiologic data covering a long period, would be necessary to fix the proportion of cases in any city which should be assigned to the various factors concerned in typhoid transmission.

In Milwaukee the preponderance of winter typhoid can only be explained by one of two factors, viz: A polluted water supply or a repeated milk epidemic occurring consistently almost every year in the winter months. The State of Wisconsin has a very low typhoid-fever rate, and in 1910 would have had a much lower rate, but for Milwaukee, Superior, Racine, Sheboygan, Kenosha, Ashland, and other cities. The rural districts supplying milk to Milwaukee have low typhoid-fever rates. Milk plays a part in the transmission of typhoid in all large cities, but under the circumstances must be assigned a minor role in the transmission of winter typhoid in Milwaukee.

Contact and flies no doubt are concerned in and largely responsible for the typhoid in the second half of the year, especially if coupled with light cases, bacillus carriers, undisinfected excreta, and insanitary yard privies, but while all these factors except flies may be operative in the winter months, they should have their greatest activity from July to December. A careful study of the facts and conditions leaves no escape from the conclusion that water is primarily responsible for the bulk of the winter and spring typhoid in Milwaukee, including the explosive outbreak of 1910.

What Milwaukee needs immediately is filtration or treatment of the public water supply. The treatment with hypochlorite of lime was tried in 1910, and the tables show that it had a beneficial effect. It was discontinued presumably because of complaints against the taste or odor of the treated water. With proper attention to dosage and mixing, these objections could be obviated. The hypochlorite method is successfully employed in other cities, and where no unreasonable prejudice exists and proper supervision over dosage and mixing is exercised there need be no complaint. Hypochlorite treatment is a temporary expedient of the greatest value in giving prompt protection to the public against a contaminated water supply. Very good and sufficient excuses are necessary to explain its discontinuance in Milwaukee and failure to use it temporarily, at least pending the installation of a permanent filter plant.

The installation of a plant to filter or treat its public water supply is a duty which can not be evaded in any city whose supply is contaminated or exposed to contamination. No system of sewage disposal, however elaborate or complete, can absolve the authorities from this duty. The proposed sewage-disposal scheme in Milwaukee,

while making conditions infinitely better from the standpoint nuisance, does not and can not remove the menace to an untreat or unfiltered public water supply. The washings of the land surface the storm overflows from sewers, and other sources of polluti will make necessary filtration or treatment of Milwaukee's wat supply even after the sewage plans are completely carried out.

Further, such improvement as may come from these plans will be the future, and years must elapse before their fulfillment. In th meantime the public water supply is exposed to such contaminatio as occurred in 1910. Sewage disposal must always be secondary t the treatment of the water supply as a measure intended for th prevention of disease, and, as indicated above, the most elabora plans can only assist in securing a good raw water for the filte and do not insure a safe water supply without filtration or treatmen It is noted with satisfaction that the commission of eminent exper recommended that the public supply be filtered, although they wer not instructed to devise plans for water purification, but only fo sewage disposal.

RACINE.

Racine is situated on the west shore of Lake Michigan at th mouth of Root River. The population in 1910 was 38,002. Ninet per cent of the population are tributary to the sewers, and com paratively few are dependent upon privies.

SEWERS.

There are about 73 miles of sewers discharging by 14 outlet into Root River and Lake Michigan. There is no treatment of th sewage.

WATER SUPPLY.

Probably 7,000 people still depend upon surface wells. The remain der, over 80 per cent, receive and use the public supply. The intak is in deep water 1¼ miles from shore and about 2 miles from th nearest sewer outlets. The greatest danger is probably from Racine's own sewage, as the Milwaukee sewage is discharged more than 20 miles north of the Racine intake.

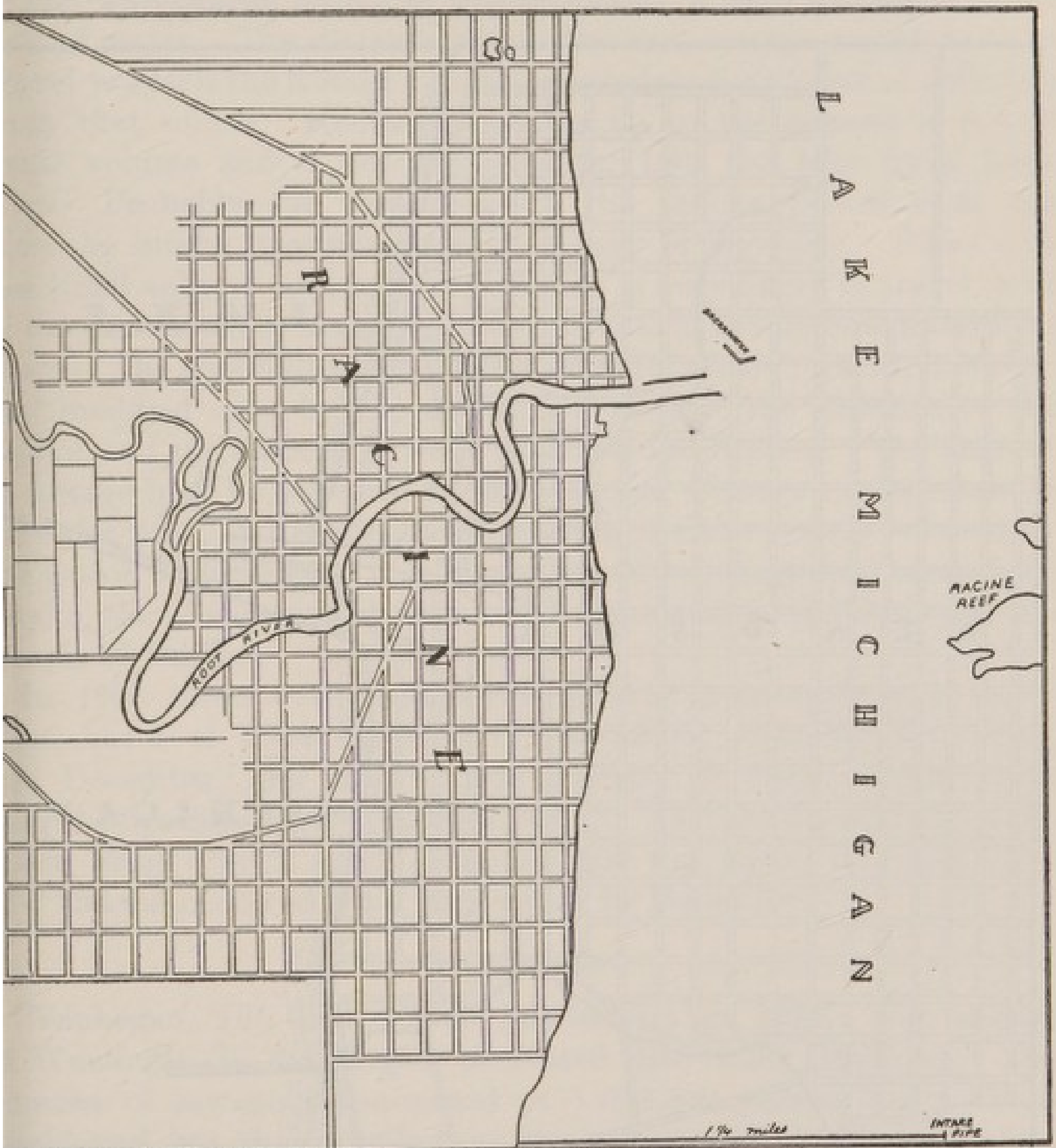
The typhoid-fever records for Racine furnished by the State boar of health for 1908, 1909, 1910 and 1911, show some interesting an suggestive features.

In 1908 the typhoid death rate per 100,000 was 16.6, but inasmuch as all these deaths occurred in February, March, and April the rate for the first half year (or really for February, March, and April) was 33.2 and that of the second half year from July to December was 0.

In 1909 the yearly death rate per 100,000 was 24.3 for the entire year; the death rate per annum for the first half year was 21.6,

e rate for the second half year was 27. In 1910 the rate for the st half of the year was still higher, 47.3, and in the second half of e year the rate was also high, reaching 68.4 For the first five onths of 1911 the rate in Racine was 31.5.

To summarize:

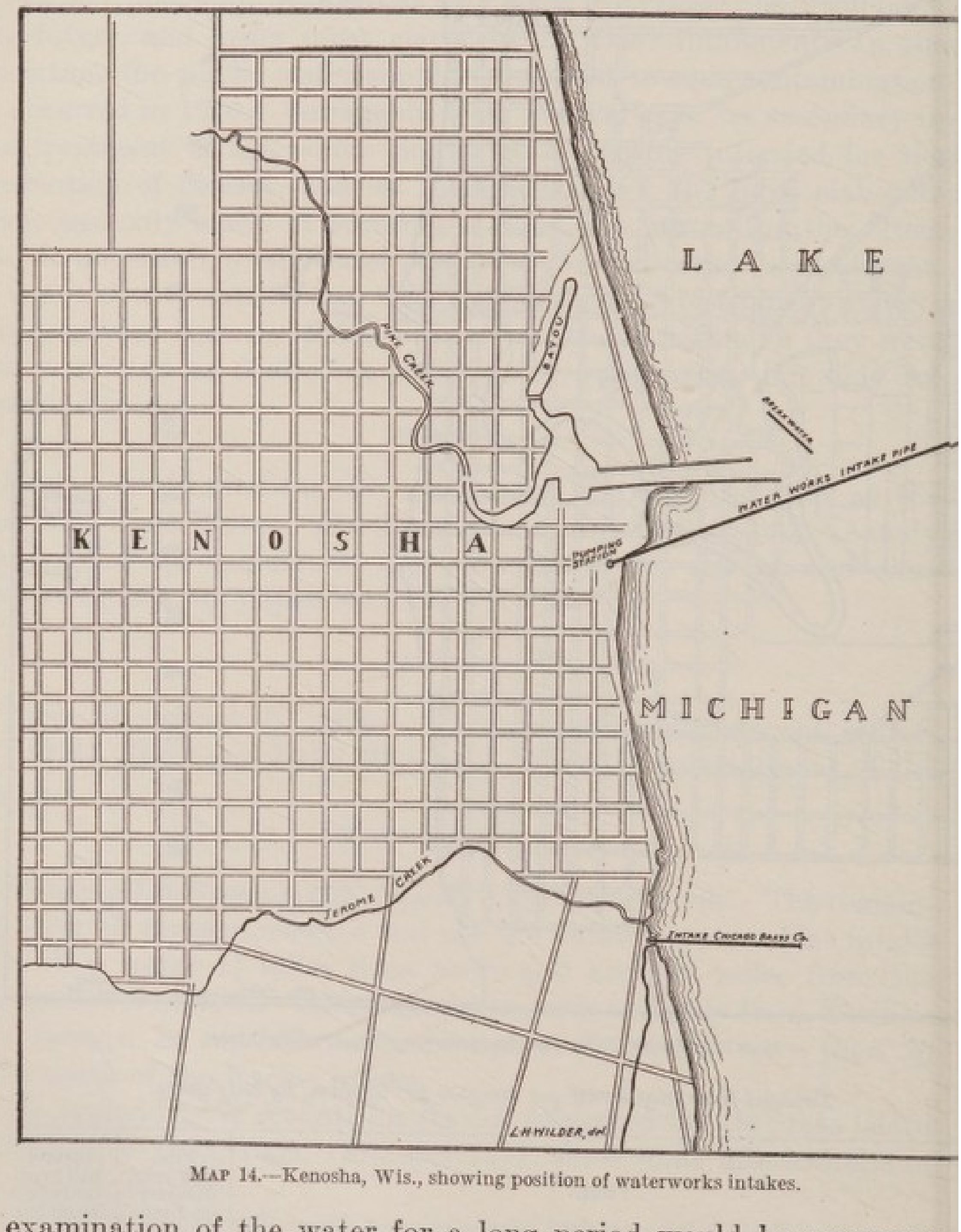


Map 13.—Racine, Wis., showing position of waterworks intake.

Typhoid fever, death rate per 100,000 per annum, by half years.

Years.	First half year, January to June.	Second half year, July to December.
[illegible]	33.2	0
[illegible]	21.6	27
[illegible]	47.3	68
[illegible]	31.5	....

There has been an average annual typhoid death rate per 100, of 33.4 in Racine from January to June for the past four y (1908–1911). This rate, compared with the rate from July to Dec ber, is abnormally high, and occurring consistently each year fo number of years suggests that a polluted water supply is responsi An intensive study of the epidemiologic data and a careful d



MAP 14.—Kenosha, Wis., showing position of waterworks intakes.

examination of the water for a long period would be necessary order to establish definitely the rôle played by water in Racin typhoid. From the facts at hand, this seems another instance too much dependence upon distance from shore and position of t intake as a protection of the public water supply from sewa pollution.

KENOSHA.

Kenosha is situated on Lake Michigan about 10 miles south of Racine. The sewage is not treated and is discharged into the lake lirect or by means of Pike Creek. The population in 1910 was 1,371

The waterworks intake is located nearly a mile off shore in 30 eet of water. The distance which Racine's sewage would have to ravel to reach the Kenosha intake minimizes the danger of pollution rom that source. Kenosha's sewage up to the present is not of reat volume and is not projected far into the lake by a large iver. Probably for these reasons the serious pollution at the Kenosha intake does not occur frequently or regularly. Pike Creek as small volume, and sewage pollution is very likely to travel most f the time north or south with the currents in the shallow water near hore. The possibilities for occasional pollution are present, however, nd modified only by the amount of sewage, the distance to the ntake, and the amount of water available for dilution. The amount f sewage may be expected to increase, the distance to the intake is nly one mile, and the factor of dilution is often greatly reduced by he action of currents. If currents should be established toward the ntake, the sewage would have little opportunity for dilution in the ransit of 1 mile.

In 1908 there were recorded 10 deaths from typhoid fever in Kenosha; 9 of these occurred in September, October, November, nd December, and only 1 from January to June. During that ear the death rate per 100,000 was 58.2. In 1909 the rate was much ower, being only 22.2. In 1910 the rate was higher (35), but 5 out f 7 deaths occurred from September to December.

WAUKEGAN.

Waukegan, Ill., had 16,069 inhabitants in 1910. The sewage f Waukegan is discharged untreated into Lake Michigan. The mount of sewage is estimated at 1,000,000 gallons daily. It is lischarged less than a mile from the waterworks intake. The lake vater is delivered without treatment or filtration to the consumers. According to analyses made by the Illinois State Water Survey and resented by Prof. Edward Bartow,[1] the water was frequently contaminated by sewage.

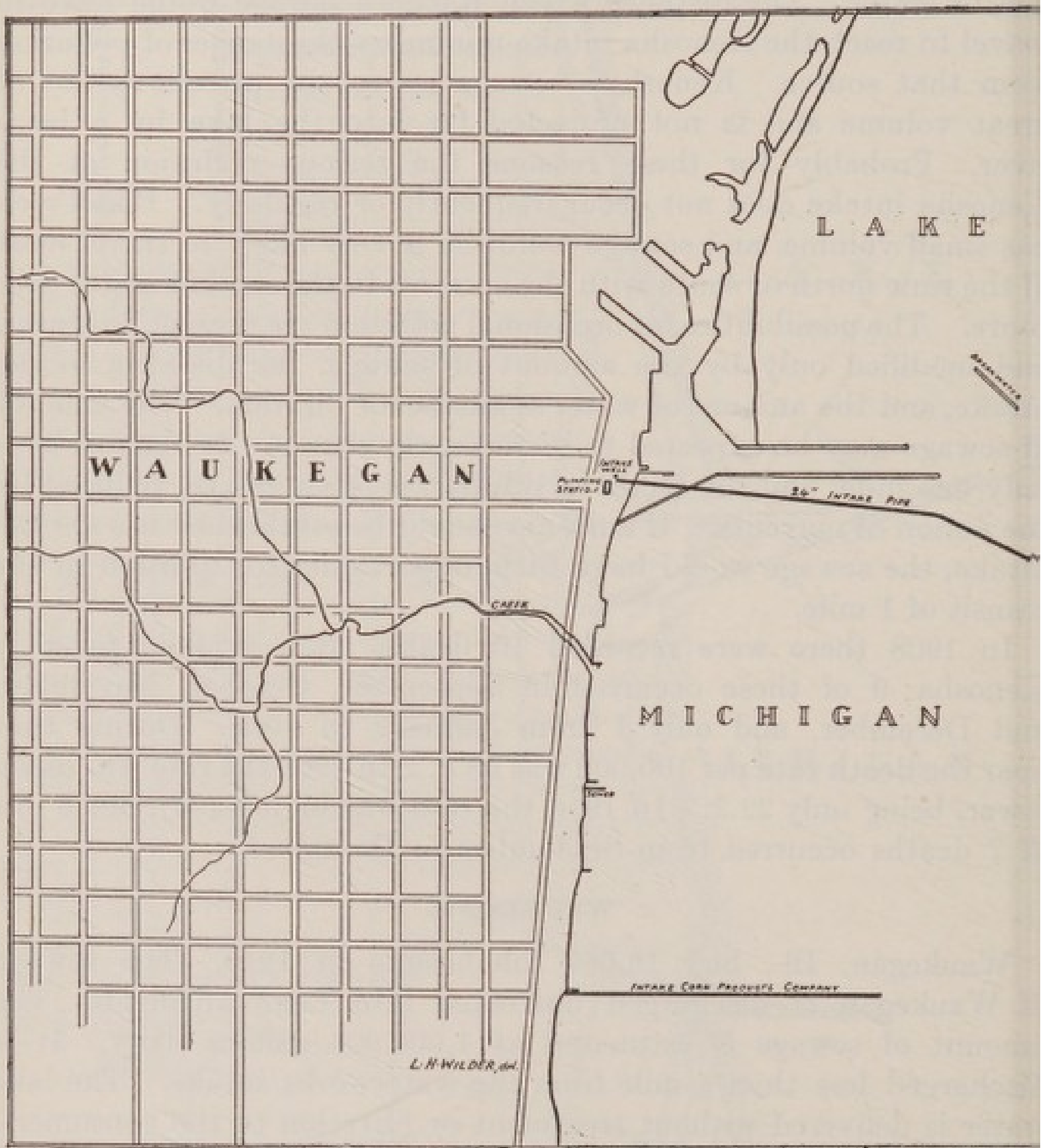
Waukegan has suffered from typhoid fever outbreaks, and in 1907 ad a typhoid rate of 49 deaths per 100,000. In 1910 there were 26 leaths from typhoid fever in Waukegan, giving the very high rate of 62 deaths per 100,000.

[1] Bartow, Edward, First Report, Lake Michigan Water Commission, 1909, p. 41.

EVANSTON.

Evanston had a population in 1910 of 25,000. It is essentially part of the city of Chicago and, although a separate municipality, included within the boundaries of the sanitary district.

The sewage of Evanston amounts to more than 6,000,000 gallon daily and is at present discharged into Lake Michigan, althoug



MAP 15.—Waukegan, Ill., showing waterworks intakes.

eventually it will be carried to the north shore channel by inte ceptors. This sewage is a considerable factor in the pollution Chicago's water front and its most direct effect is naturally on th Lake View Intake. Evanston's own water supply is taken fro Lake Michigan and is probably polluted by Evanston's sewage.

A survey made by Prof. Edward Bartow[1] showed the wate works intake to be within 1½ miles of the sewer outfalls. Numerou

[1] Bartow, Edward, First Report of the Lake Michigan Water Commission, 1909, p. 46.

nalyses of Evanston's water are presented by Prof. Bartow which howed a contaminated water. Evanston's typhoid fever rate is igher than Chicago, but lower than that of Waukegan. The typhoid ever rate in 1910 was 28 deaths per 100,000.

During the latter part of 1908 and 1909 Evanston improved and xtended its intake. Prior to this improvement, Evanston had a 0-inch intake extending to a submerged crib one-half mile from hore. The improvement consisted of a line of 36-inch pipe extendng from the shore to the end of the 30 inch at which the 30 inch and 6 inch were joined into a single line of 42-inch pipe which extended o the new inlets located $1\frac{1}{16}$ miles from shore. The improvement vas completed October 15, 1909.

Very recently (January, 1912) hypochlorite of lime was used as a emporary expedient to cut off a typhoid epidemic. The results vere good in making the water safe; but the local health department egards the hypochlorite treatment as a temporary expedient only, s the objectionable turbidity is not removed thereby. For this eason, the health department has strongly recommended the installaion of a filter plant.

CHICAGO.

The growth of the city of Chicago finds no parallel in history. From a population of 7,500 in 1843 it has grown to be the second ity in the United States with a population in 1910 of more than ,000,000. No argument is necessary to show the importance to he whole country of sanitary conditions in Chicago. Its vast comnerce and giant industries make it the metropolis of an enormous erritory and bring thousands of visitors daily from nearly every State in the Union. These visitors drink Chicago's milk and water nd eat Chicago's food. Contamination of these articles of food or lrink by typhoid fever germs means infection of transients as well s citizens—transients who go to their homes in other States to establish new foci of typhoid fever. These transients and interstate ravelers are less able to protect themselves against contaminated ood or drink than the citizen who heeds the warnings of Chicago's xcellent department of health. Thousands of interstate travelers lrink water on trains which is taken aboard cars in this great railway enter, and the character of Chicago's water supply is of vital importnce to these travelers and to the States to which they are destined.

SEWERAGE SYSTEM.

In considering the sewerage system of Chicago as it exists to-day, t is necessary to note the origin and development of the sanitary listrict of Chicago.

The sanitary district of Chicago was organized in 1889 under the general law of Illinois providing for the creation of sanitary districts.

This effect is accentuated in summer, when the oxygen content of tl lake water is at a minimum. As a result the limit of 10,000 cu feet per second is already barely sufficient without waiting for t population to reach 3,000,000, which would be about 1920.

The officials of the sanitary district, and especially Mr. George Wisner, chief engineer, have recognized for years this eventuali and very wisely prepared for it. A testing station was establish in 1909 where sprinkling filters, sedimentation tanks, and oth devices for the rapid treatment of sewage are under observatio This station has been conducted under the supervision of Mr. Langd Pearse, the assistant engineer of district. Tanks of the Imhof pa tern and original modifications have been tested. The work done this station is not only of immense value in determining the mo economical and efficient method of solving Chicago's sewage proble but is destined to have an educational value far wider than this.

Detailed description of the methods devised and recommended f the sanitary district to continue caring for Chicago's sewage with t amount of lake water available may be found in an excellent repo on sewage disposal made to the board of trustees of the sanitary di trict of Chicago by George M. Wisner, chief engineer, in Octob 1911. Further details of the very interesting and valuable work the experimental station are given by Mr. Langdon Pearse (assista engineer, in charge of sewage disposal investigations) in the Enginee ing News, March 31, 1910.

The problem arising in Chicago in consequence of prematur reaching the limit of disposal by dilution presented broadly two sol tions—either the removal of a small percentage of solids from tl entire sewage or a more thorough purification of a smaller portion the sewage.

Mr. Wisner shows that it is more economical to purify more com pletely a portion of the sewage than to effect the same result by ve slight purification of the entire sewage of the city. This purificatio will be accomplished at convenient sites, as indicated on Mr. Wisner map. The tanks will probably be constructed on the Imhof pattern combining an ordinary sedimentation with a lower septic compar ment. The application of these remedies will be progressive, an Mr. Wisner recommends beginning at once. The final purificatio with sprinkling filters is provided for, but necessity for their installa tion will not be urgent before 1930. This thorough and comprehen sive report covers every phase of the problem, and it is deemed ad visable to print Mr. Wisner's conclusions and recommendations i full, as follows:

CONCLUSIONS.

1. The present scheme of sewage disposal by dilution has been a pronounced succes When the canal was designed it was not intended that the crude manufacturing wast should be deposited therein, as they have been and are now being. Practically noth

ng was known of the absorption of oxygen from water by organic sludges that deposit n the bottom of the river and canal. In spite of these limitations the canal for 12 ears has furnished a most efficient and economical method of disposal of the sewage f the district.

2. The amount of water available for dilution, if taken at 10,000 cubic feet per second, will be insufficient after 1922, when supplementary methods of sewage disposal vill have to be installed.

3. A local nuisance exists in the North Branch, South Fork of the South Branch, and he West Fork of the South Branch. This condition can be materially improved by he installation of settling tanks to remove the settling suspended matter. These anks should be installed in the stock yards district, at certain places along the North Branch, and in connection with the sewers now discharging into the Ogden ditch.

4. The construction of settling basins of the Emscher type at various points as specified will improve the condition of the canal as a whole, as well as locally. Eventually, round 1930, the construction of sprinkling filters or other methods of treatment, supplementary to sedimentation, will be required.

5. The maximum amount of water possible should be flowed through the canal at ll times.

6. The condition of the Illinois River is vastly better than it was prior to the opening of the canal. The river, during the past year, owing to the lack of spring floods to cour it of deposits of mud, has not been as good as it was for the previous few years. With the installation of sedimentation plants, and the improvement of the sewage as utlined in this report, the water of the Illinois River will be in excellent condition. The water in the river should be kept flowing as swiftly as possible. Dams will probably prove a detriment from the standpoint of sanitary conditions.

7. A minimum of at least 2½ parts per million of dissolved oxygen should be kept in he Illinois River below Marseilles at all times. It is desirable that an amount around 3½ to 4 parts per million be always present. However, specific tests on the various kinds of fish are required to definitely determine the amount of oxygen necessary for ish life.

8. The speedy construction of the Calumet-Sag Channel is essential for the Calumet listrict in order to remove the danger of gross pollution of the Sixty-eighth Street crib ntake. It is also highly desirable in order to improve the conditions of the Main Channel and the Des Plaines River by supplying additional dilution water.

9. The use of water to-day in Chicago is excessive and should be cut down by the proper inspection of plumbing and the installation, on an extended scale, of meters. This does affect directly the interests of the sanitary district of Chicago, as the size of intercepting sewers, sewage pumping stations, and plants for treatment under the scheme in consideration is materially affected. Not only is the size of the plants and their design affected, but there is an annual cost which is practically wasted to cover the pumping of sewage due to this extravagant use of water. This is a direct drain on the community without any return, as the water can be flowed more cheaply for dilution purposes directly through the Chicago River and Drainage Canal.

RECOMMENDATIONS.

1. Steps should be taken immediately to develop the scheme outlined herein, and the details of the project which require the earliest attention should be fully developed. The chief engineer should be ordered to prepare plans and specifications for the most immediate projects.

2. Property and rights of way should be secured at once to cover the probable sites required for the improvements up to 1930.

3. Wherever the city of Chicago undertakes any new sewer work, the sanitary district of Chicago should secure provisions for settling plants. In general such plants should be constructed simultaneously with the sewer outfall.

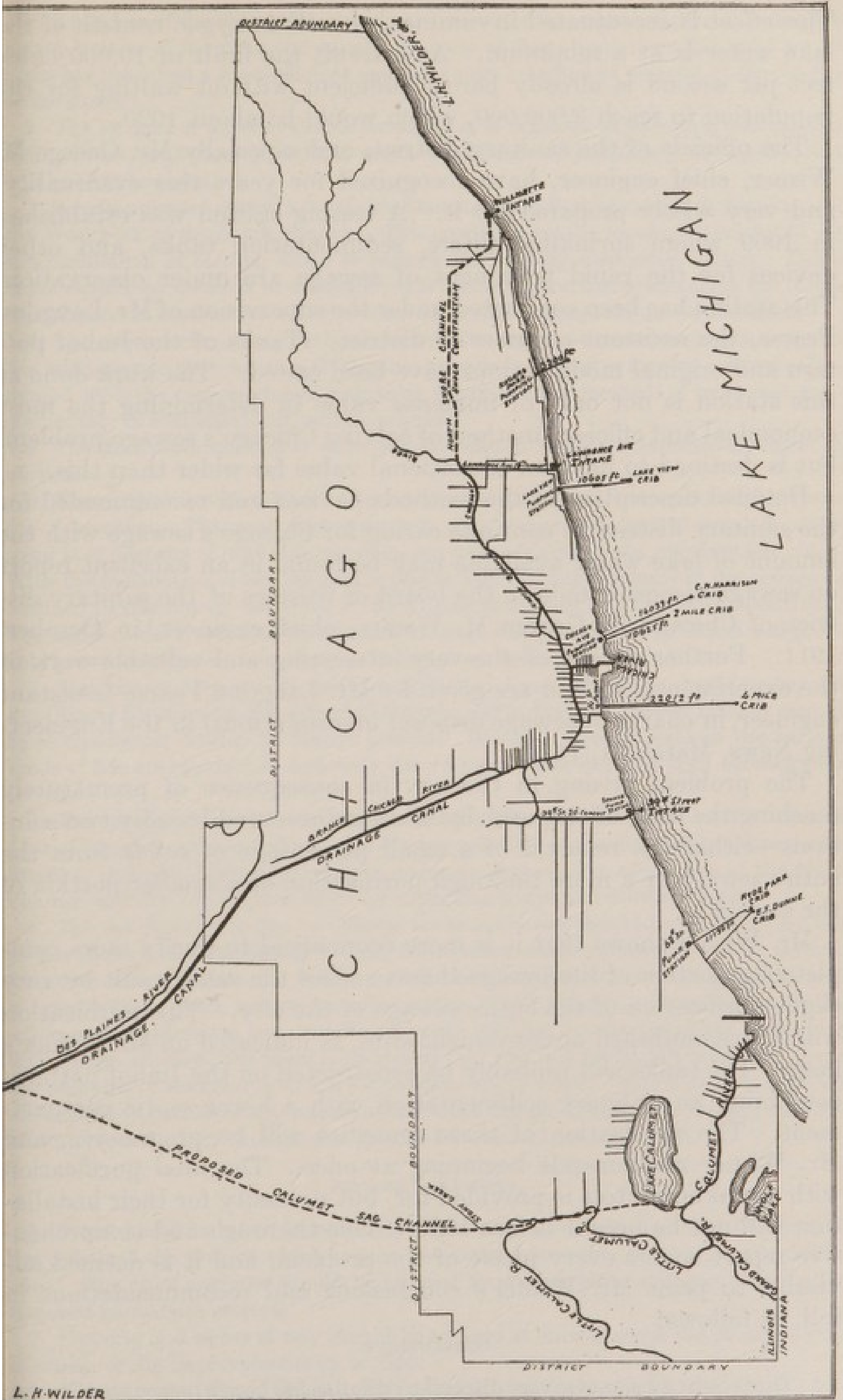
The organization of a sanitary district of Chicago had for its primary object the protection of its public water supply by diverting the sewage from the lake front to the river and canal. Its secondary object was to relieve conditions which were extremely offensive to sight and smell. As a result of the activity of the sanitary district, the Chicago Drainage Canal was constructed.

Chicago is situated on the west shore of Lake Michigan at the mouth of the Chicago River. The divide between the lake drainage area and the drainage basin of the Mississippi is here very close to the lake. Advantage was taken of this topographical feature to carry Chicago's sewage away from the lake and toward the Mississippi. Chicago's sewage, instead of discharging, as it formerly did, into Lake Michigan, now travels by means of the sanitary canal from the Chicago River at Robey Street to the Desplaines River at Joliet, 35 miles away. From Joliet by means of the Desplaines and Illinois Rivers the sewage theoretically reaches the Mississippi.

Map No. 16 shows the drainage canal (the main channel and the north shore channel), the Chicago River, and the two pumping stations, intercepting sewers and conduits through which the lake water is forced into the system for dilution purposes. This map also shows the proposed Calumet sag channel which will reverse the flow in the Calumet, and is destined to care for that portion of Chicago sewage which still reaches the lake by means of the Calumet River.

NECESSITY FOR OTHER MEANS THAN DILUTION.

The employment of dilution in the disposal of Chicago's sewage has served its purpose admirably. In the past 10 years it has diverted the bulk of the sewage from the lake and the vicinity of the waterworks intakes and has immeasurably improved the condition of the Chicago River. The amount of dilution used was based on Mr. Rudolph Hering's estimate, and the charter of the sanitary district provides that 3.3 cubic feet per second of lake water for each 1,000 inhabitants be used. The population is now about 2,000,000, requiring, according to the charter, about 6,000 cubic feet per second for dilution. At this rate, when the population reaches 3,000,000, 10,000 cubic feet per second would be required. The War Department has ruled that 10,000 cubic feet per second is the limit which the sanitary district may divert from Lake Michigan. There are other reasons, however, why the limit of dilution by 10,000 cubic feet will be reached even earlier in Chicago. Enormous quantities of industrial wastes of an oxygen-consuming character are poured into the waterway. The dams and long reaches with slow flow cause accumulations of septic sludge which take the oxygen out of the lake water rapidly. This reduces the oxidizing power of the diluting water from the lake.



MAP 16.—Chicago, Ill., showing diversion of sewage from the lake by the sanitary drainage canal system. When the North Shore Channel is in operation, all the sewage from Wilmette to Eighty-seventh Street will be diverted from the lake. The proposed Calumet Sag Channel is shown, which will divert from the lake the sewage at present carried by the Calumet River. The various waterworks cribs or intakes are shown. Note the position of the Hyde Park crib in relation to the sewage polluted Calumet River.

4. The discharge of industrial wastes into the river or sewers should be regulated and kept under the control of the sanitary district. Present conditions should be improved as far as practicable. The removal of the settling suspended matter is absolutely essential. Other treatment may be required where wastes are harmful to fish life or the dilution scheme.

5. Sewage-disposal plants located inside the sanitary district of Chicago should be subject to the supervision of the district.

6. The sewers that now discharge into that portion of the West Fork of the South Branch west of the collateral channel should be extended to discharge into the main channel, after which the so-called Ogden ditch should be filled up, as it will serve no useful purpose. If left open this ditch will be an expense, a nuisance, and a breeder of mosquitoes.

7. Intercepting sewers should be constructed from the mouth of the Calumet River to the beginning of the Calumet-Sag Channel near Wildwood.

8. Construction of settling basins of the Emscher type should be included in the plan of the Calumet-Sag region. These should be constructed at the outfall of the proposed intercepting sewers and should be completed before the opening of the Calumet-Sag Channel.

9. Negotiations should be started with the proper authority in Indiana to induce the municipalities located along the Calumet watershed to take immediate steps to purify the sewage now being discharged into the Calumet River and thence into Lake Michigan. Work along these lines should be started at once in order that the project may be completed as soon as possible.

10. Intercepting sewers should be constructed for the removal of the sewage now being discharged by Evanston into Lake Michigan. It is also advisable that a settling basin of the Emscher type be built at the outlet of this intercepting sewer in order to keep the condition of the North Shore Channel as good as possible. With regard to the towns north of Wilmette a detailed report should be made covering the question of the purification of the water and the treatment of the sewage for the various towns as a whole and as units. The cost of filtration plants for the water supply and sewage disposal works, with their annual maintenance, should be compared with the cost of intercepting sewers.

11. The sanitary conditions of the tributaries of the Illinois River should be investigated, particularly on account of the conditions existing in the industrial towns. The discharge, quality, and source of sewage, both industrial and human, should be made a matter of record. Measurements of the flow and chemical analyses of the Illinois River and its tributaries should be systematically kept. Experiments should be made to determine the amount of oxygen required for the various kinds of fish.

12. The emergency use of hypochlorite of calcium as a sterilizing agent on the water supply coming from the Sixty-eighth Street crib should be undertaken at once. With a heavy flood in the Calumet River, accompanied by a southerly wind, the pollution of the water supply coming from this crib is certain. If possible the apparatus should be built during the coming winter. This should be built by the city of Chicago in case the sanitary district has not the right or power to do so. If this chemical is applied properly it will render the water harmless, but if not applied pending the completion of the Calumet-Sag Channel the water from this crib will be unsafe at times.

13. To protect the intakes of the water supply the Federal and State authorities have the right to prohibit the discharge of sewage from vessels inside the harbor or its entrance. Regulations should be established and rigidly enforced covering the construction of tanks to carry the refuse, or else the closets should be locked while the vessels are within a minimum distance of, say, 5 miles from shore.

The Government also has a right to establish a dead line around the intakes, with buoys or otherwise, to prohibit all vessels from passing within these buoys or zones

protection. It is recommended that the Government officials be requested to ablish such regulations.

14. In order to rigidly enforce the provisions of the Federal statute and the con- cts made thereunder for dredging and the disposal of spoil in the lake, action should taken to prosecute the captains of all tugs who are negligent in carrying such spoil the distance prescribed by law and contract. While this does not relieve the con- ctor of his liability, it does impress upon the man in active charge of the work the cessity of obeying the law. The promiscuous dumping of waste materials into the ce, even 8 miles from shore, is an economic loss to the community, for if the material re saved by dumping it in shoal water behind tight bulkheads it would create lues many times in excess of the cost of disposal. This created land would be eful either for park purposes or outer harbor improvements when it would be impos- le, on account of storms, to deposit the excavated material 8 miles from shore.

15. The water services in the city of Chicago should be metered.

16. In connection with the systematic study of the Illinois River, the operation of e Thirty-ninth Street testing station should be continued, particular study being ven to the extension of partial purification by aeration and roughing filters.

The laboratory and engineering organization in the sanitary department are abso- ely essential to the program outlined, both as regards immediate and future devel- ments in construction, operation, and maintenance.

17. It is recommended that no municipalities outside the sanitary district of Chicago allowed to discharge into the Drainage Canal or any of its tributaries a putrescible wage; but if municipalities outside the limits of the sanitary district desire to deliver nonputrescible effluent from a sewage-purification plant to the Drainage Canal or y of its tributaries, it is recommended that they be encouraged to do so.

THE CALUMET SAG-CANAL PROJECT.

The greatest menace to Chicago's water supply and the most nportant sewage problem confronting Chicago at present is the dis- osal of sewage in the Calumet drainage area. As a protection gainst this menace, and as a solution of this problem, the Calumet ag-Canal project is offered by the officials of the sanitary district.

As shown above, the sewage of Chicago north of Eighty-seventh reet, including Glencoe, Winnetka, and Wilmette, is to be diverted om the lake to the drainage canal. Evanston still sewers into the ke, and the district south of Eighty-seventh Street still sewers into e Calumet River.

When the sanitary district act was passed, this so-called Calumet strict was not included. It was not thickly inhabited and its tax- ble value was low. After the district was formed, the Calumet sec- on grew rapidly and desired a sewer system discharging into their tural drainage channel, the Calumet River. As the mouth of this ver is only about 4½ miles from the Sixty-eighth Street water orks intake, Chicago very naturally objected. The ensuing dis- ute resulted in the Calumet district being included in the sanitary strict. This was done in 1903, and the same act took in the orthern towns from Evanston to the Cook County line. A commis- on on the problem of sewerage for the Calumet district was formed, e members being Messrs. G. M. Wisner, chairman; John Ericson,

C. D. Hill, and William S. MacHarg, secretary. The following extra from their report made in February, 1909, explains the situation:

The natural drainage of this district is into the Little Calumet and the Calum Rivers, discharging into Lake Michigan at the Calumet Harbor entrance. The d tance from the mouth of the river to the Sixty-eighth Street crib, measured arou the eastern end of the Government breakwater, is about 4½ miles.

The drainage area of the Calumet River, which is formed by the junction of t Little Calumet and Grand Calumet Rivers at or near the city limits and Torren Avenue, is 806 square miles, of which 455 square miles are in Indiana and 351 in Il nois. The Grand Calumet has a small drainage area, and practically may be ignor as a flood factor. The flow of water is derived almost wholly from the Little Calum and gaugings show that the mean daily rate of flow is about 970 cubic feet per secon the lowest rate for a monthly period being less than 400 cubic feet per second, a the highest 3,323 cubic feet per second, with a maximum flood discharge for a sh period at the rate of 13,000 cubic feet per second.

The sanitary district of Chicago contains substantially 350 square miles, and t portion of the district tributary to the Calumet River lies south of Eighty-seven Street and comprises 100 square miles, 40 square miles of this latter area lying withi the city limits.

Fifty-six per cent of the watershed of the Calumet River lies in the State of Ind ana, and the people in this watershed and adjacent to Lake Michigan are now co sidering the construction of works to take care of the sewage and storm water of th area. It is proposed to construct a cut from the Little Calumet to Lake Michigan i Porter County, Ind., which will divert a large part of the storm water directly into t lake. Even with this relief, however, the flood waters which we will have to dea with will probably exceed 6,000 cubic feet per second.

Having stated the natural conditions which obtain in this district, we proceed wi with our report, and confine our attention to that part of the Calumet district lyi within the city limits, an area of 40 square miles.

From inspections made by this commission, both the Little Calumet and Gran Calumet Rivers, in this State and in Indiana, with the present population, are in a extremely polluted condition, and with the rapid increase of population which wi ensue from the industrial development of the district lying 15 to 20 miles east of th State line of Illinois, this pollution will increase and is wholly without the jurisdi tion of the city, the sanitary district, or of the State of Illinois.

We are of the opinion that whatever may be done in the matter of sewage purific tion in the towns of northern Indiana it will be practically impossible to make the tri utaries of the Calumet River unpolluted streams, and that it will be necessary und any conditions to divert the daily flow of this river to the drainage canal.

We assume, therefore, that a canal will be built of sufficient capacity, connecti the Little Calumet River to the drainage canal at or near the Sag. Because of the floo in the river, controlling works would be built at the point of junction of the can and river to prevent the passage of excessive flood water into the drainage canal.

Owing to flood conditions, it is unwise to discharge raw sewage into the river. No only would the water be heavily polluted at all times and subject to flow into th lake, but a considerable deposit of organic matter would occur and the accumulate deposit would be thoroughly scoured out into the lake by flood. Whether equall dangerous with the dissolved or suspended sewage or not, the decomposing matte composing this deposit would be highly offensive, and the discharge would be co tinuous over a considerable period of time.

To prevent this discharge of sewage into the river, it is practicable to build inte cepting sewers on each side of the river, beginning near the mouth of the river, wit

onstant fall to a pumping station located at a convenient point, which probably uld be at or near Indiana Avenue and One hundred and thirtieth Street, whence sewage would be pumped and delivered into the canal west of the controlling rks. The controlling works may be located near the junction of the river and ny Creek at Center Avenue and One hundred and thirty-first Street, at which nt it is probable the Sag Canal would commence.

The intercepting sewers would ordinarily collect the sewage only, but in time of n would take the first run of storm water; the latter as it increased in quantity and ocity would pass over the intercepting sewers and discharge into the river. The antity of storm water from the 40 square miles lying within the city limits would ount to about 2,000 cubic feet per second. The storm water from the paved and fed area of the city delivered through sewers would arrive in the river more quickly an would the run-off from the outlying portion of the district, and would in ordiry storms have passed down the canal in time so that the latter would receive and ry away the succeeding run-off, of which the rate of discharge would be less.

On the river at the present time there are two principal centers of pollution—the st near the mouth, where the sewers from the Strand and from Ninety-second Street pty at the north bank and where the Ninety-fifth Street system of sewers now aring completion will discharge the sewage from a large district at Ninety-fifth reet on the same side of the river. The total area draining to this center will aggrete 6,000 acres.

The second center of pollution is about 12 miles from the mouth of the river, where e Indiana Avenue, Wentworth Avenue, and Halsted Street sewers discharge, also the north bank, the sewage of 6,000 or 7,000 acres.

As the sewers at both centers discharge into the river at the north bank, the first tercepting sewer to be built would be that running through the district lying between e river and Eighty-seventh Street. The general course of the sewer would be, rting with its highest point at the intersection of the Strand and Harbor Avenue, Harbor Avenue to Ninety-second Street, where it would intercept the Ninetycond Street sewer; thence to the pumping station at Ninety-fifth Street and Erie venue, where it would receive the sewage from the Ninety-fifth Street system; ence in a general westerly and southerly direction in One hundred and first reet and Cottage Grove Avenue through Pullman, where it would intercept the wage of the Pullman system of sewers; thence in One hundred and fifteenth d One hundred and eighteenth Streets through Kensington, where it would tercept the Indiana Avenue sewer; thence to a point on the river south of One ndred and twenty-seventh Street, which is the probable location of a pumping ation, where the sewage would be raised and discharged into the river beyond the ntrolling works.

The sewage from the Wentworth Avenue and Halsted Street sewers may be brought the same pumping station and raised and discharged with that from the east.

This would involve the construction altogether of about 10 miles of intercepting wers, the largest of which would be 8 feet in diameter.

There is immediate need of a change in the sewerage systems of Pullman and Kengton, because the existing sewers are inadequate. This condition has been conlered in outlining the route of the above intercepting sewer, and it may be that afford relief to these systems it would be necessary in the near future to construct e portion of the intercepting sewer between Pullman and the river.

That portion of the city lying east and south of the Calumet River would be cared r by a similar intercepting sewer, which would also discharge the sewage at the imping station at or near the river and One hundred and twenty-seventh Street. his sewer would be built later, when called for by increase of population in this part the city.

The work of constructing the Calumet-Sag Canal has been delay pending Federal permission, but actual excavation is expected begin very soon.

WATER SUPPLY.

Chicago's water supply is taken from Lake Michigan from t following intake cribs:

Lake View Crib.—Twenty-eight feet of water; 6 ports throu breakwater, each 2½ feet wide, for full depth of water; 4 ports throu cylinder structure 25 feet to bottom of crib; each port 4 feet by feet; 3 ports in cast-iron cylinder 22 feet below the water.

Carter H. Harrison Crib.—Depth of water in the lake surroundi crib is 36 feet; water gains entrance to the well room through s ports, each 4 feet 6 inches square; bottom of said ports located feet below the surface of the water; depth of water in the well roo 28 feet; water gains access to tunnel shaft through three ports, ea 4 feet 6 inches square with bottom of ports 14 feet from the botto of the well room.

Four-Mile Crib.—Depth of water in the lake surrounding crib 38 feet. Water gains access to well room through five ports, ea port being 4 feet 6 inches square. Said ports are located about feet below the surface of the water. Depth of the water in the w room is 30 feet. The water gains access into the tunnel shaft throug three ports, each 4 feet 6 inches square. Bottom of said por located 20 feet from the bottom of the well room.

Two-Mile Crib.—The Two-Mile Crib is divided into two structures— one known as the Old Two-Mile Crib and containing one 5-foot tun nel shaft and one 7-foot tunnel shaft. The other part is known the Ross & Ross addition and contains one 7-foot tunnel shaft.

Ross & Ross Addition.—Depth of water surrounding this additio is 35 feet. The water gains access to the well room through cri piling and rocksill without any ports. The depth of the water in th well room is 24 feet. The water gains access to the tunnel sha through three ports, each 4 feet 6 inches square, the bottom of sa ports being located 15 feet below the surface of the water.

Old Two-Mile Crib.—Depth of water surrounding said crib is 3 feet. The water gains access into the well room through four port each 4 feet 6 inches square. One port is located 18 feet below th surface of the water, one port is located 16 feet below the surface o the water, and two ports are located 4 feet below the surface of th water, all measurements being to the top of said ports. The wate in the well room is 24 feet deep. The water gains access throug one 7-foot tunnel shaft through three gates, each 4 feet 6 inche square, the bottom of said gates being 18 feet below the surface o the water. The water gains access into a 5-foot tunnel shaft throug

vo ports, each 4 feet 6 inches square, the bottom of said ports being 6 feet from the bottom of the well room.

Sixty-eighth Street Crib.—Thirty-five feet of water; two ports in reakwater structure, each 25 feet wide, for full depth of water; our ports in crib structure, each 5 feet 6 inches by 3 feet 6 inches, with ottom of same located 30 feet below the level of the water. There is 0 feet of water in the well room. The water gains entrance to the unnel through three ports, each 4 feet 6 inches by 5 feet, located with ottom of port 6 feet below water level.

Map No. 16 shows the location of these various cribs and tunnels, nd also the relative position of the nearest and greatest source of ollution, the Calumet River.

The sewage of Chicago north of Eighty-seventh Street is intercepted and kept out of the Lake. This is also true for Winnetka, Vilmette, Glencoe, Fort Sheridan, and the United States Naval raining Station. In spite of this fact the amount of pollution eaching the lake after heavy rains is large. The surface washings f this very populous strip make a wide zone of polluted water along ne shore after heavy rains independent of direct sewage discharge.

The sewage of Evanston is discharged into Lake Michigan at resent. In spite of the drainage canal, in times of unusual storm nd heavy rains large amounts of pollution may reach the lake by neans of the Chicago River.[1]

Even after the Calumet-Sag Channel and the interceptors which nake up that system are constructed, a large amount of pollution vill be delivered by the Calumet in flood or after heavy rains. It is stimated by Mr. Wisner that, after the completion of the Calumet-ag Channel, whenever the stream flow of the Calumet exceeds 2,000 ubic feet per second, the river will discharge into the lake, and that his occurrence may be expected 22 days in the year.

Waukegan and several smaller north-shore communities still discharge sewage into the lake, and north of the Wisconsin line the ities of Kenosha, Racine, and Milwaukee discharge their sewage nto the lake. How far and how rapidly this shore pollution travels epends upon currents. The effect of distance and dilution are o be reckoned with, but it has been shown that under certain weather onditions these are but slender reeds to lean upon. Currents in the ake are changeable and can not be relied upon to protect intakes. On the contrary, they may carry pollution from considerable distances to the intakes, although pollution from a great distance can carcely cause the easily recognizable explosive outbreaks stamped water borne." Such dilute pollution may be responsible for many

[1] Mr. Langdon Pearse estimates that a run-off of 44 cubic feet per second per square mile over an area of 180 quare miles would be necessary to reverse the current in the Chicago River toward the Lake. This would e a very unusual storm and while its occurrence is possible, in Mr. Pearse's opinion, it is unlikely to occur

cases, scattered over a considerable period or occurring during th summer or autumn months when other factors can not be excluded. Further, water-borne cases, even if few in themselves, are indirectly responsible for many cases usually ascribed to contact by furnishing new foci from which these contact factors may operate. Even if all the sewage were kept out of the lake, the Chicago water supply could not be expected to be safe without filtration or treatment 365 days in the year. However, the sewage discharged into the lake by means of the Calumet River is the greatest present menace.

The Calumet drainage area carries the pollution of about 200.000 people to the lake. The drainage area is small, being only about 800 square miles, but its population is increasing rapidly, and much of it is urban with a direct sewage contribution to the stream.

In addition to the pollution carried to within 4 miles of Chicago waterworks intakes by the Calumet River, the water in the southern end of Lake Michigan is further polluted by the sewage and surface washings from Whiting, Indiana Harbor, Gary, and Michigan City, Ind. Conditions in these communities will be more fully discussed later under their proper headings.

From these various sources the pollution of the southern portion of Lake Michigan is such that contamination at the Chicago intakes is common, not only at the Sixty-eighth Street or Hyde Park Crib, which is nearest to the Calumet River, but at the other intakes as well.

The following table shows results of bacteriologic examination during 1909, made by the Chicago department of health:

Source of sample.	Number of samples.	Number found positive for B. coli.
Lake View	18	[illegible]
Carter Harrison	155	[illegible]
Chicago Avenue	154	[illegible]
Four-Mile Crib	124	[illegible]
Hyde Park	112	[illegible]

In 1911 the following results were obtained, using 1 c. c. samples in lactose bile for the B. coli test; samples taken at the pumping stations, 1911:

Source of sample.	Number of samples.	Number positive for B. coli.
Lake View	51	[illegible]
Chicago Avenue	48	[illegible]
Fourteenth Street (4-mile crib)	69	[illegible]
Sixty-eighth Street (Hyde Park)	56	[illegible]
Rogers Park (filtered)	50	[illegible]

These results were obtained and furnished the writer by Dr. F. O. onney, director of the laboratory of the Chicago Health Depart-ent. They show that at present (1911) the Hyde Park crib is ost subject to pollution, but the Lake View crib, which is farthest om the Calumet, was also polluted, as was shown in 25 per cent of e samples examined. The 4-mile crib was polluted less frequently, it was contaminated at times. Samples from the filtered water at ogers Park indicate that the plant was at times unable to remove e shore pollution taken in at the intake 3,000 feet offshore.

The immediate necessity of treating the Chicago water supply must apparent to every one acquainted with the facts. A plant for eating with hypochlorite could be installed quickly, and the expense operation would be only one-tenth the cost of filtration. The fact at no explosive winter outbreak has occurred recently is no argu-ent for delay and no excuse for furnishing a water which is contami-ited, even if the pollution is only occasional or dilute.

TYPHOID FEVER IN CHICAGO.

In studying the typhoid-fever history of Chicago, one naturally di-des the record into several distinct periods. The period from 1881 1893 was one of continuously high rates. From 1893 to 1899 there is a falling tendency evident in the typhoid curve, but the rates ere still high. In 1900, after the opening of the drainage canal, the west typhoid rate in Chicago's history up to that time was achieved. 1901, 1902, and 1903 there were epidemics, probably water-borne, hich raised the yearly rate; since 1904 there has been a low yearly te, with a tendency to decrease since 1907.

Average death rate per 100,000 typhoid fever: 1881 to 1893, 105; 1894 to 1899, 35.9; 00, 19.8; 1901 to 1903, 35.1; 1904 to 1910, 17.7.

Chicago's typhoid-fever rate in the past seven years has been low rough to occasion considerable satisfaction among its city officials, id certainly the reduction of the typhoid-fever rate from an average 59.7 in the 10 years ended in 1900 to an average of 17.7 in the past years is an achievement to be proud of. There seems little doubt, owever, that the splendid results on the typhoid-fever rates following e installation of the drainage canal and the North and South Side terceptors have delayed the necessary and inevitable treatment of e public water supply and diverted attention toward other factors the typhoid problem.

Chicago has always been progressive, and more than 45 years ago egan its practice of pumping water (or more correctly sewage) from e Chicago River at Bridgeport into the old Illinois and Michigan anal. This pumping would cause a reverse current away from the

lake in the sluggish river and tend to protect the intakes, but in times of thaws and heavy rains the sewage was projected far out into the lake. The effect of the drainage canal in 1900 was noticeable, and caused many persons to think the problem was solved. However Chicago was growing very rapidly and the growth was in the district which still sewered into the lake.

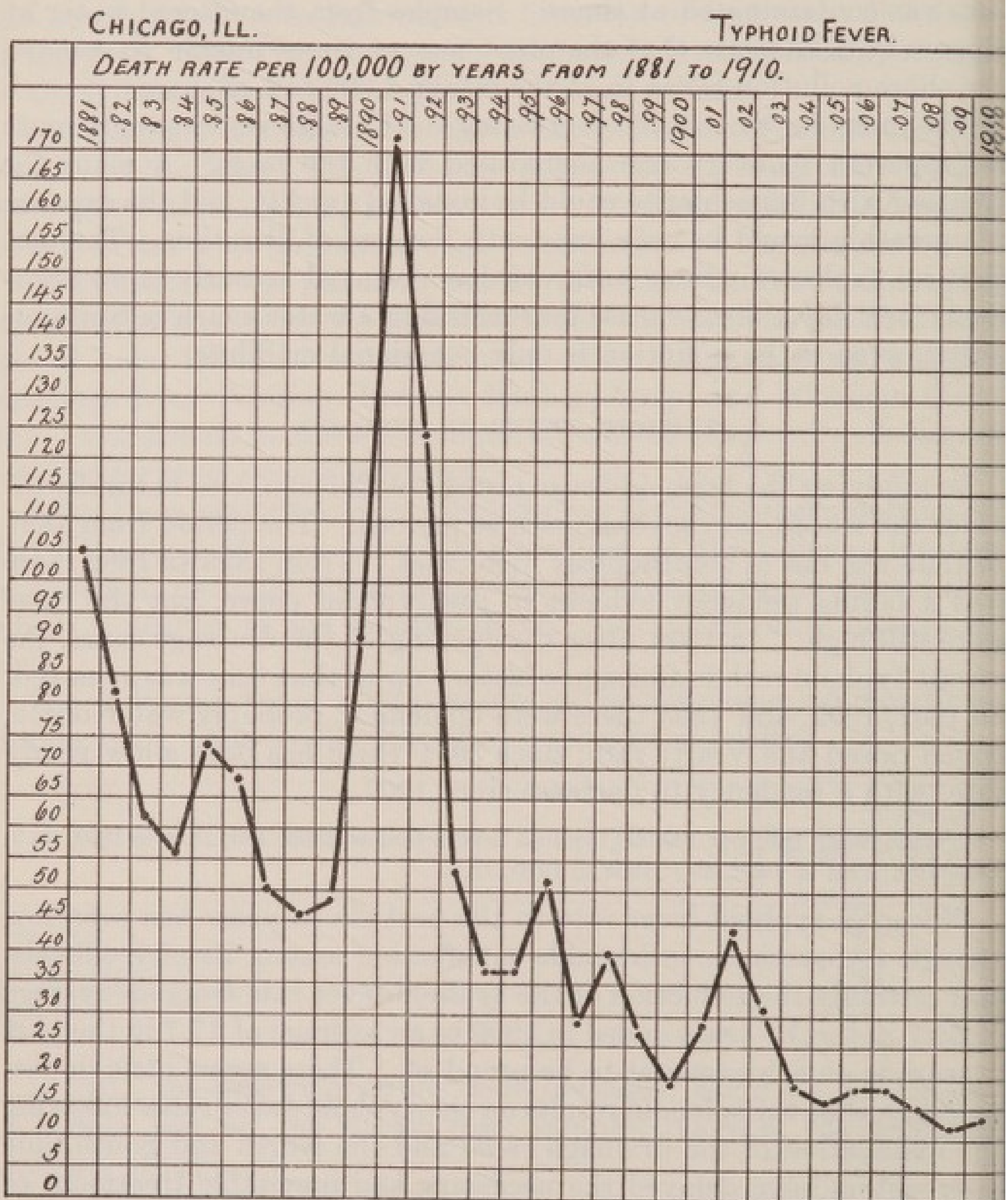


CHART 37.—Typhoid fever death rates in Chicago, Ill., by years, 1881 to 1910.

In 1902 the North and South Side interceptors had not been built and the drainage canal at that time did not carry the sewage of the district north of Lincoln Park and south of Thirty-ninth Street, a population of nearly a quarter of a million which sewered direct into the lake. To the installation of the North and South Side intercep-

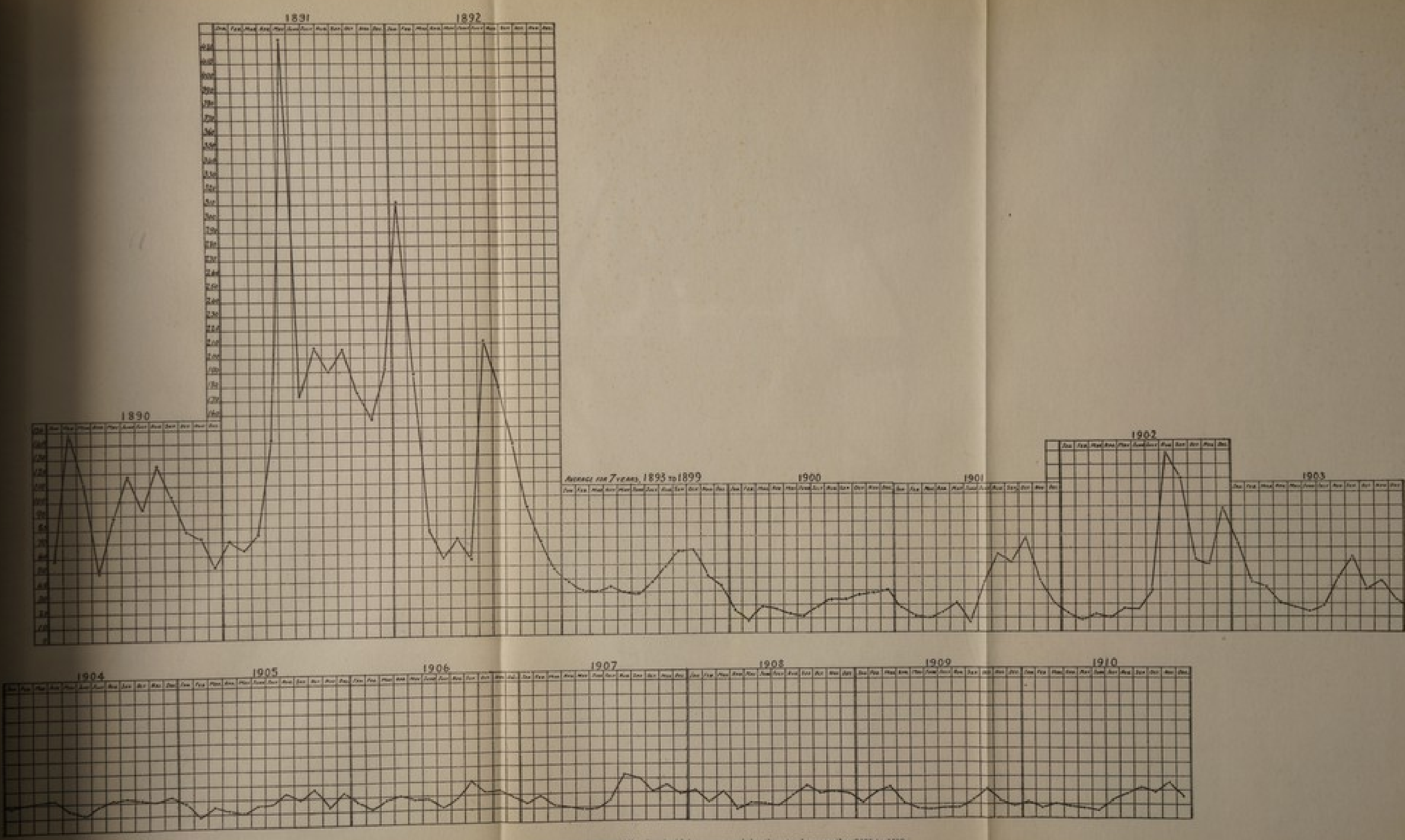


CHART 28.—Chicago, Ill. Typhoid fever annual death rates by months, 1890 to 1910.

37958°—12. (To face page 146.)

ors may be attributed the bulk of the typhoid reduction noticeable nce 1903.

That Chicago suffered terribly from water-borne epidemics of yphoid fever in the past is evident from a study of the records. xplosive epidemics of such magnitude and with such general disibution as those of 1890, 1891, and 1892 could be caused by no other ngle factor. The same is true of the 1902 epidemic, a sudden masve outbreak, with a general distribution, which occurred in the immer months. Coming so soon after the opening of the drainage anal, many were inclined to think the water supply innocent, and lay the blame upon some other factor.

Water-borne epidemics may occur at any time of the year. Waterorne typhoid is not necessarily a disease of the first half of the year, ut epidemiologists have found it easier to exclude other factors uring that period, and consequently have laid stress upon winter nd spring outbreaks in connection with a polluted water supply.

The pollution of a water supply is often made possible by the thaws nd heavy rains in winter and spring, but it must be remembered at heavy rains sometimes occur in June, October, or other months, nd may be equally disastrous. The very heavy rainfall of May, ine, and July, 1892, was followed by the massive outbreak in that ear. In 1902 the rainfall was shown by Jordan[1] to have been eater in May, June, and July than in any year since 1892, and folwed by the explosive outbreak shown in Chart No. 38.

SEASONAL PREVALENCE.

With a typhoid death rate in 1909 of 12.6 per 100,000 there is some ason for considering water a negligible factor, but close study of the asonal prevalence, coupled with the known contamination of the iblic water supply, suggest that water is a factor to be reckoned with. he dilution available in Lake Michigan is so great that explosive assive outbreaks easily traceable to water are unlikely to occur, nce the bulk of Chicago's sewage has been removed from the lake. ill the dilute pollution may be responsible for many cases of typhoid hose origin is difficult to trace.

The Hyde Park intake is nearer the source of greatest pollution, and eoretically the district served by this water should show more phoid, provided water was the vehicle of transmission.

No accurate conclusions regarding the relation between water supply d typhoid fever in the various wards can be drawn, for two reasons. rst, although taken from many intakes the water is mixed to some tent by intercommunicating mains, and the boundaries of a district ing exclusively water from any particular intake can not be defined.

[1] Jordan, E. O. Journal American Medical Association, Vol. XXXIX, 1902, p. 1564.

The amount of mixture depends upon consumption and pressure; second, the comparison of one intake with another could be but relative, as they were all polluted at times during the year. In fact, in 1909 there was little difference between them in this regard.

For these reasons we must not expect striking differences in the various wards at present. Formerly the districts supplied by each intake were more clearly defined, and deductions might have been drawn.

The seasonal prevalence of typhoid fever in Chicago is abnormal and irregular. Table 24 shows the typhoid death rates per 100,000 per annum in Chicago by half years.

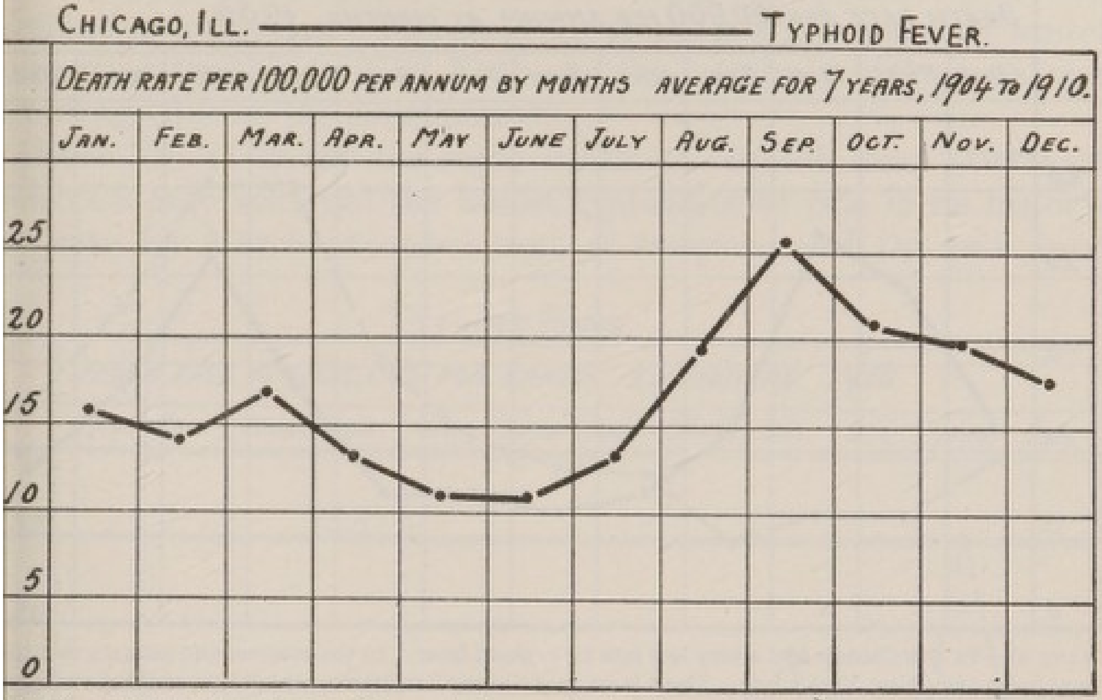
TABLE 24.—*Typhoid-fever death rate per 100,000 per annum, by half years, from 1900 to 1910, Chicago, Ill.*

Years.	First half, January to June.	Second half, July to December.
1900	14.4	25.[illegible]
1901	12.5	45.[illegible]
1902	13.0	76.[illegible]
1903	30.4	33.[illegible]
1904	13.0	20.[illegible]
1906	16.6	20.[illegible]
1907	12.4	23.[illegible]
1908	14.0	17.[illegible]
1909	13.1	12.[illegible]
1910	8.7	18.[illegible]

It will be seen that for 10 years 1900 to 1909, the rate for the first half of the year was never below 12. In 1903 it was 30.4. Leaving out the epidemic years and taking the years since 1903 (1904, 1905, 1906, 1907, 1908, and 1909) there has been an average rate of 14.5 for the months from January to June. The average rate for the entire year for this period was 15.9. Cities whose annual typhoid death rate is below 14 per 100,000 should not have a rate for the first half of the year above 8, provided the water supply is safe and that a milk epidemic does not occur regularly every year in the winter or spring.

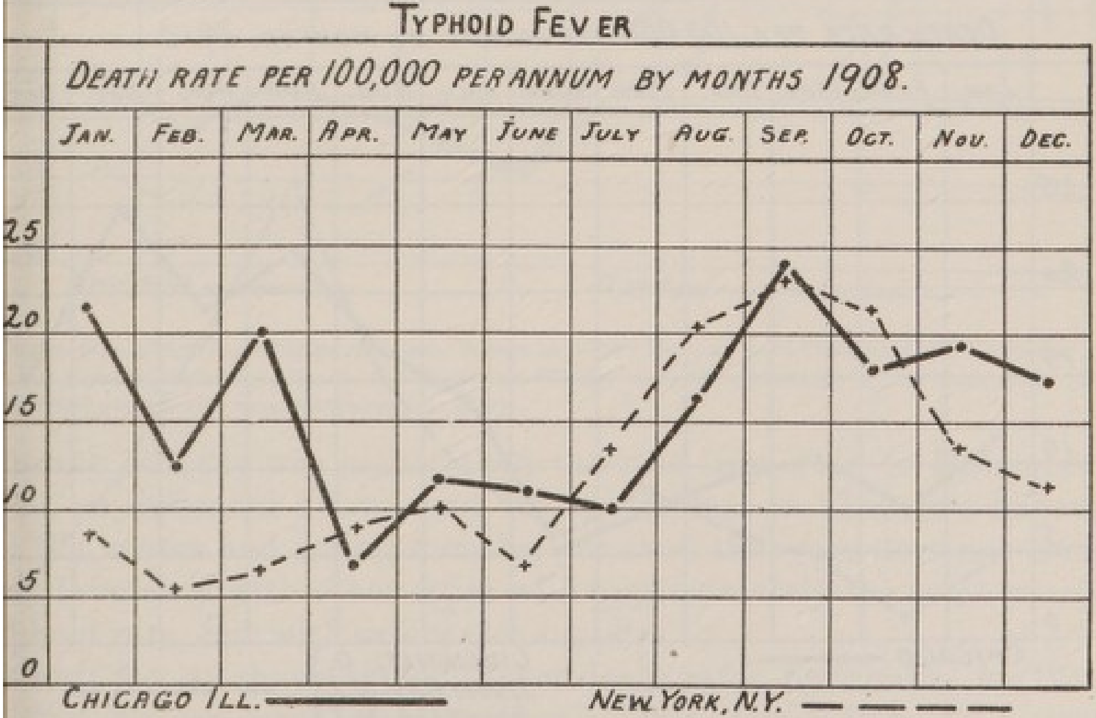
Chicago's typhoid fever rate in these six years was almost as high in the first six months of the year as the average rate for the entire year. Such a phenomenon can only be explained by water-borne typhoid or by a never-failing milk-borne infection manifested in the winter months. Even more striking is the seasonal prevalence in Chicago when studied by months instead of half years, and compared with other cities. In making these comparisons of typhoid death rates by months, it is essential, in fairness, that the cities compared have about the same yearly rate for typhoid fever. Chicago had a rate of 12.8 in 1909 and 13.7 in 1910. These low rates for typhoid placed Chicago "among the elect," and in comparison only cities having rates below 14 will be used.

Chart No. 39 shows the average rate by months for the past seven ears (1904 to 1910). During this period there were no marked idemics, and the general yearly rate for typhoid fever was low.



ART 39.—Average annual typhoid-fever rate by months in Chicago, 1904 to 1910. Note the persistently high rates in January, February, March, and April.

e steady, persistently high rate in January, February, March, and oril is clearly shown.



RT 40.—New York and Chicago, comparing seasonal prevalence of typhoid fever in 1908. Note the relatively high rate in Chicago for January, February, and March.

In 1910 Chicago had the lowest typhoid fever rate from January June in the history of the city. The rate for the entire year was

higher than in 1909, due to an increased prevalence in the summer and autumn months. Yet even in this year (1910) the rate was 8.5 fo[r]

TYPHOID FEVER.

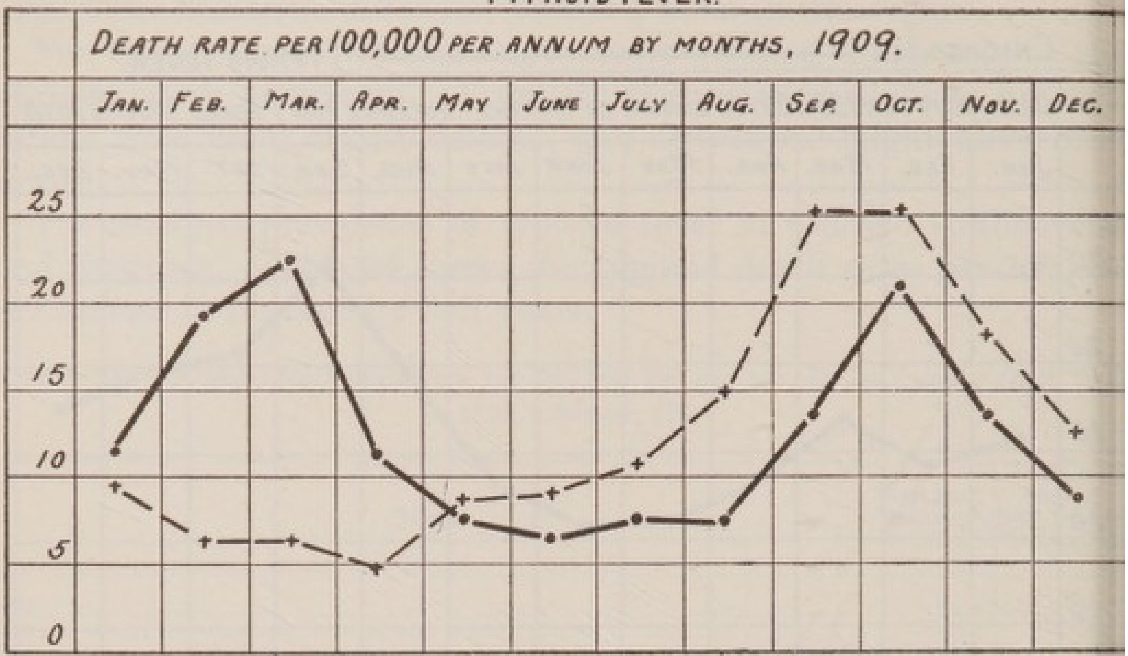


CHART 41.—In 1909 Chicago had a very low rate for typhoid fever. In the summer and autumn months [it] was lower than New York's rate. There is an ugly "hump" in March, which is in striking contrast t[o] the low rate for New York for March.

the period from January to June, which is not low in proportion to th[e] total yearly rate of 13.7.

TYPHOID FEVER

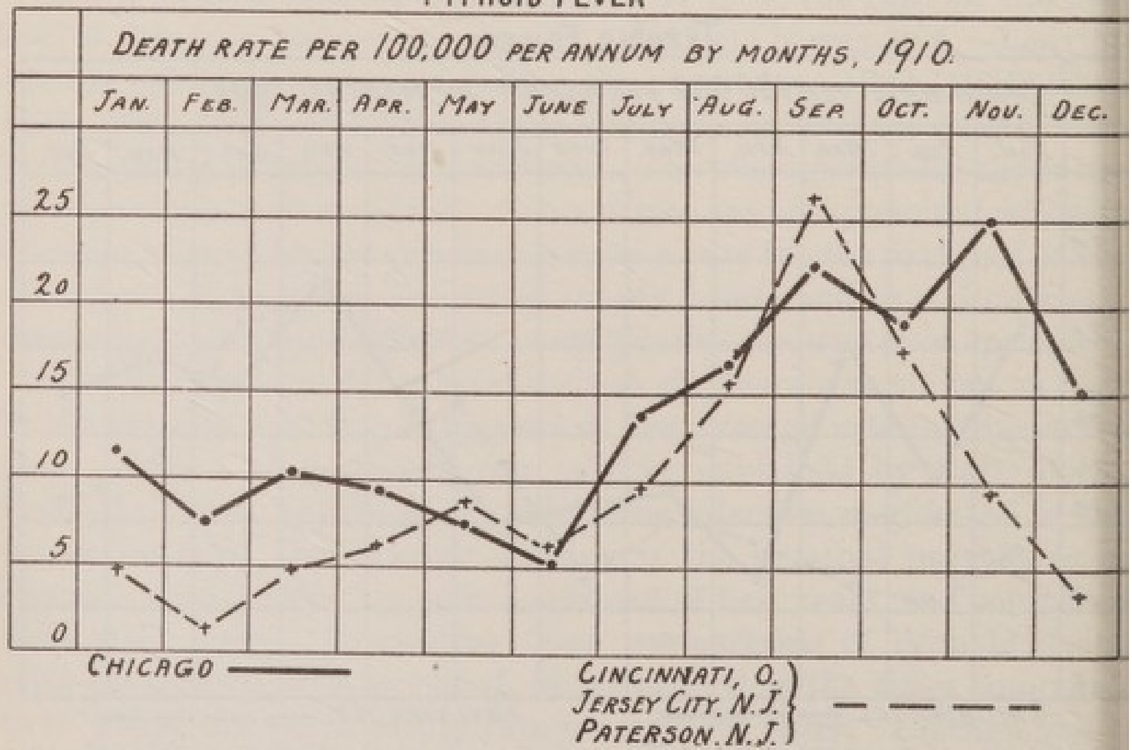
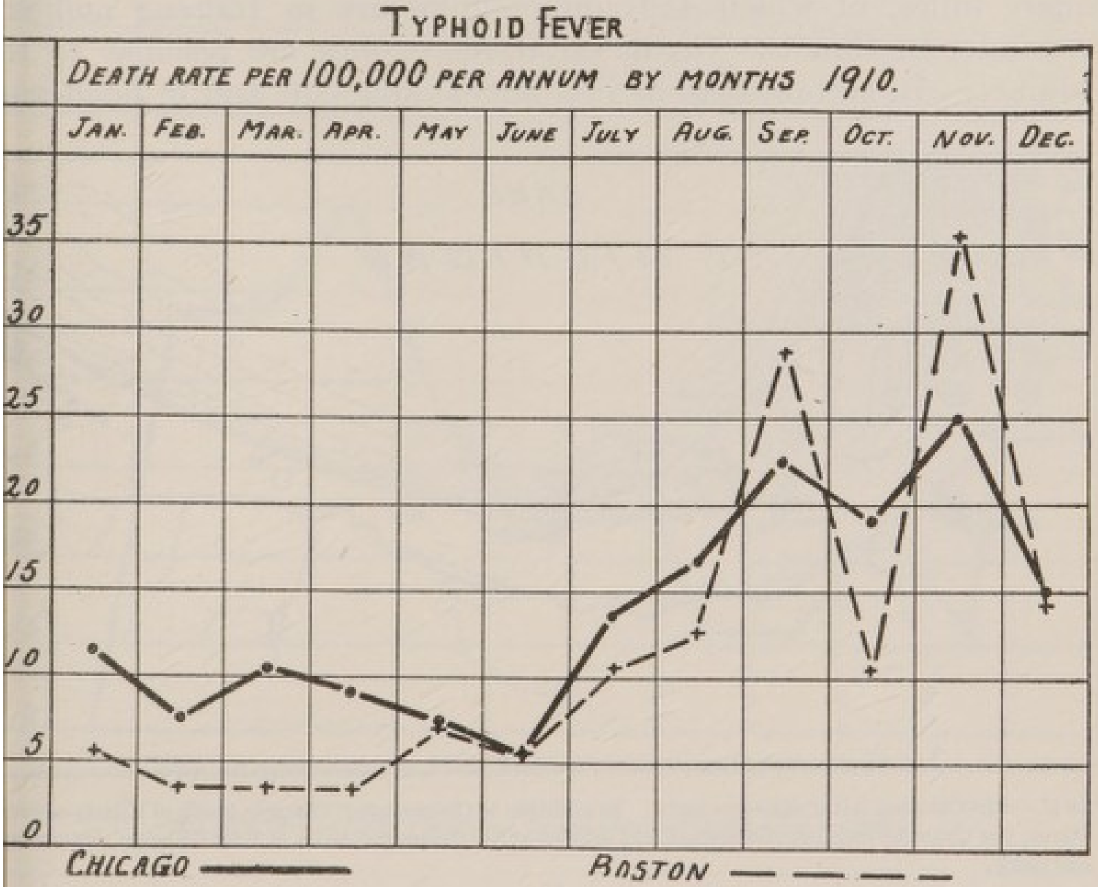


CHART 42.—In 1910 Chicago had the lowest rate for typhoid fever from January to June in its history. Still, compared with Cincinnati, Jersey City, and Paterson—cities with safe water supplies—the rat[e] in Chicago was consistently higher in January, February, March, and April.

Chart No. 40 shows the typhoid-fever death rate per 100,000 pe[r] annum, by months, in 1908 in Chicago compared with New York

ew York's water supply is not absolutely safe, as it is an unfiltered ırface water. It comes from a watershed carefully patrolled, howver, and has large storage reservoirs. It must be classed as a good ater supply and is probably safe, although the possibility of conımination is present. The chart shows the low prevalence of winter ıd spring typhoid in New York and the relatively high prevalence Chicago during the same period.

Chart No. 41 shows the same contrast. In this year (1909), in hich Chicago achieved the lowest typhoid-fever rate in its history, ıe rate for March exceeded that of October, and the rate from



HART 43.—Boston had a higher rate than Chicago in 1910 for the months of September and November. For January, February, March, and April the Chicago rates are constantly higher than those of Boston even in this most favorable year 1910).

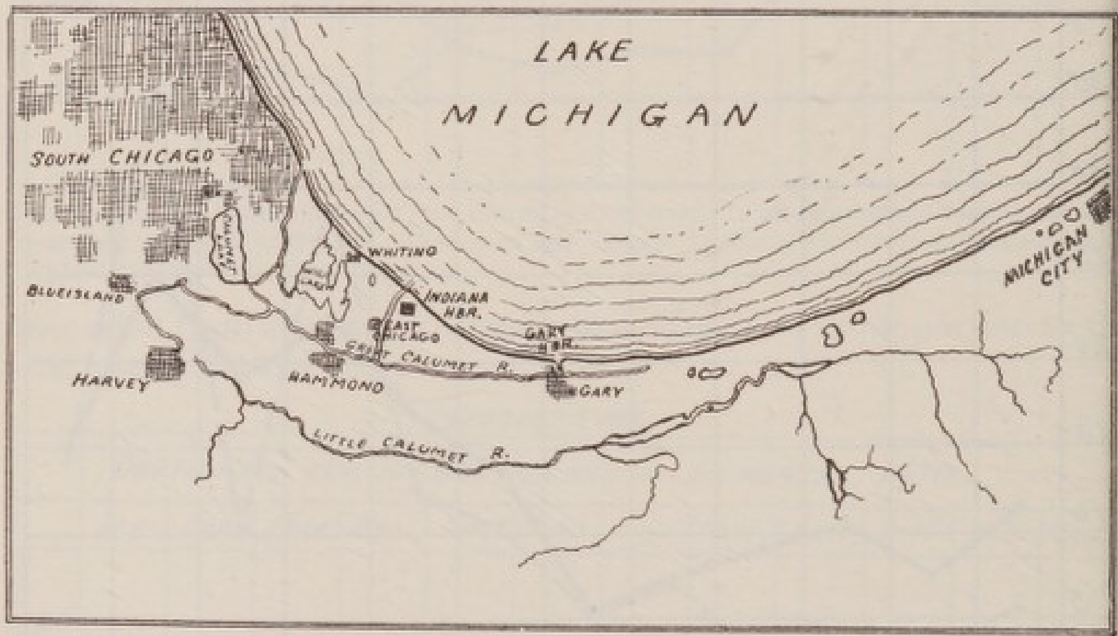
ınuary to June was higher than the rate from July to December; 10, as indicated above, had the lowest rate in Chicago's history r the winter and spring months, yet even this year does not comre favorably with other cities with approximately the same yearly phoid rate, but with safe water supplies.

Chart No. 42 shows typhoid-fever death rates, by months, for 1910 Chicago compared with Cincinnati, Ohio, Jersey City, N. J., and ıterson, N. J., combined. These are the three cities in the "honor t" which have safe water supplies. Cincinnati and Paterson have tered water, and Jersey City's water supply is treated with hypolorite of lime.

Chart No. 43 shows the typhoid curve by months in Chicago's best year, 1910, compared with Boston, Mass. Boston has an unfiltered surface supply obtained by impounding streams. The watershed is controlled and carefully watched, and there is very large storage capacity in the reservoirs. The supply at present seems to be safe, although the possibility of pollution is present. The difference in January, February, March, and April in the two cities is at once apparent.

CALUMET RIVER DRAINAGE BASIN.

The drainage area of the Calumet River consists of about 800 square miles, of which 450 square miles are in Indiana and the remainder in Illinois. Great variations in flow are peculiar to the Calumet. In certain seasons it is almost stagnant and in flood may



MAP 17.—The Calumet River drainage basin. In addition to the sewage of Chicago, south of Eighty-seventh Street, the Calumet receives the sewage and wastes of the industrial cities of East Chicago, Hammond, and Gary.

carry as much as 13,000 cubic feet per second. The population in the Calumet drainage area is growing rapidly and is now about 200,000. The sewage of about 150,000 of Chicago's population south of Eighty-seventh Street is tributary to the Calumet, as is also the sewage of East Chicago, Hammond, Gary, and other communities in northern Indiana.

EAST CHICAGO.

The population of East Chicago was 19,098 in 1910. The sewers discharge into the Calumet River. One ward of East Chicago, which is called Indiana Harbor, and contains more than one-third of the total population, is situated on and discharges its sewage into Lake Michigan direct.

The waterworks intake for East Chicago is located 3,000 feet off-
ore in 20 feet of water. There are no wells, and the entire popula-
on depends upon the public supply. The sewage of Indiana Harbor
discharged into the lake at a point about one-half mile east of the
ast Chicago waterworks intake.

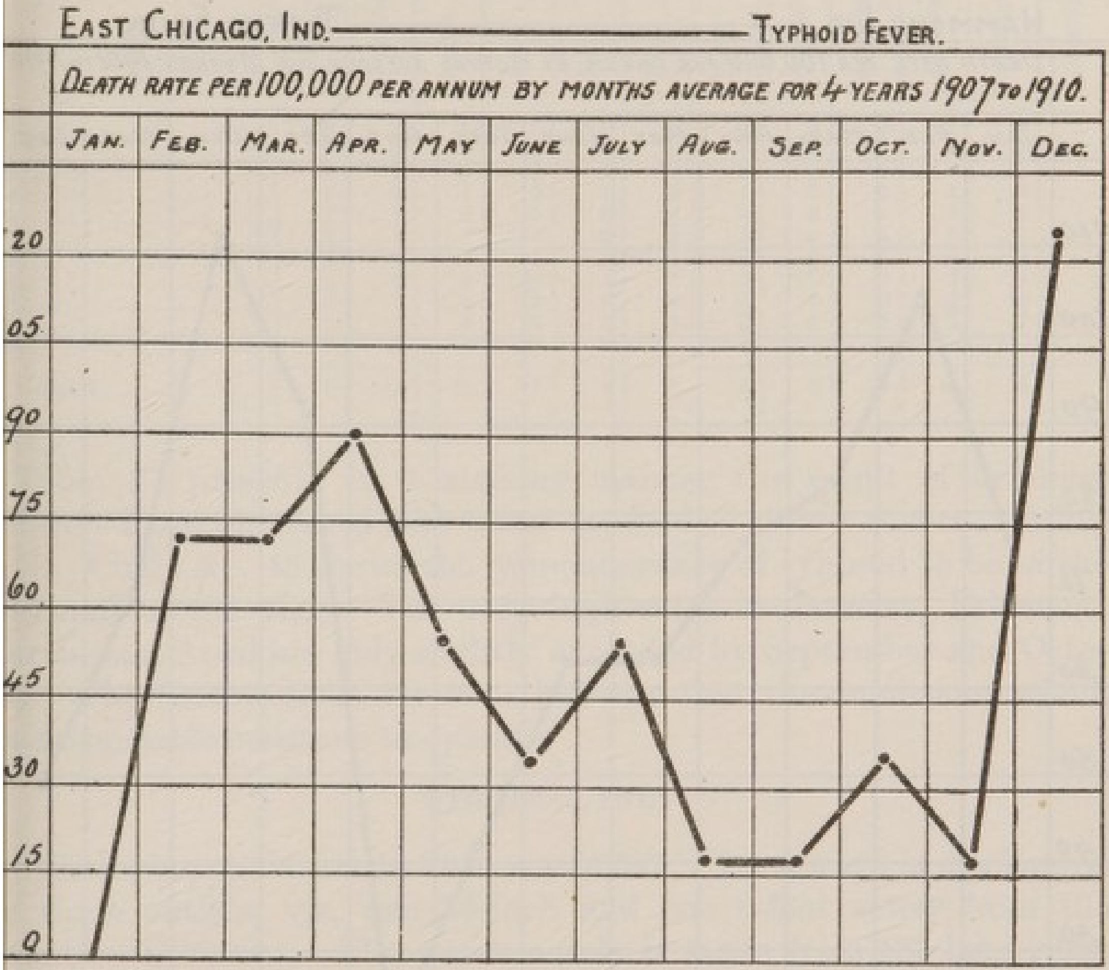


CHART 44.—East Chicago, Ind. Seasonal prevalence of typhoid fever.

TABLE 26.—*East Chicago, typhoid-fever deaths by months.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
01	0	0	0	0	0	1	0	0	0	0	0	1
02	0	0	0	0	0	0	0	0	0	0	1	0
03	0	0	0	0	0	0	0	0	0	0	0	0
04	0	1	0	0	0	0	0	0	0	0	2	0
05	0	0	0	0	0	0	0	0	0	0	1	1
06	0	0	0	0	0	0	0	0	0	0	0	0
07	0	1	1	0	2	1	0	1	1	1	1	3
08	0	2	3	2	0	1	1	0	0	1	0	1
09	0	1	0	2	1	0	2	0	0	0	1	2
10	0	0	0	1	0	0	0	0	0	0	1	1
Total	0	5	4	5	3	2	3	1	1	2	7	9

The appended table of typhoid deaths tells its own story. Chart
o. 44 shows the death rate per 100,000 by months for the last four
ears. The months which in towns with good water supplies have

the highest typhoid rates—August, September, and October—have the lowest rates in East Chicago. On the other hand, February, March, April, and December, which have low rates almost invariably in towns with safe water supplies, have the highest rates of all months in East Chicago.

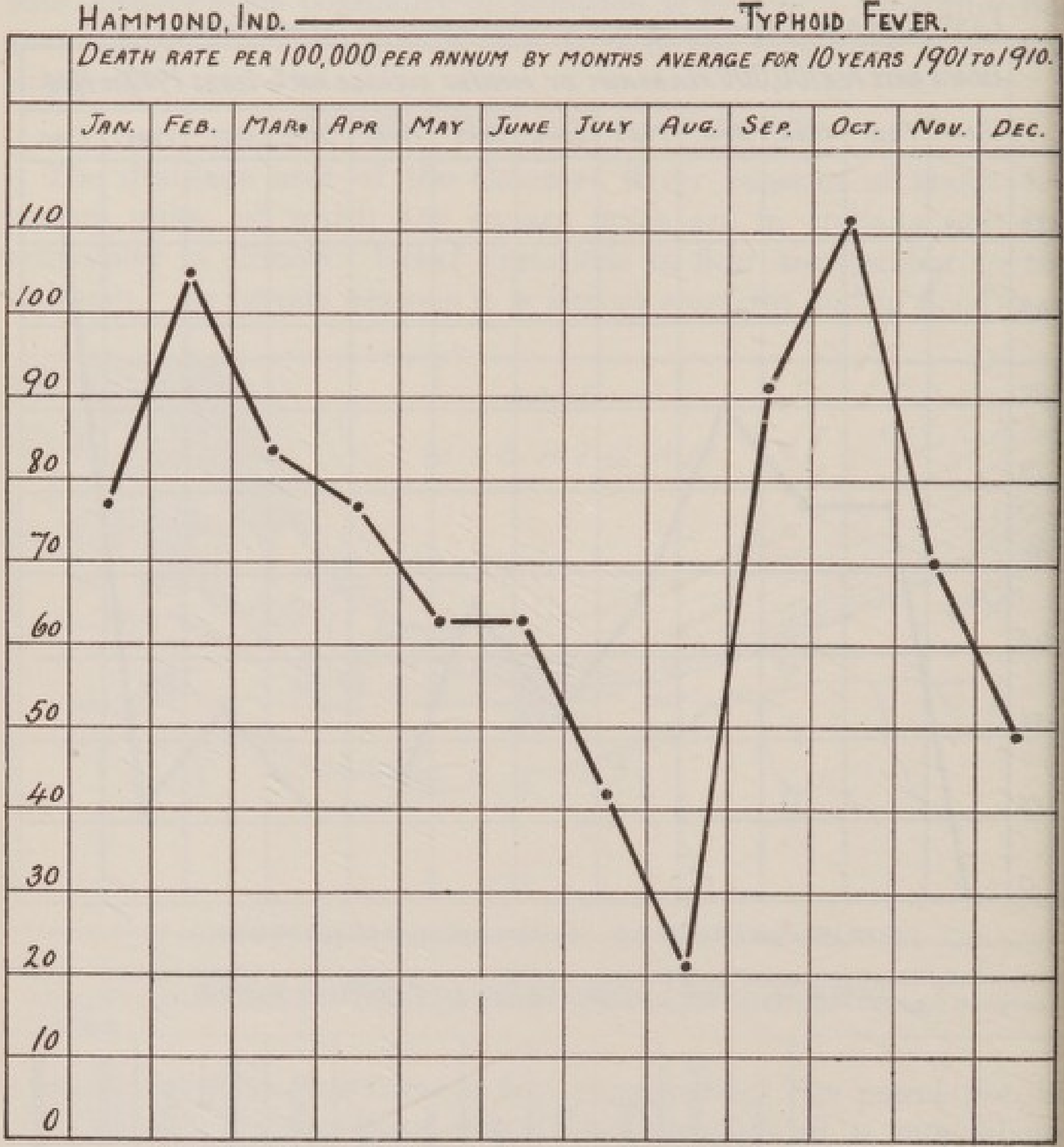


CHART 45.—Hammond, Ind., showing seasonal prevalence of typhoid fever.

HAMMOND, IND.

Hammond had a population in 1910 of 20,925. The city proper is 5 miles inland, but a portion called Robertsdale borders on the lake. The sewage of Hammond is discharged into the Calumet River.

The Hammond water supply is drawn from Lake Michigan by three pipes of 30, 20, and 16 inch diameter, respectively. The intake is 2,000 feet offshore in 20 feet of water. There are very few wells, and the use of the public supply is general. In addition to the discharge from the Calumet, the intake is subject to pollution from the sewage of the glucose plant; from the Whiting sewers; two 36-inch

wers discharging at the Hammond-Whiting boundary line, and also a lesser degree to the 36-inch sewer at Indiana Harbor.

TABLE 27.—*Hammond, typhoid-fever deaths by months.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	0	2	1	0	2	0	0	0	3	1	1	1
2	1	0	2	1	0	0	0	0	1	1	1	0
3	1	1	3	3	1	2	0	1	2	2	1	1
4	1	0	1	0	1	2	1	0	0	1	2	1
5	1	1	0	0	1	1	0	0	1	1	2	2
6	0	2	1	3	0	1	1	0	1	1	1	1
7	0	0	1	1	1	1	0	1	1	4	0	0
8	6	6	3	3	1	1	2	0	3	2	0	0
9	0	1	0	0	1	0	0	0	0	3	0	0
0	1	2	0	0	1	1	2	1	1	0	2	1
1	0	0	3	1	0	......	......	......	......	......	......	......
Total	11	15	15	12	9	9	6	3	13	16	10	7

Table 27 presents in a striking manner the result of drinking nfiltered and untreated lake water exposed to almost constant pollu-on. Chart No. 45 shows the preponderance of typhoid to be in the rst half of the year. The very high rates in January, February, arch, and April are only slightly exceeded by September and Octo-er. The figures given for 1911 indicate that the conditions which e responsible continue to operate.

WHITING, IND.

Whiting's population in 1910 was 6,587. Its sewage is discharged y three outlets, viz, two 36-inch and one 6-foot sewer from the andard Oil plant. The water supply is taken from the lake 2,000 et from shore in 20 feet of water. The entire population depends pon the public water supply.

TABLE 28.—*Whiting, typhoid-fever deaths, by months.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
4	......	0	1	1	1	0	0	0	0	0	0	0
5	0	0	0	1	0	0	0	1	1	0	1	0
6	1	0	1	0	0	0	0	0	1	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	0	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
0	3	0	0	0	0	0	0	0	0	1	0	0
Total	5	1	2	2	2	0	0	1	2	1	1	0

Whiting's typhoid records resemble those of Hammond and East hicago. The unfiltered water from the contaminated southern end

of Lake Michigan is responsible without doubt for the high rate and peculiar seasonal distribution of the deaths as shown by Chart No. 46.

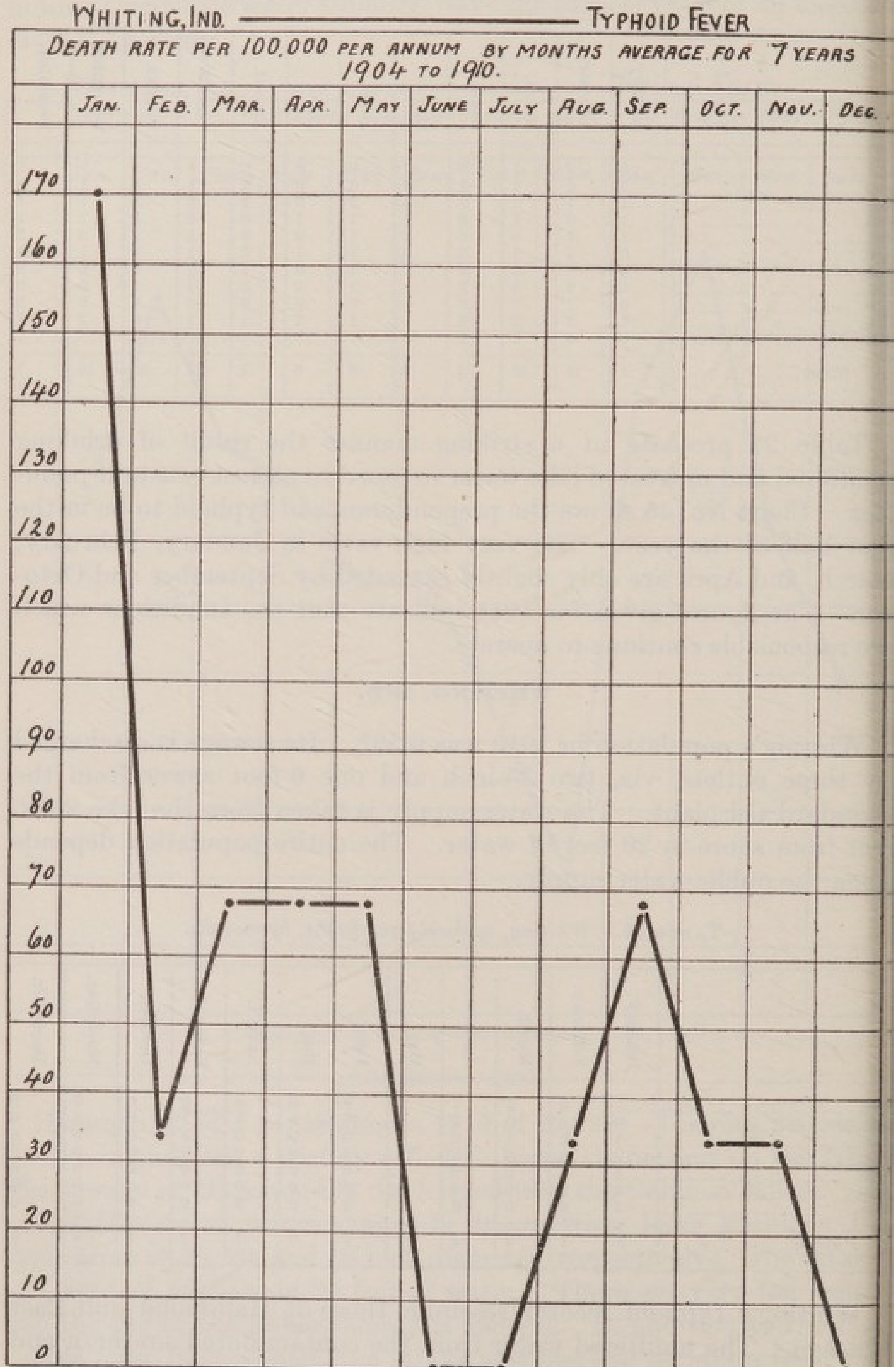


CHART 46.—Whiting, Ind., showing seasonal prevalence of typhoid fever.

GARY, IND.

The new industrial city of Gary has had a mushroom growth. It only about four years old, but in 1910 had a population of 16,802. ɔ typhoid figures were available from Gary except those for 1910 d a portion of 1911. No conclusions can be drawn from one year's atistics in a small city. The same general conditions may be pected to prevail as in adjoining communities.

Typhoid fever deaths by months.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
)......................	0	1	0	0	0	1	1	1	2	1	7	1
1......................	1	0	0	0	0	0	0	0	0	0	0	0

Gary's water supply is taken from Lake Michigan, 1½ miles from ore. The sewage of Gary is discharged into the Grand Calumet. ie sewerage system has been installed with a view to future puri-ation as the city grows.

MICHIGAN CITY, IND.

Michigan City's population in 1910 was 19,027. The sewage of ichigan City is discharged into the harbor, or Trail Creek, which npties into the lake at Michigan City. The sewage from the State ison, with about 1,000 inmates, must also be considered, as such wage is discharged untreated, with a portion of the city sewage, to the harbor.

In 1908 a very thorough sanitary survey of Michigan City was ade by Barnard and Brewster,[1] of the Indiana State Board of Health. am indebted to them for material relating to the water supply, hich follows:

The water supply is taken from Lake Michigan, 3,700 feet from e harbor's mouth, in 40 feet of water. There is also a harbor intake, hich is used when the lake intake becomes clogged with ice. The rbor water is grossly polluted, and the use of this harbor intake s been followed by disastrous results, as evidenced by epidemics so-called winter cholera and typhoid fever. The State prison s its own water system, with an intake 3,800 feet offshore and 1 ile west of the mouth of the harbor. There are quite a number dangerous shallow wells in use. Barnard and Brewster found o-fifths of these shallow wells to be contaminated.

[1] Barnard, H. E., and Brewster, J. H. The character of the water supply of Michigan City, Ind. First ort of the Lake Michigan Water Commission, 1909, p. 135.

Table No. 29 shows the deaths from typhoid fever in Michigan City by months from 1901 to 1910.

Typhoid fever deaths by months.

	January.	February	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1901	1	0	0	0	0	0	0	0	0	0	1	
1902	2	0	0	1	1	0	0	1	0	0	0	
1903	1	1	0	0	1	3	1	2	0	1	0	
1904	1	2	0	2	0	3	0	0	0	1	0	
1905	0	0	1	0	0	1	1	0	1	0	2	
1906	0	0	1	1	1	1	0	1	0	0	0	
1907	0	2	1	1	0	0	1	1	0	0	0	
1908	1	2	1	1	0	0	0	0	1	1	1	
1909	1	0	1	0	1	0	1	0	0	0	0	
1910	0	2	1	2	2	2	0	0	0	0	0	
Total	7	9	6	8	6	10	4	5	2	3	4	

Chart No. 47 shows the seasonal prevalence of typhoid fever in Michigan City, an average for 10 years being taken. It is very irregular. The highest month is June, the next highest are December and February, and the lowest is September. This peculiar curve could only be explained by the existence of a contaminated water supply, considering the fact that the preponderance of winter and spring cases was consistent and in evidence every year. As a matter of fact the analyses made by Messrs. Barnard and Brewster amply proved this fact. Both the public supply and many private wells were found contaminated.

CONCLUSIONS.

1. The installation of a filter plant in Escanaba has had a striking result. In spite of poor efficiency at times, the general effect is manifest and the typhoid fever rate has been reduced from an average of 203 for the six years (1904 to 1909) preceding filtration to 61 for 1910, the first year after filtration was practiced. There was a coincident drop in the "enteritis" rate from an average of 213 for 10 years (1900–1909) to 123 in 1910. Although the filter efficiency left much to be desired, the customary "hump" in the typhoid curve for March, April, and May was eliminated in 1910 and the reduction in the yearly rate was really effected by the cutting off of this winter and spring typhoid.

The rate in Escanaba is still very high. Maintenance of good filter efficiency and the judicious use of hypochlorite at times as an adjuvant to filtration will probably reduce this rate somewhat. Imported cases have some influence on Escanaba's rate. Before really low rates may be expected in Escanaba, in addition to the

fe water supply much must be done to eliminate the insanitary rd privies and dangerous shallow wells.

2. The water supply of Menominee is exposed to sewage pollu- on and is delivered unfiltered and untreated. The typhoid fever evalence suggests water-borne infection.

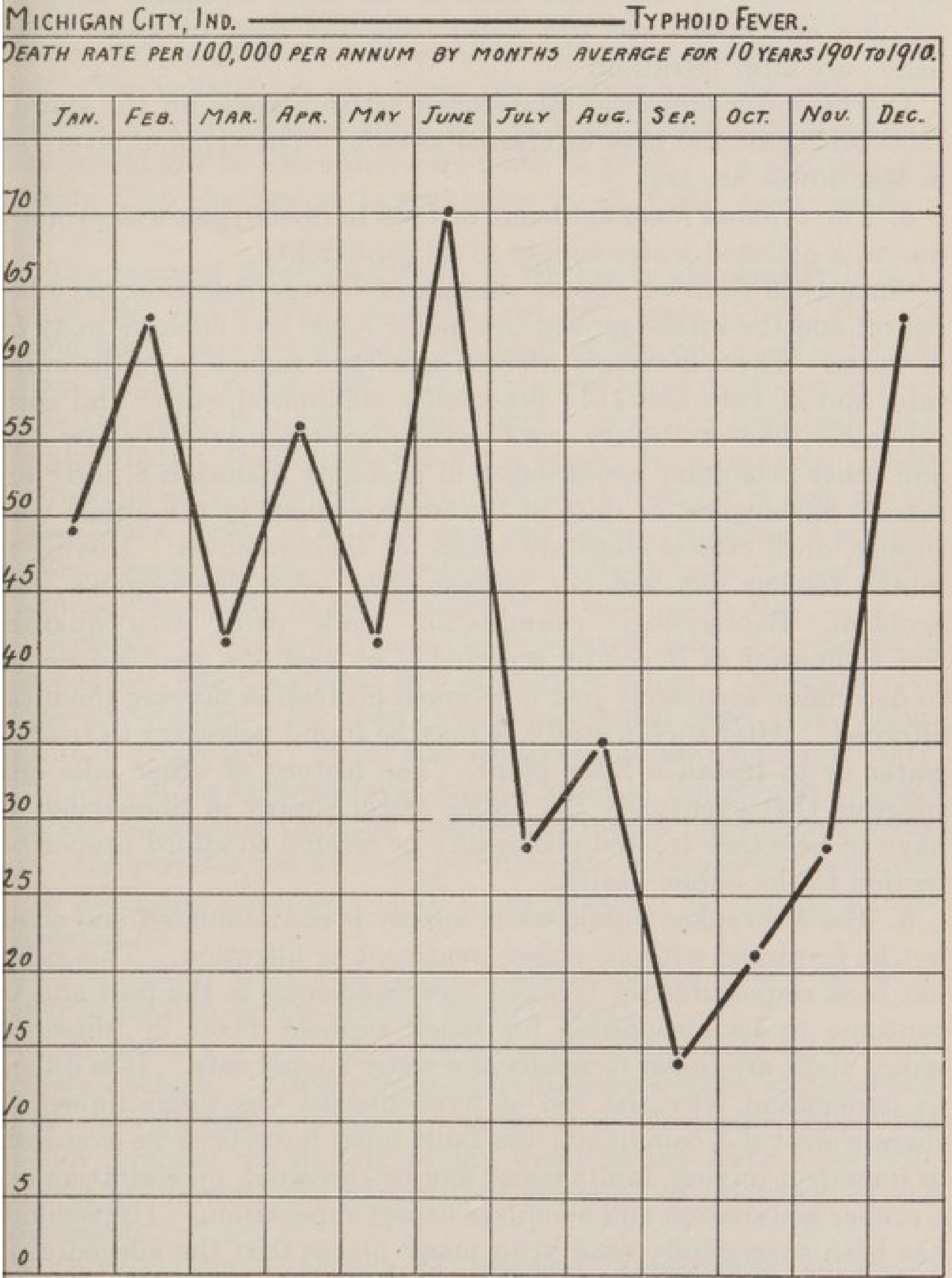


CHART 47.—Michigan City, Ind., showing seasonal prevalence of typhoid fever.

The Marinette water supply has a similar source to that of Menomi- e, but is filtered before delivery and the seasonal prevalence is dically different in the two cities. Menominee has the greatest evalence in December, January, and February, while Marinette's

greatest prevalence is in September. The water supply of Menominee should be rendered safe at once by the use of hypochlorite of lime pending decision as to the permanent method to be employed.

3. The Fox River and some of its tributaries are grossly polluted by sewage. Fortunately, the raw river water is not used as a water supply. Some of the cities and towns have adequate deep-well supplies and others use the water from the river or Lake Winnebago only after filtration.

4. The water supply of Manitowoc is from wells on the shore of Lake Michigan and may be classed as safe. The typhoid fever rates in Manitowoc are low.

5. The typhoid fever epidemic of 1908 in Sheboygan was primarily due to a polluted water supply in all probability.

Since 1908 the two nearest sources of sewage pollution have been cut off and the intake moved to a point 5,000 feet offshore in 47 feet of water. These measures effected a marked reduction in the annual rate, and in 1910 and 1911 practically eliminated winter and spring typhoid. The insanitary yard privies, contaminated shallow wells and other insanitary conditions will probably maintain a fairly high rate in Sheboygan, in spite of the improvement in the public water supply, until radical steps are taken for their removal. Moving the intake farther out will not permanently solve Sheboygan's water problem. Bacteriologic examination made daily with quantitative estimation of *B. coli* for a period of at least one year is necessary to determine accurately just how much protection moving the intake afforded. After such a study, it may be found necessary to treat the water or to install a filter plant. The history of other lake cities suggests that eventually the public water supply of Sheboygan will have to be either treated chemically or filtered to afford proper protection to the public health.

6. The Milwaukee public water supply is contaminated and should not be furnished without either treatment or filtration. This supply has been responsible for typhoid fever epidemics in the past and will continue to be responsible for much typhoid fever in Milwaukee unless steps are taken to render the water supply safe. It is difficult to understand why the use of hypochlorite was discontinued. If there were valid complaints the fault must have been in overdosing or imperfect mixing, faults which can be corrected, necessitating only a proper installation and adequate expert supervision. Hypochlorite has been successfully used in so many places that the alleged drawbacks no longer discourage its use, and simply suggest more care in manipulation. Milwaukee needs the safeguard of treatment or filtration at once. The installation of the comprehensive sewage-disposal system recommended by Mr. Whipple, Mr. Alvord, and Mr.

ddy will require a great deal of time for completion and when com-
ete will not render the water supply safe. The system recommended
ill accomplish its purpose of sewage disposal in an admirable man-
er. It will also, when completed, improve the quality of the raw
ater at the intake, but is not a substitute for filtration or treatment of
e water supply. Filtration of Milwaukee's water supply would
tail a very large annual expenditure after the installation of the
ant. The installation of a plant for treating properly with hypo-
lorite of lime would cost much less, and the annual cost of mainte-
nce would not be more than one-tenth as much. In addition it is
obable that the use of hypochlorite would fulfill every sanitary
dication.

7. The typhoid fever death rate in Racine is abnormally high in
e first half of the year. For the past four years (1908–1911) the
phoid death rate per 100,000 has been at the rate of 31.5 for the
st six months of the year. This rate compared to the rate from
ly to December is excessive, and, being consistently high each year,
ggests strongly that a polluted water supply is responsible. Daily
cteriologic tests, especially the quantitative tests for B. coli, should
made for a period of at least one year before rendering a positive
inion. Pending such an investigation hypochlorite of lime might
applied, especially in the months from October to May.

8. Kenosha differs from Racine in two particulars; the amount of
wage is less, and the stream flow of its river is less. Otherwise con-
tions are similar. The two points mentioned give a precarious
easure of protection. So far Kenosha seems to have been fortunate,
the bulk of its typhoid fever has occurred in the regular typhoid
eason," suggesting that the waterworks intake has escaped pollu-
n. The possibilities for such pollution are here present, however,
d to make the water safe at all times filtration or treatment must
resorted to.

9. Waukegan's water supply is contaminated and should be either
ered or treated before delivery to consumers.

10. Evanston's water supply is contaminated, according to Prof.
rtow's analysis. The diversion of Evanston's sewage, as projected,
ll not only furnish a better raw water at the Evanston intake but
ll also improve the quality of the water at the Lake View crib.
is will not obviate the necessity of filtration or treatment of the
ter supply.

11. Chicago has a history of frequent water-borne outbreaks
evious to 1893. From 1893 to 1899 the rates were lower, but aver-
ed 35.9 per 100,000. The diversion of the sewage from the lake to
drainage canal is probably responsible for much of the great reduc-
n effected since 1899. Water-borne epidemics probably occurred

in 1901, 1902, and 1903, but since the completion of the interceptors and the increased sewage diversion from the lake, the rates have been low. In 1910 Chicago ranked among the 10 large American cities having the lowest typhoid fever rates, with a rate of 13.7. Yet with this low rate the seasonal distribution is peculiar and distinctly different from the seasonal distribution of cities with safe water supplies. The winter and spring typhoid rates for the past decade are relatively high in Chicago, compared with cities which have approximately the same yearly typhoid rate, but which have safe water supplies.

Chicago's water supply is known to be polluted at times, not only at the Sixty-eighth Street crib, which is nearest the Calumet River and the Lake View crib, which is exposed to Evanston's sewage, but at the intervening intakes pollution is shown by bacteriologic examination to be a frequent occurrence. The diversion of Evanston's sewage, and other sources of pollution north of Chicago in Illinois will not make the water at the Lake View crib safe without treatment. The construction of the Calumet Sag Canal and the Calumet interceptors will improve the quality of the raw water, especially at the Sixty-eighth Street crib, but in times of high water in the Calumet even after the project is completed, when the stream flow exceeds 2,000 cubic feet per second, the Calumet will discharge its polluted water into the lake.

At such times the storm-water overflows of the sewers will reach the river direct. Even after Chicago's complete comprehensive plans for future sewage disposal are carried out, the zone of polluted water along this populous shore will be wide and its boundaries subject to much variation because of winds and currents. These conditions will make advisable treatment or filtration of the water supply even after the complete sewage disposal plans are consummated.

At present the need for treatment of the water supply is more pressing. The treatment of such a large supply as that of Chicago can be effected most economically by the use of hypochlorite of lime, and this method properly applied will render the water supply safe.

12. There is ample evidence to show that no waterworks intake is safe from pollution at all times in the southern end of Lake Michigan from the Calumet River to Michigan City, Ind.

The quality of the water will be improved by the construction of the Calumet Sag Canal and the Calumet River intercepting sewers; also by the partial purification of some other sewage contributions to the lake; but these measures will not render safe the water in southern Lake Michigan at the points where intakes are placed, nor remove the necessity of filtration or treatment. Accordingly, for the prompt protection of the public health, East Chicago, Hammond, Whiting,

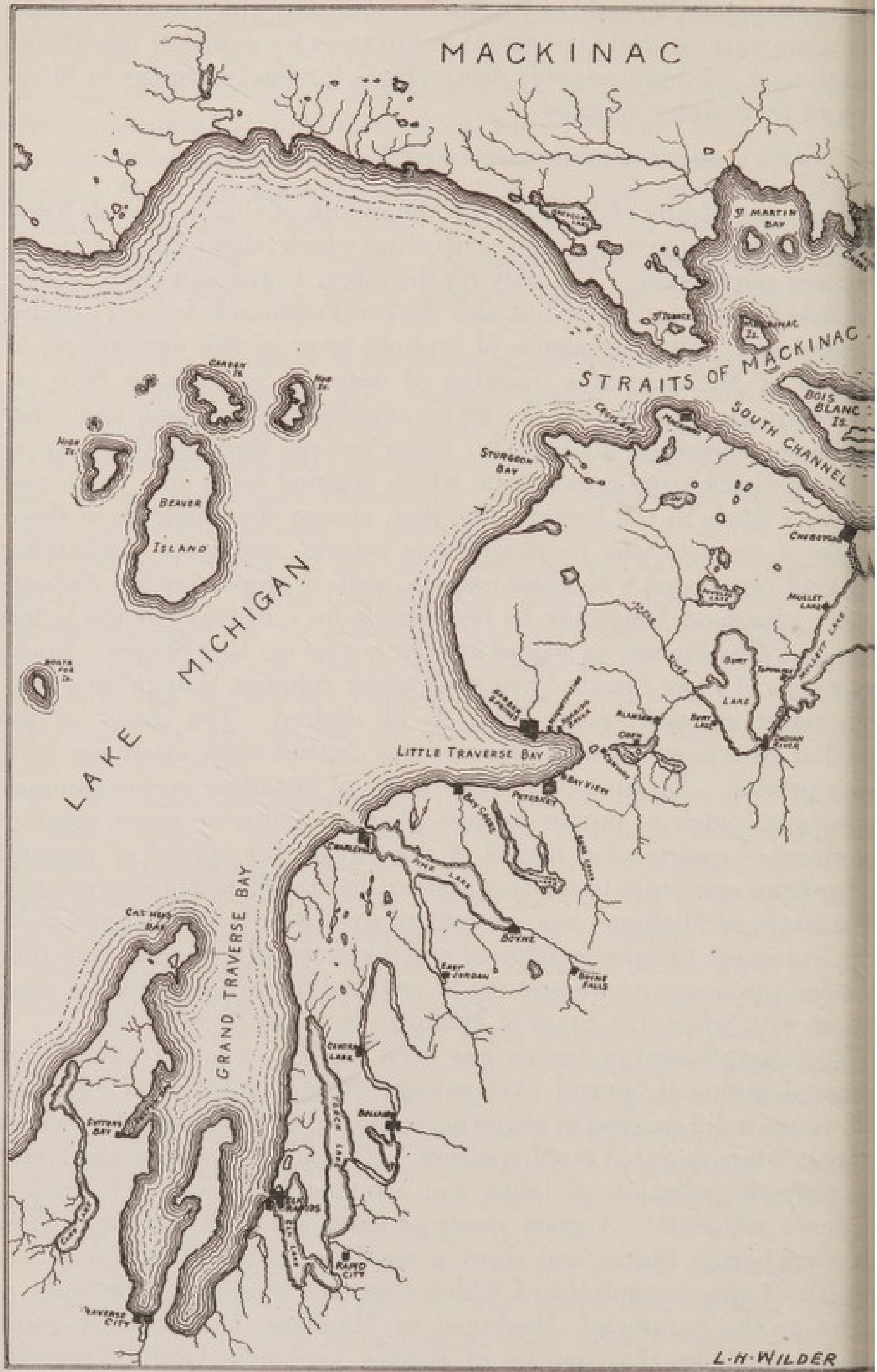
ry, Michigan City, and any other communities which are using Lake chigan water without treatment or filtration for domestic use, should tall with the least possible delay plants for the treatment or filtra-n of their water supplies.

THE EASTERN SHORE OF LAKE MICHIGAN.

From the Straits of Mackinac to the mouth of the St. Joseph River coast of Michigan is dotted with cities which have a large transient mmer population. Not only do the larger towns and cities attract rists in large numbers, but also the rural communities and isolated mhouses. The prevalence of typhoid fever in this summer-resort tion of Michigan is a question of immense importance from an erstate standpoint. If the water supplies are polluted, and other itary necessities inadequate, these resorts through the tourists come distributing points from which typhoid fever may be carried every State in the Union. Further, among the hundreds of thou-ds of tourists who frequent these resorts, many are discharging phoid organisms with their excreta, and, if proper sewage disposal not practiced, they may be responsible for outbreaks at the hotels d boarding houses, as well as at their homes in other States. Luck- many of these resorts have good water supplies, though, as a rule, sewer systems leave much to be desired. Too many of the aller resorts and isolated farmhouses depend upon insanitary out-or privies. The enormous importance of installing proper sanitary cessities, such as proper sewage disposal and pure water supplies summer resorts as a means of preventing the spread of typhoid er from one State to another has not been sufficiently appreciated. e State of Michigan has no control over incorporated municipali-s in respect to sewage disposal and water supply, and the fact that conditions are no worse must be credited to the abundance of good ter with which the State of Michigan is naturally provided.

The State board of health has been unable so far to have a law acted giving it control over sewage disposal and water supplies. wever, it did succeed in acquiring control over summer resorts which re not incorporated municipalities. This law will enable the board prevent pollution of lakes and streams by excreta of careless mmer residents. A great many of these are from the large cities neighboring States and show a reckless, selfish disregard of the alth of the community of which they are temporary residents.

From the Straits of Mackinac to Manistee, the summer-resort tion, includes the counties of Benzie, Leelanaw, Grand Traverse, trim, Charlevoix, Emmett, and Cheboygan. Thousands of sum-r visitors from every State in the Union fill these resorts to over-wing from June to September. Worthy of consideration in this



Map 18.—Summer-resort section from Mackinac Island to Traverse City, Mich.

thern summer-resort area of Michigan are the following cities
villages:

City or village.	Normal winter population.	City or village.	Normal winter population.
inac Island	714	East Jordan	2,516
oygan	6,859	Elk Rapids	1,613
or Springs	1,805	Traverse City	12,115
key	4,778	Frankfort	1,555
evoix	2,420		

everal thousand visitors and excursionists spend vacations in
rural parts of these counties.

Typhoid fever prevalence.

Counties.	Average yearly number of deaths per 100,000 in the 18 years from 1891 to 1908, inclusive.
le	31.0
naw	19.4
d Traverse	28.9
im	28.0
levoix	21.7
iett	34.6
oygan	12.6

Excessive prevalence of typhoid is noted in Emmett, Benzie, ınd Traverse, and Antrim Counties. Charlevoix and Leelanaw below the average for the State, and Cheboygan has the low rate 12.6.

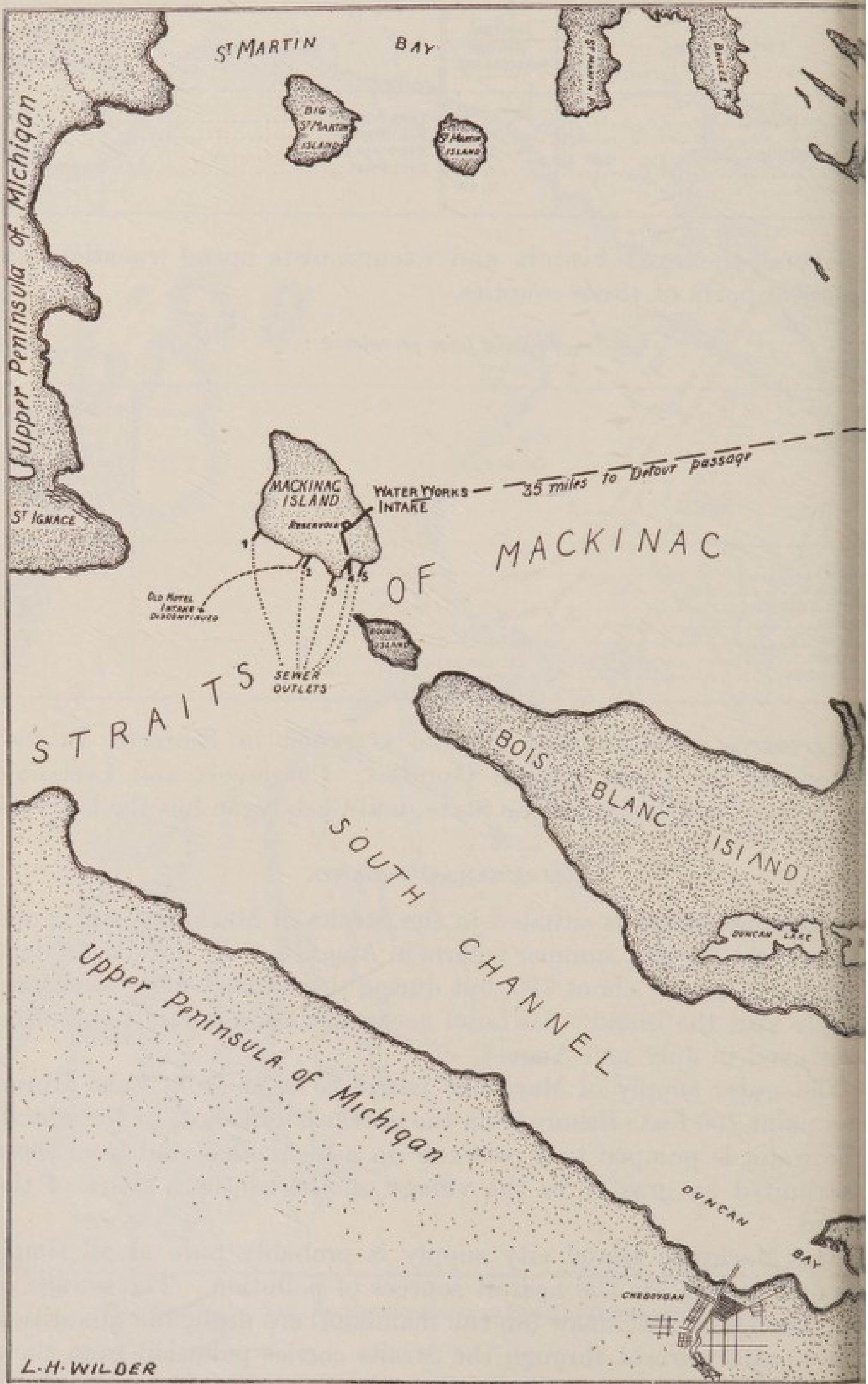
MACKINAC ISLAND.

Iackinac Island is situated in the Straits of Mackinac, and is one he most popular summer resorts in America. Its normal resident ulation is only about 700, but during the summer many thousand ple visit the island. Its hotel accommodation is large, and often rtaxed in July and August.

The water supply of Mackinac Island is taken from Lake Huron a point 700 feet offshore from the northeastern shore of the island. e water is pumped to a reservoir on a high ridge, and from there tributed by gravity to the village on the southern shore of the nd.

The Mackinac Island city supply is probably pure at all times. own sewers are the nearest sources of pollution. The sewage of Ignace and Mackinaw (on the mainland) are negligible quantities. e normal current through the Straits carries pollution from these rces from west to east, or through the south channel to Lake

Huron. A certain number of days each year the current in th
Straits is reversed and flows into Lake Michigan; at such times



MAP 19.—Mackinac Island, Mich., showing sewer outlets and waterworks intakes.

ıns strongly through the Straits south of Mackinac Island, carrying ıe pollution from Mackinac Island sewers with that of St. Ignace nd Mackinaw westward toward Lake Michigan. The pollution om Cheboygan River is picked up by the reverse current in the uth channel and carried northwest toward Lake Michigan. The ewage from Sault Ste. Marie, after passing the St. Marys River with ıe excellent sedimentation basin of Potaganissing Bay, enters Lake Iuron through Detour passage. From here the distance to the Iackinac Island intake is 37 miles, and the water is very deep.

There is usually no current westward, but occasionally there is a everse current in the Straits at Mackinac, which would be coinci-ent with a rather slow movement of the enormous volume of water ı northern Lake Huron toward the west. This movement, increasing a current as it converges and narrows at the Strait, even if it arried pollution, would carry it through the Straits south of Mackinac sland and not northward over the intake. The sewers of Mackinac sland discharge by five outlets on the south shore of the island.

As indicated above, the pollution does not extend to the water-orks intake because of the currents through the Strait. The ffect of the pollution on distant cities is negligible, because of the reat mass of water for dilution and the distance to the nearest city sing lake water. From an interstate standpoint it is a fortunate ircumstance that Mackinac Island's public water supply is uncon-aminated.

Mackinac Island is remarkably free from typhoid fever. One of he large hotels formerly had an independent water supply. In ugust,. 1908, the annual convention of State and National Food nd Dairy Departments met at Mackinac Island. Most of the articipants stopped at this hotel and were stricken with the form of iarrheal illness commonly called "winter cholera." An investiga-ion showed that the water used was drawn from the Straits at a oint in close proximity to the sewer outfall of the hotel and that he water supply was contaminated at this time. The hotel manage-nent after considerable discussion discontinued their intake and nade connection with the city supply, which is safe for reasons de-cribed above.

CHEBOYGAN.

Cheboygan has a population of about 7,000 persons. In the ummer this is considerably increased by summer visitors. The vater supply is from artesian wells and is pure; less than 10 per cent f the population use water from shallow wells. About 30 to 40 er cent still depend upon outdoor privies. The sewers discharge y more than 20 outlets into Cheboygan River and the Straits of Mackinac. There is no treatment of the sewage before discharge.

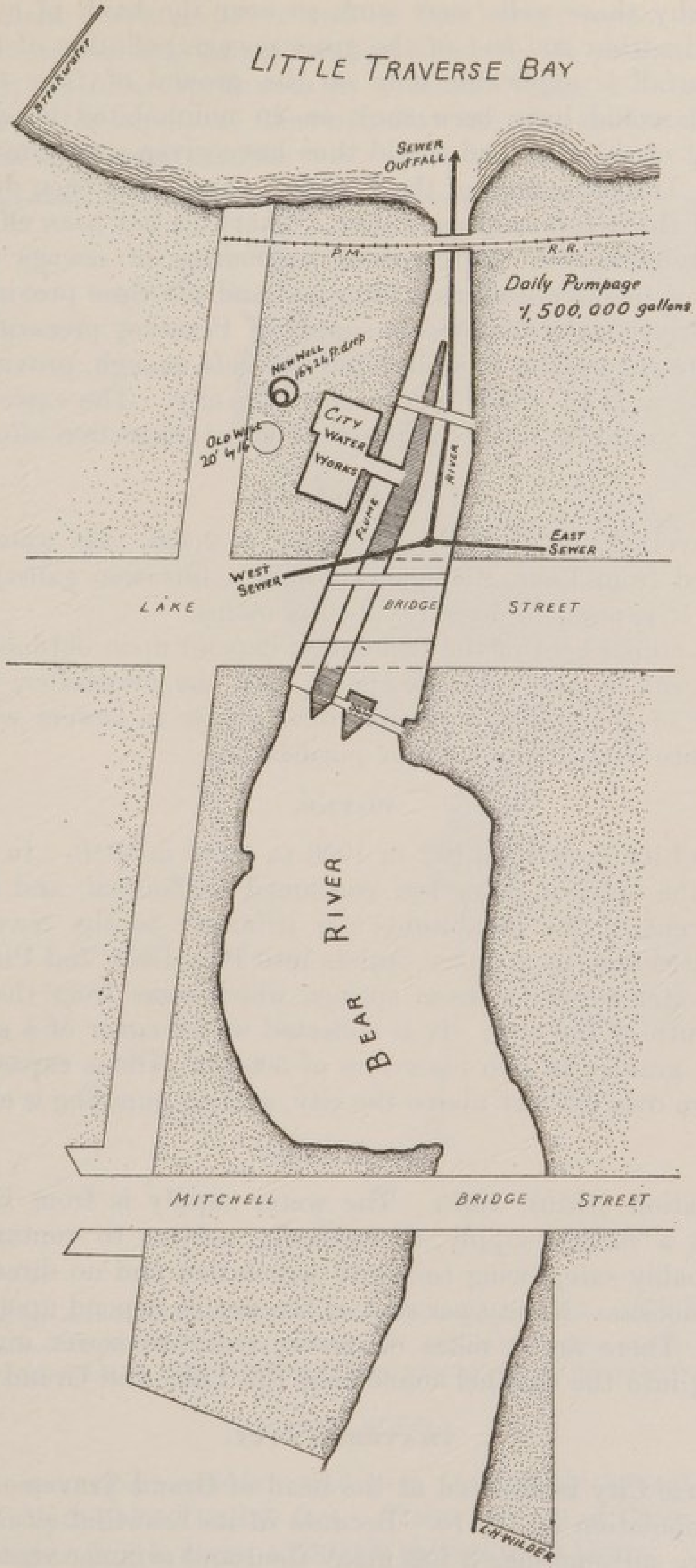
Typhoid fever rates in Cheboygan are very low. Only 10 deaths from typhoid fever have been recorded in Cheboygan in the past 11 years. Between Cheboygan and Harbor Springs there is a continuous belt of artesian water supply. This belt lies along what is known as the "inland lake route" between Cheboygan and the resorts on Little Traverse Bay. This bountiful supply of pure water is a great protection to the many visitors to Cheboygan, Mullet Lake, Topinabee, Indian River, Burt Lake, Alanson, Oden, and Conway.

HARBOR SPRINGS.

This resort is situated on the north shore of Little Traverse Bay and has a normal resident population of about 1,800, with a much larger summer population. The water supply is from flowing wells, and is excellent from a sanitary standpoint. The flowing well district of Harbor Springs extends along the beach to Wequetonsing, and there are dozens of artesian wells in this small area. They range from 26 to 320 feet in depth. Five of the waterworks wells are from 66 to 88 feet deep, three are 100 feet deep, and one 320 feet deep. One-half the permanent population depends upon outdoor privies. The other half and the total hotel population of Harbor Springs depend upon sewers which discharge into Little Traverse Bay, without treatment of the sewage.

PETOSKEY.

Petoskey has a population of 4,778, and is beautifully situated on Little Traverse Bay. It has good hotel accommodations and a large summer population. As shown on map 20, the entire sewage of Petoskey is carried by two sewers (the east and west sewers) to the bed of Bear River below the dam. Here the two sewers unite and are carried in the bed of the river about 200 feet to the bay. The city waterworks is situated on the shore of Bear River just below the junction of the east and west sewers. The power for the works is derived from Bear River, supplemented by coal when necessary. The water supply is drawn from a well 20 feet deep and 14 feet in diameter. The level of the water in this well is said to bear a constant relation to the lake level and to bear no relation to the level of the water in Bear River. This well is about 140 feet from the nearest point on the lake shore and about 200 feet from the outfall of the main sewer of the city. The supply from this well, especially in summer, is at times inadequate, and water has been pumped direct from Bear River into the mains. To remedy this shortage a new well near the old one was being dug (July, 1911), 24 feet deep and 16 feet in diameter, about 25 feet nearer the lake than the old well



MAP 20.—Petoskey, Mich., showing sewer outfall and waterworks system.

Just why these wells were sunk so near the bank of a polluted river and within 200 feet of the gross sewage pollution of the main sewer outfall is explicable only on the ground of false economy. The wells could have been sunk on an uninhabited beach a half mile west of the city, and would thus have given a very much safer supply. The protection of the Petoskey supply has been due to the action of the beach sand as a filter. That this has been effective so far is probable, but the constant outpouring of sewage within a few feet of the area used as a filter bed and the close proximity of a polluted river make the present supply of Petoskey precarious.

The present system of wells would be safe enough, provided wells were sunk at least a half mile west of the city. The extra expense of piping would be small compared with the protection afforded the public.

CHARLEVOIX.

Charlevoix has a resident population of 2,420. Its water supply is derived from Lake Michigan through a filtration gallery on the beach. It is pumped directly into the mains.

About 80 per cent of the population depend upon outdoor privies; 10 per cent depend upon cesspools, and the remainder, with the majority of the summer visitors, have access to sewers which discharge into Pine River without purification.

BOYNE.

Boyne City grew from 912 in 1900 to 5,218 in 1910. In its rapid growth the outdoor privy has continued to flourish, and less than 10 per cent of the inhabitants are tributary to the sewers. The sewers discharge by a dozen outlets into Pine Lake and Pine River.

The water supply is from springs which issue from the base of a hill south of the city. It is collected under cover of a shed, and flows by gravity to two reservoirs of 500,000 gallons capacity each. These are over 60 feet above the city, and no pumping is employed.

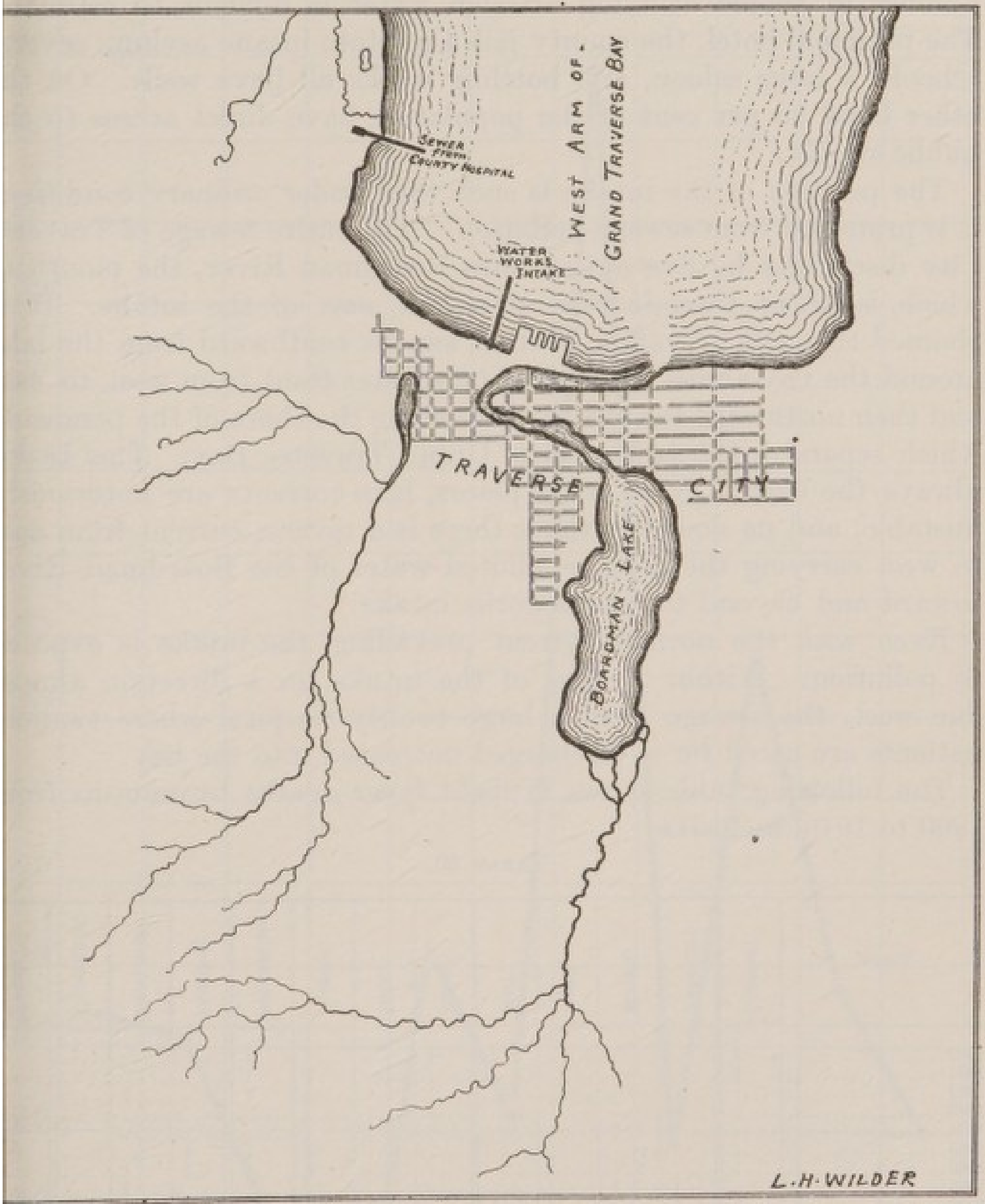
ELK RAPIDS.

Population (1910), 1,673. The water supply is from Elk Lake, which is a surface supply, theoretically, subject to contamination, but probably safe, owing to sparse population and no direct sewage contamination. Ninety per cent of the people depend upon outdoor privies. There are 2 miles of sewers and two sewer outlets discharging into the channel connecting Elk Lake and Grand Traverse Bay.

TRAVERSE CITY.

Traverse City is situated at the head of Grand Traverse Bay and has a population of 12,115. Because of its beautiful situation and attractive surroundings it has many thousand summer visitors. The

evelopment of water power and its fine harbor render probable a teady industrial and commercial growth. In its present condition nd with its future prospects as a tourist resort it is imperative hat the water supply of Traverse City be safe, to prevent spread f disease in interstate traffic.



AP 21.—Traverse City, Mich. Note the position of the water-works intake in relation to the hospital sewer outfall, and to the mouth of Boardman River, which receives the entire sewage of the city.

WATER SUPPLY.

There is a small artesian well area in Farfield township, giving ows at depths of 50 to 400 feet. There are 190 of these wells, and he aggregate flow is about 1,500,000 gallons in 24 hours.

This would barely provide for the present population at 100 gallons per capita. There is evidence that this flow is decreasing, and engineers have expressed the opinion that a flowing well supply would be inadequate in time. The public supply is taken from Grand Traverse Bay and is supplied to 90 per cent of the inhabitants. The number of people drinking artesian water is difficult to estimate. The principal hotel, the county jail, the State insane asylum, several schools, a large saloon, and bottling works all have wells. On the other hand 90 per cent of the population have direct access to the public supply.

The position of the intake is such that under ordinary conditions it is protected from sewage pollution. The entire sewage of Traverse City discharges by five outlets into Boardman River, the mouth of which is about three-fourths of a mile east of the intake. It is claimed that the prevailing current sweeps southward from the lake around the bay across Traverse City's water front from west to east and then northward toward the lake along the shore of the peninsula which separates the two arms of Grand Traverse Bay. This is not always the case. As in other places, lake currents are notoriously unstable, and no doubt at times there is a reverse current from east to west carrying the sewage-polluted water of the Boardman River toward and beyond the waterworks intake.

Even with the normal current prevailing, the intake is exposed to pollution. Within 2 miles of the intake, in a direction almost due west, the sewage from a large county hospital where typhoid patients are cared for is discharged untreated into the bay.

The following table shows typhoid fever deaths by months from 1900 to 1910, inclusive:

TABLE 30.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1900	1					1			1				3
1901	1							1	1				3
1902									1		1		2
1903													0
1904			2					1				1	4
1905								1	1	1			3
1906								1	5	4	1		11
1907		1	1								1		3
1908	1	1			1				1		2	1	7
1909			1			1	1			1			4
1910		1										2	3
Total by months.	3	3	4	0	1	2	1	4	10	6	5	4	......

Chart No. 48 shows the excessive prevalence of typhoid fever during certain years in Traverse City. The worst year (1906) showed a seasonal prevalence in the autumn months. With the exception of this year of 1906 the figures show too many deaths from January to

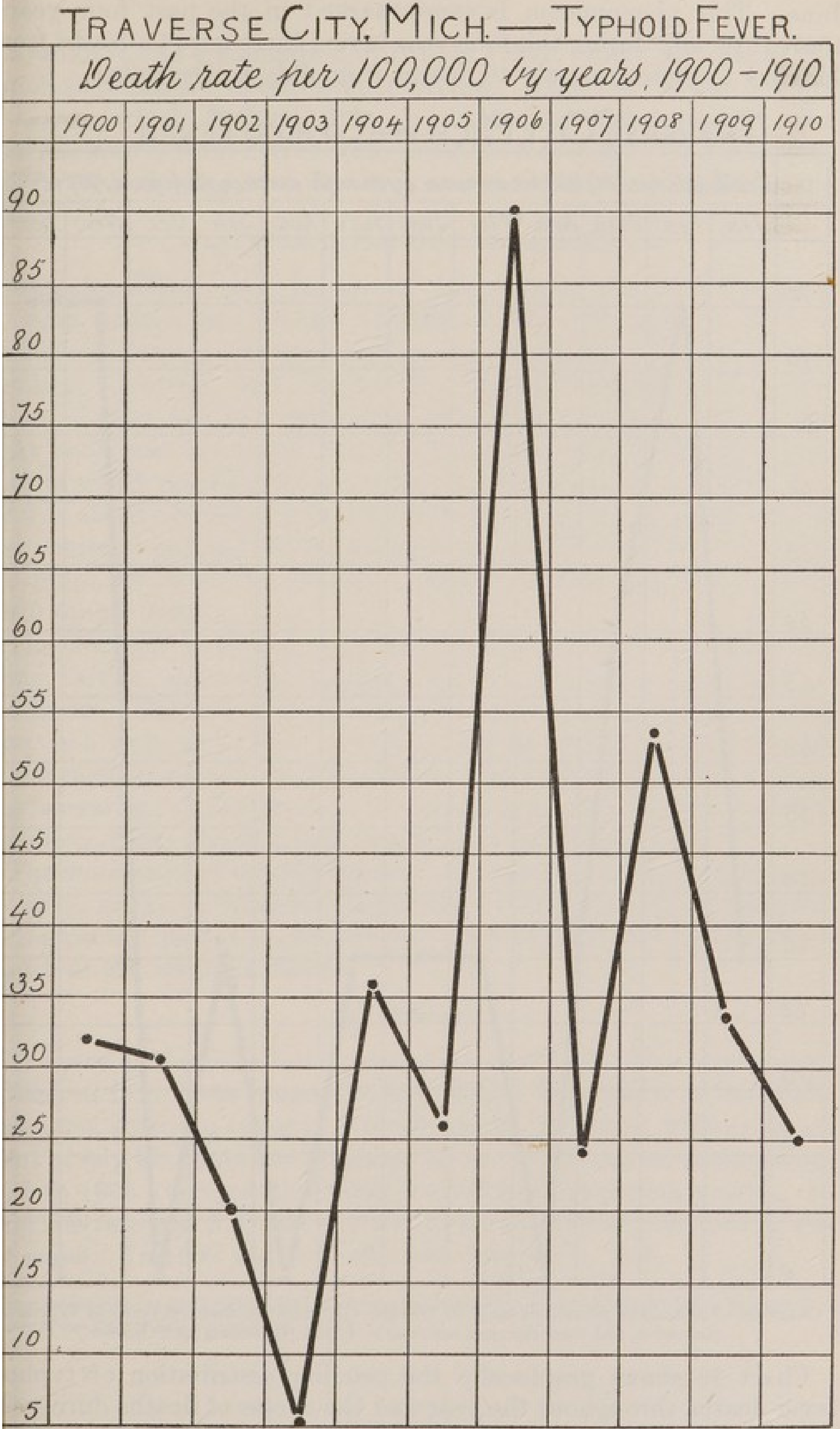


CHART 48.—Traverse City, Mich. Typhoid fever by years. A very irreguler curve with sudden marked fluctuations.

June. This phenomenon is more marked in the past four years, 1907–1910, and during this four-year period there were 11 deaths from January to June and only 10 deaths from July to December.

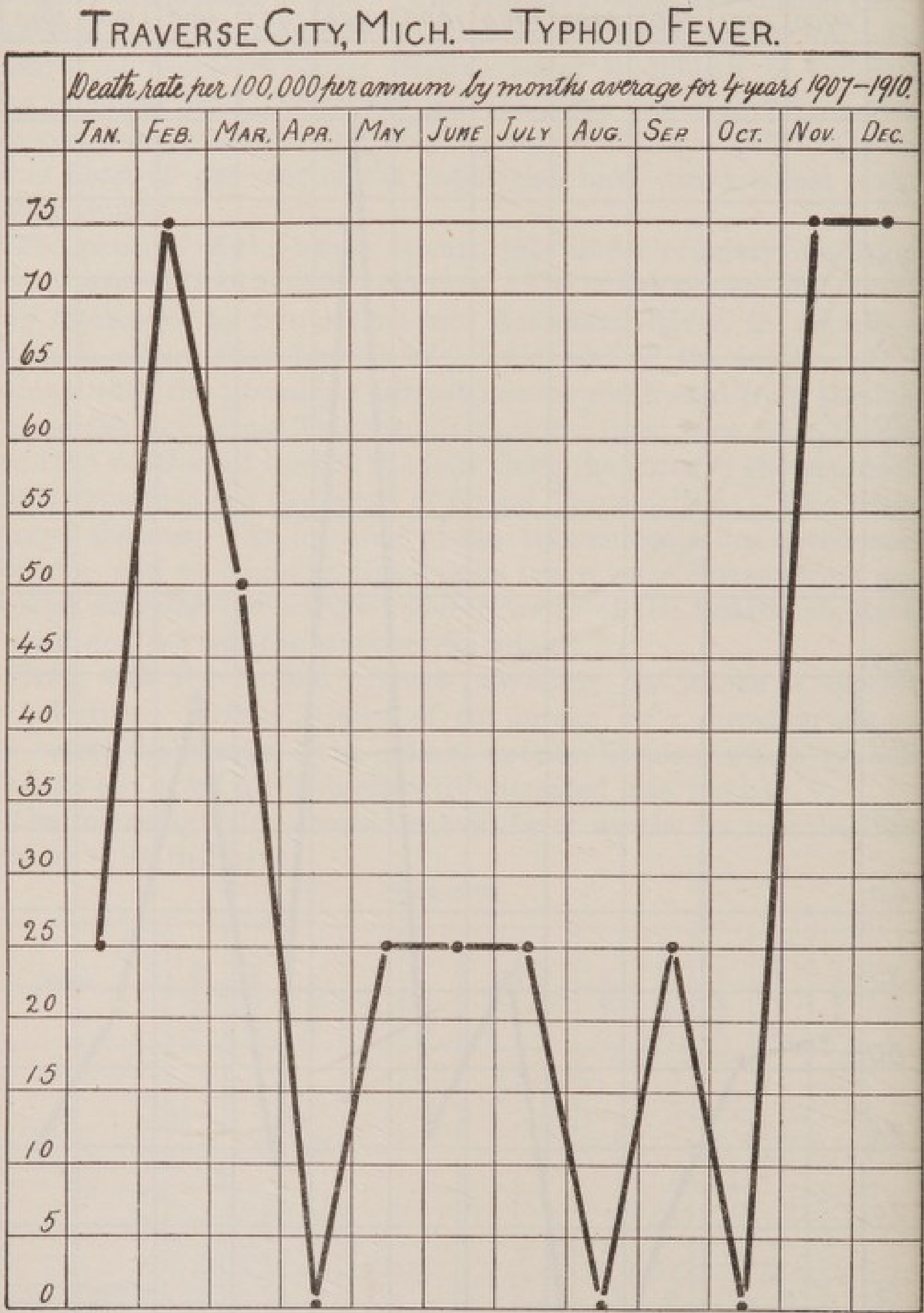


CHART 49.—The seasonal prevalence curve in Traverse City shows pronounced peaks in February, November, and December, and low rates in August, September, and October.

Chart 49 shows graphically the peculiar distribution of typhoid fever deaths throughout the year and the excess of deaths during the winter and spring months, suggesting the polluted water supply as the only logical explanation of the peculiarity.

FRANKFORT.

Frankfort had a population in 1910 of 1,555. Fifty per cent of the ›pulation depend upon outdoor privies. There are about 2 miles sewers, which discharge into the harbor by three outlets. The ater supply is from driven wells about 90 feet deep. The wells just ll short of flowing by a few feet and the water is pumped to the ains.

MANISTEE RIVER DRAINAGE BASIN.

Manistee River rises in several lakes along the boundary line tween Antrim and Otsego Counties in the north-central part of ichigan, flows southwestward across Kalkaska, Wexford, and anistee Counties, and empties into Lake Michigan at Manistee, ich. It has but two important tributaries, the Big Bear on the ght bank and the South Branch of the Manistee on the left bank, th of which enter in the lower part of the river. The length of the ver is about 110 miles, not taking into account the numerous bends d angles; but following its windings its total length must be about 0 miles, for it is very crooked. The total drainage area is about 120 square miles.[1]

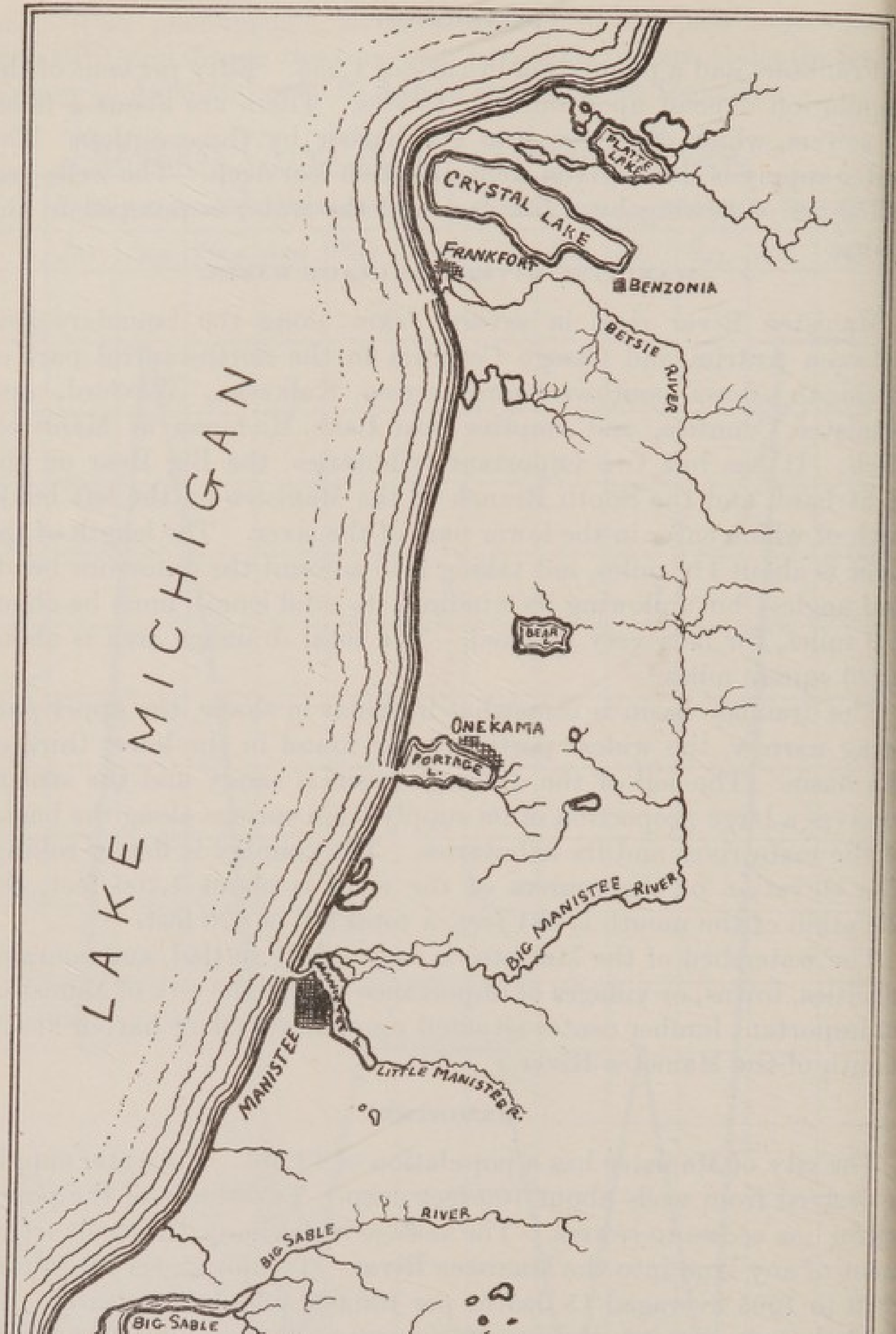
The drainage basin is somewhat irregular in shape, the upper part ing narrow, the widest portion being found in the lower third of e basin. The soil of the drainage basin is sandy and the stream ceives a large proportion of its supply from springs along the banks the main river and its tributaries. The country is flat or rolling. ie elevation of the sources of the river is about 1,200 feet, the evation of the mouth is 581 feet, a total fall of 620 feet.

The watershed of the Manistee is very thinly settled, and contains cities, towns, or villages of importance except the city of Manistee, important lumber center situated upon an excellent harbor at the outh of the Manistee River.

MANISTEE.

The city of Manistee has a population of 12,381. Its water supply derived from wells about 100 feet deep. Two-thirds of the population has access to sewers. The sewage is discharged without treatent of any kind into the Manistee River. Typhoid-fever rates from 89 to 1905 averaged 15 deaths per 100,000 population yearly. In 06 the rate was 8.4, but in 1907 it rose to 41.6, and in 1908 it was e same. In 1909 and 1910 the rate dropped to 16.6.

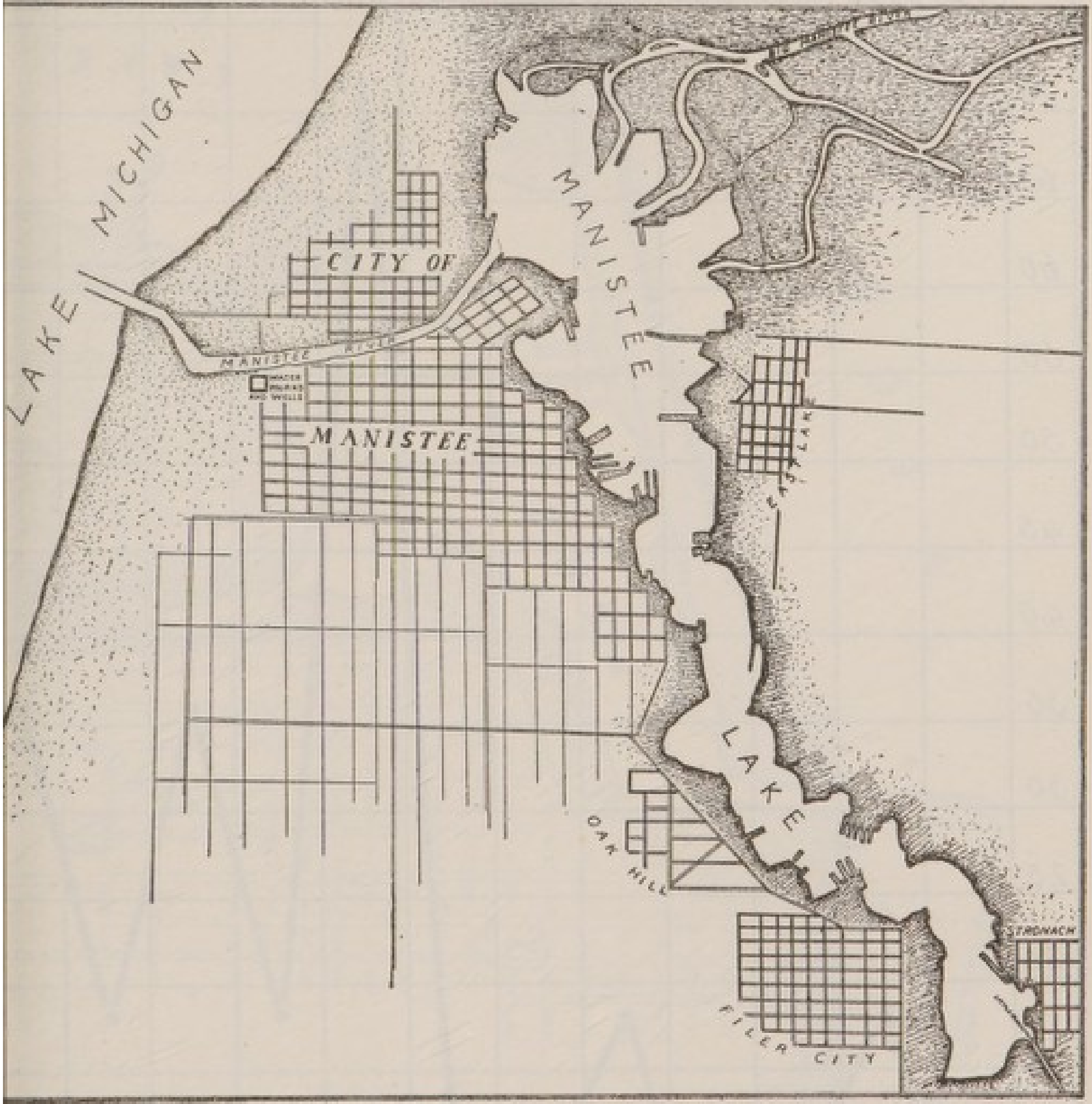
For descriptions of the drainage basins of rivers in Michigan the writer is indebted to the excellent orts of the United States Geological Survey.



MAP 22.—The Michigan shore of Lake Michigan from Crystal Lake to Ludington,

TABLE 31.—*Summary of typhoid fever in Manistee.*

	Deaths per 100,000.		Deaths per 100,000.
ar average, 1889–1905	15.0	1905	8.3
90	25.0	1906	8.4
91	8.3	1907	41.6
92	16.6	1908	41.6
93	8.3	1909	16.6
94	33.3	1910	16.6



P 23.—Manistee, Mich., showing the expansion of the river (Manistee Lake) and the position of the waterworks.

The increase of typhoid in 1907–8 occurred in each year from ugust to October. There are many insanitary privies and shallow ells in use in Manistee. Chart No. 50 shows the seasonal preva- nce of typhoid fever for 10 years. There is nothing in the chart to dicate pollution of the water supply. The supply is made up of ur units. Each unit consists of a well 30 feet in diameter and about feet deep, with which are connected 8-inch tubular wells which go wn 100 feet through sand and 10 feet of brick clay at the bottom.

The wells are located in the sand dunes south of the Manistee River and between the city and the lake. The character of the soil (sand) and the absence of near sources of pollution obviate the danger of surface contamination during rains, the wells being covered and

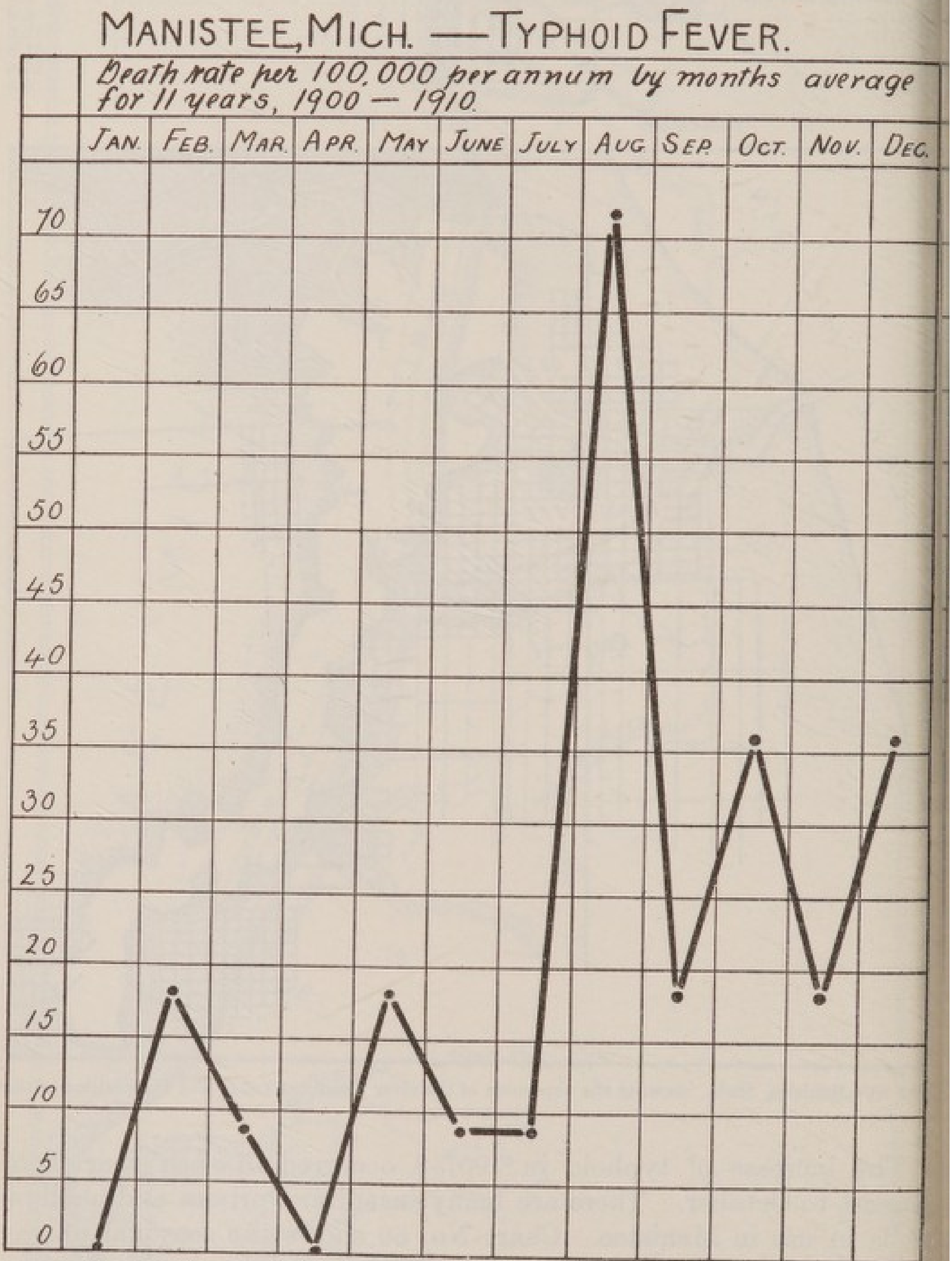
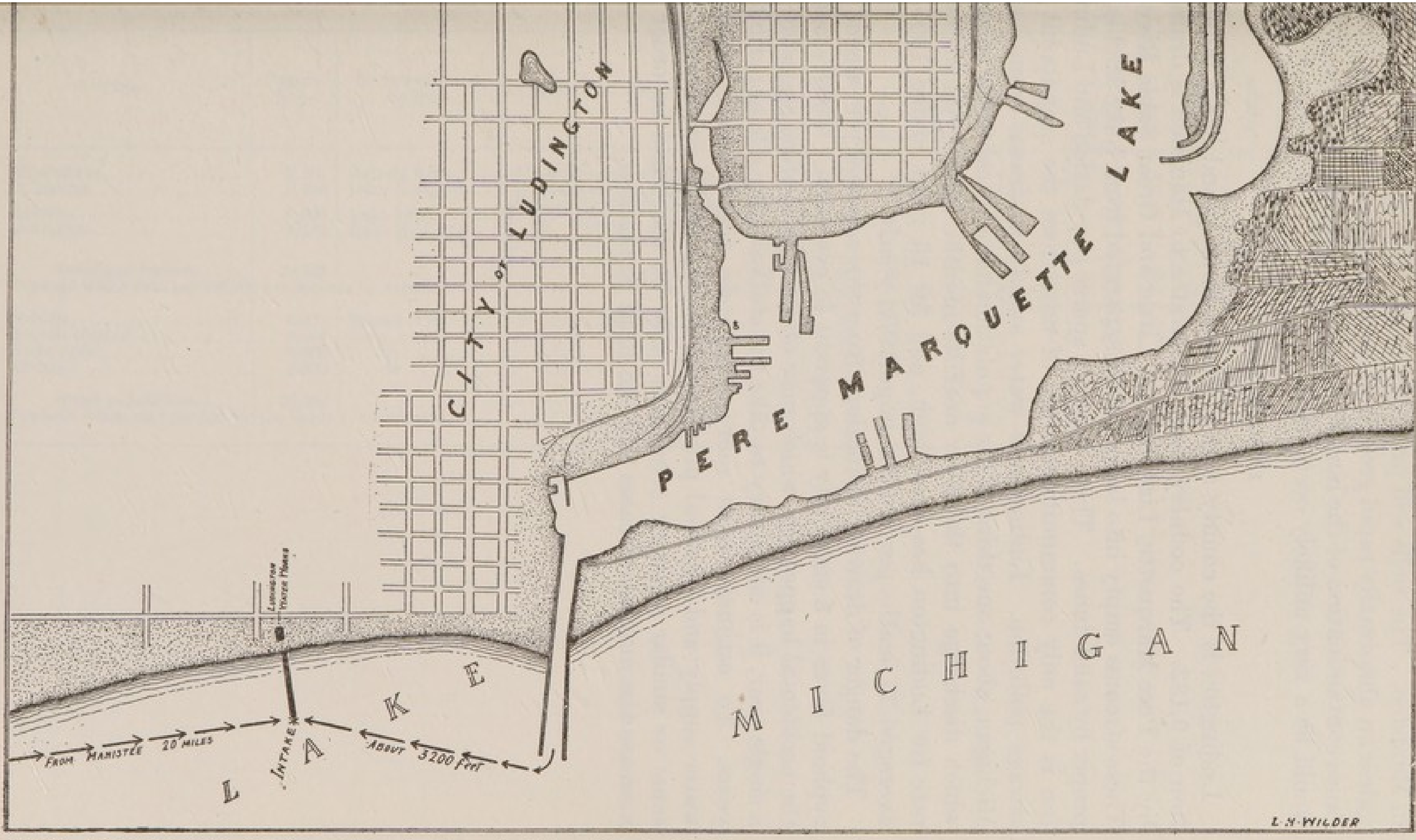


CHART 50.—The Manistee seasonal prevalence chart shows a low rate in the winter and spring months.

curbed above the ground surface. The small tubular wells go through an impervious stratum. The large central well of each unit is through sand, gravel, and bowlders. The supply may be con-



MAP 24.—Ludington, Mich., showing position of waterworks intake. Note the lake-like expansion of the Pere Marquette River, which receives the sewage of the city.

sidered safe and largely responsible for the low rate of typhoid fever in Manistee. The wells will probably continue to produce safe water, unless an abnormally rapid growth of the city toward the wells should cause contamination of the larger central well through seepage, which would be a very unlikely occurrence.

LUDINGTON.

Ludington is the county seat of Mason County and has a population of 9,132. The country from Pentwater to Manistee is drained by the Pere Marquette, Lincoln, and Little and Great Sable Rivers. These streams empty into lakes partly separated from Lake Michigan proper by sand dunes. There is a very sparse population and Ludington is the only community worthy of note from the standpoint of sewage pollution. Ludington's water supply is drawn from Lake Michigan, about one-third of the population have access to the sewers, which discharge into the river near its mouth. The typhoid-fever rate for Ludington has been high, and for 16 years ended 1905 it averaged 26 deaths per 100,000 population yearly.

The danger of drawing deductions from the seasonal prevalence of typhoid fever in a small city is apparent to everyone. To overcome the accidental happenings which may obscure or confuse statistics of a single year, it is customary to take the statistics for a long period of years. To estimate even more accurately the relation between water supply and seasonal prevalence, several small cities with the same or similar sanitary conditions may be combined in order to increase the number of cases and the total population.

Cities.	Population.	Source of water supply.	Character of water supply.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average yearly death rate per 100,000.
Wyandotte	8,287	Detroit River	Contaminated constantly	2	5	3	2	4	2	4	4	4	7	7	9	60.0
St. Joseph	5,936	Lake Michigan	Exposed to sewage pollution.	0	2	6	3	6	0	1	0	2	0	1	0	32.5
Monroe	6,893	Lake Erie	Sewage pollution modified by distance, sedimentation, and dilution.	1	1	1	1	0	0	0	2	1	1	1	0	12.3
Ludington	9,132	Lake Michigan		1	2	0	2	3	1	1	4	2	1	0	2	19.0
Total population	30,248			4	10	10	8	13	3	6	10	9	9	9	11	
Typhoid death rate per 100,000 per annum by months				14.4	36	36	28.8	46.8	10.8	21.6	36	32.2	32.2	32.2	39.6	
Cadillac	8,375	Inland lake	No urban pollution, fair.	1	2	0	0	1	2	2	3	9	5	7	2	38.6
Benton Harbor	9,185	Deep wells	Safe	1	1	1	1	2	0	0	2	2	4	3	1	18.0
Cheboygan	6,859	do	do	1	0	0	1	0	0	1	0	1	3	2	1	13.6
Albion	5,833	do	do	1	1	1	0	0	0	2	0	0	2	0	1	12.3
Total population	30,252			4	4	2	2	3	2	5	5	12	14	12	5	
Typhoid death rate per 100,000 per annum, by months				14.4	14.4	7.2	7.2	10.8	7.2	18.0	18.0	43.2	50.4	43.2	18.0	

Table No. 32 shows the deaths by months for a period of 11 years (1900–1910) in eight small Michigan cities of about the same size. The first group of four have water supplies subject to sewage pollution. Their typhoid rates are high in direct proportion to the degree of pollution. Wyandotte's pollution is constant applied to a rapidly flowing river. St. Joseph's pollution is less in amount but little

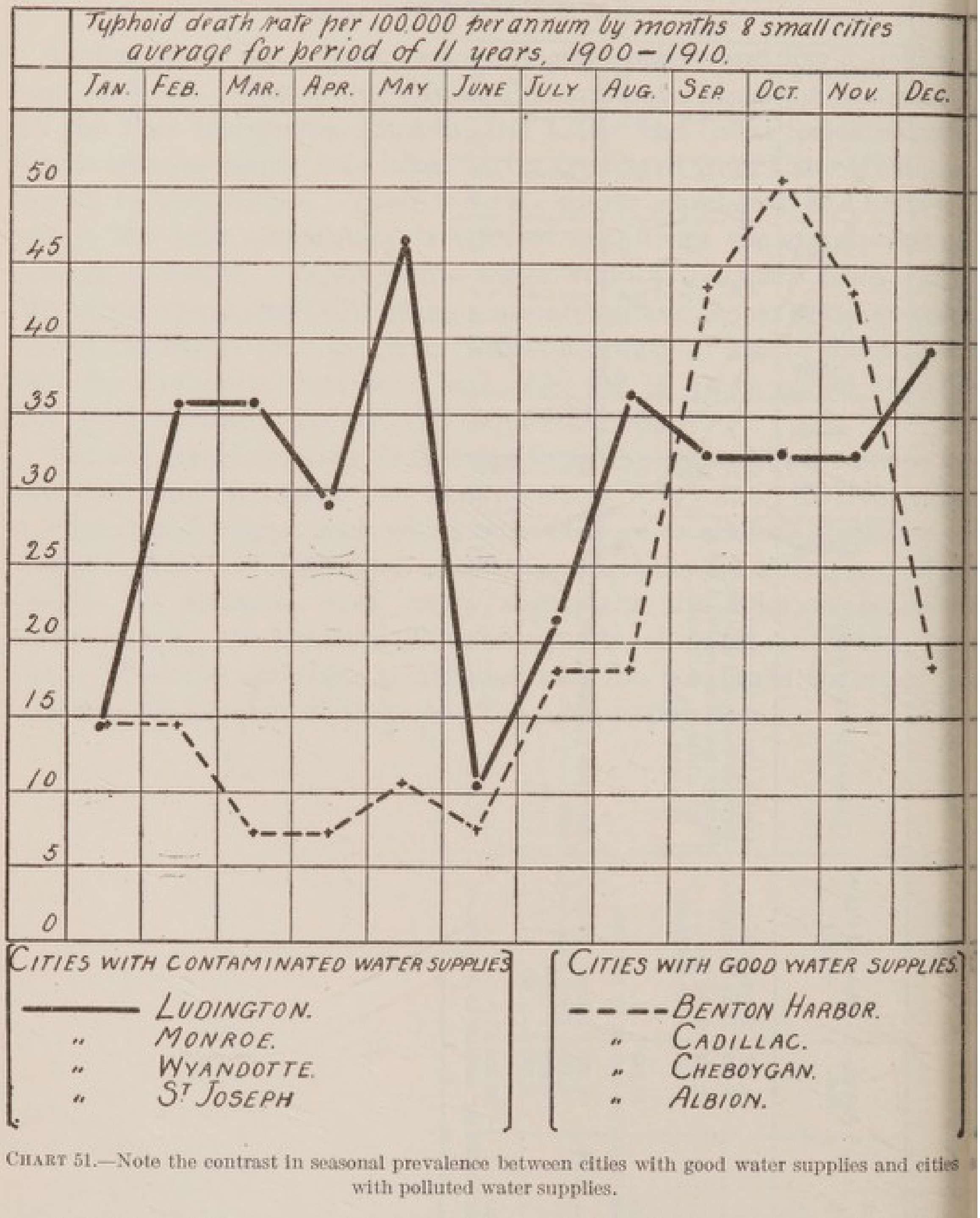


CHART 51.—Note the contrast in seasonal prevalence between cities with good water supplies and cities with polluted water supplies.

modified by distance or sedimentation, although there is considerable dilution. Ludington is exposed to intermittent sewage pollution from a smaller urban population than that of Benton Harbor and St. Joseph, and the sewage must first pass through Lake Marquette which acts as a sedimentation basin.

Monroe's supply is polluted, but it is protected by the great sedi-
nentation basin in the western end of Lake Erie. The distance from
Detroit is considerable and there is great dilution of Detroit sewage
by the time it reaches Monroe.

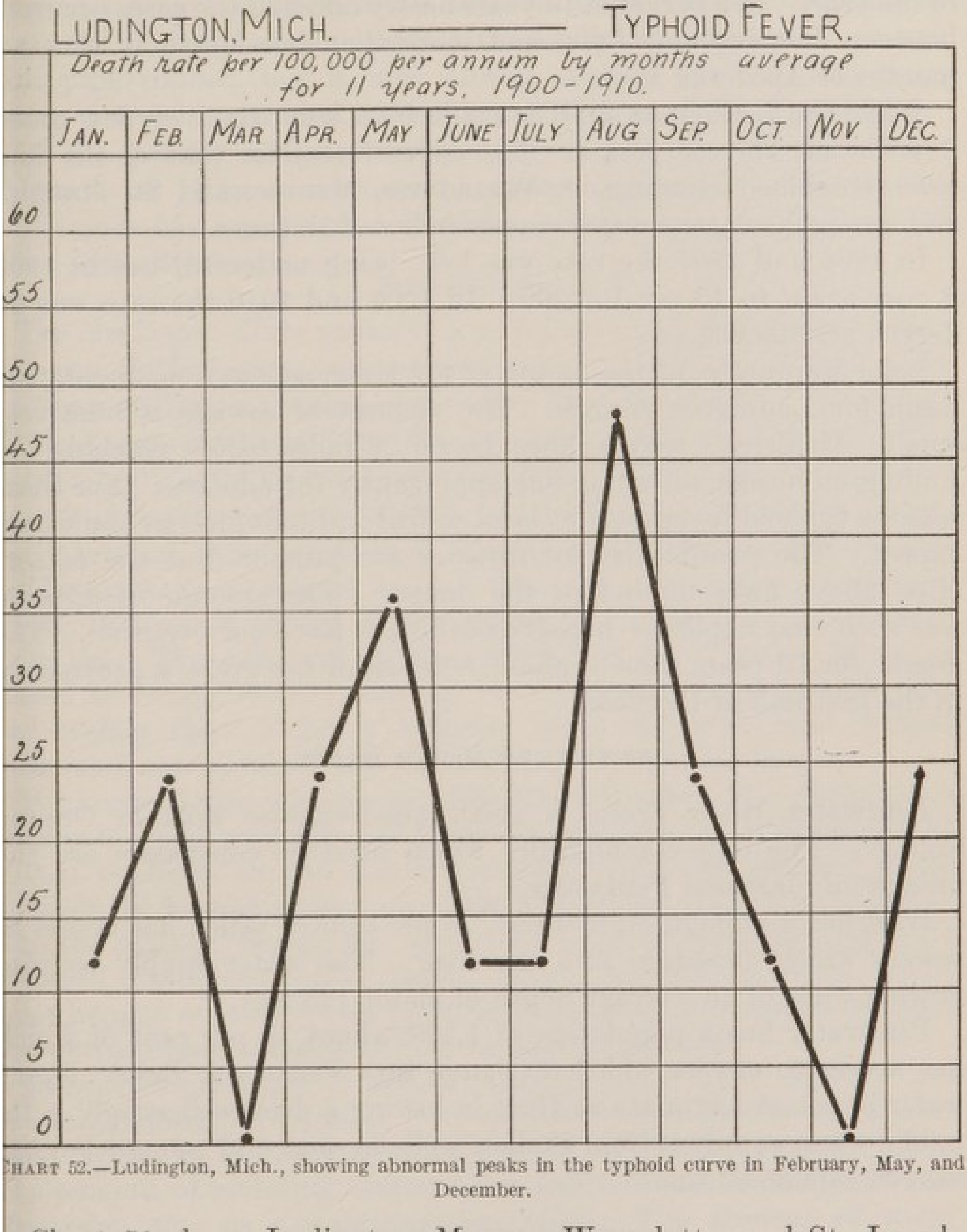


CHART 52.—Ludington, Mich., showing abnormal peaks in the typhoid curve in February, May, and December.

Chart 51 shows Ludington, Monroe, Wyandotte, and St. Joseph, four cities furnishing unfiltered water known to be contaminated or subject to sewage pollution, compared with Benton Harbor, Cadillac, Cheboygan, and Albion, cities with good water supplies.

The population of these two groups is almost the same, a little over 30,000 each.

The water supply of Benton Harbor, Cheyboygan, and Albion is from deep wells. The Cadillac supply is from an inland lake which is not exposed to urban pollution, and furnishes a fairly safe water.

Ludington shows too many cases of typhoid fever in the first half of the year. In a period of 10 years nearly one-half the cases occurred between January and June, and more than one-fourth in the two months of April and May.

While the Ludington chart is made from comparatively few cases, it is for an 11-year period. The curve resembles that of the four cities combined (Ludington, Wyandotte, Monroe, and St. Joseph), and strongly suggests water supply polluted at times.

In 1906 and 1907 the rate was low, being under 13, but in 1908 it rose again to 45 per 100,000. In 1909 and 1910 the rate was 22 deaths per 100,000.

Lake Marquette, at the mouth of the river, acts as a sedimentation basin for Ludington sewage. The amount of sewage is relatively small. Manistee's sewage must travel 20 miles before reaching the Ludington intake, affording fine opportunity for dilution. For these reasons typhoid fever has not been so bad in Ludington as one would expect. The possibilities for disaster are present, but the factors cited above have minimized the danger. The amount of dilution was such that explosive massive outbreaks have not occurred. The deaths for 10 years from typhoid fever show too great a prevalence in the first half of the year.

PENTWATER RIVER BASIN.

Pentwater River drains a small quadrangular area in Oceana County. The only communities which need be considered are the villages of Hart and Pentwater.

Hart has a population of 1,555, 75 per cent of which has access to sewers which discharge into the river. The water supply is from flowing wells of an average depth of about 125 feet.

Pentwater has a population of 1,129, about 10 per cent of which has access to sewers which discharge into Pentwater Lake. Pentwater is not so fortunate as Hart in having a deep-well supply. Its public water supply is from shallow wells in sand and can not be considered safe at all times.

WHITE RIVER BASIN.

White River drains a small area in Oceana, Muskegon, and Newaygo Counties. The rural population is small, and there are no towns or cities on the watershed. Whitehall, a village of 1,400 persons, has sewers to which a population of about 150 is tributary; the discharge is into White River near its mouth

MUSKEGON RIVER BASIN.

Muskegon River drains an area 2,663 square miles in extent, lying rectly north of the Grand River Basin. Its headwaters rise in the rth-central part of the southern peninsula of Michigan, whence it ws in a general southwesterly direction until it enters Lake Michin near the city of Muskegon. Originally its basin was covered ith pine timber, but is now almost entirely cleared, and large ump-covered areas form a conspicuous feature of the topography.

On the sparsely settled watershed of the Muskegon River there are towns or cities of importance except Muskegon at its mouth. ig Rapids has a population of about 4,500, but is situated over 50 iles above Muskegon.

MUSKEGON.

The Muskegon River expands near its mouth into Muskegon Lake. he city of Muskegon, with a population of 24,000, is situated upon e shore of this expansion of the river near its mouth. The sewers Muskegon discharge into the Muskegon Lake and River. The ater supply is taken from Lake Michigan. There are two intakes. ne 24-inch pipe extends 900 feet from shore and is called an emerncy intake. Another 30-inch pipe extends 3,970 feet offshore, and e intake is in 45 feet of water. The first or emergency intake is eatly hampered by ice in the winter and is in the line of shore llution. The principal intake, 3,970 feet from shore, is better aced to escape shore pollution, but in November, 1911, the pipe as broken about half way between shore and intake and clogged ith sand, necessitating the use of the emergency intake.

Muskegon Lake acts as a sedimentation basin for Muskegon's wage in quiet weather. In times of flood the sedimentation peritted is slight, as the currents quickly carry the polluted water rough the harbor entrance to Lake Michigan. Once arrived in the ke the polluted water may easily reach the intakes, especially the -called emergency intake nearer shore. In such an event, which ust happen at least once a year, the only protection that is afforded e water supply comes from the amount of dilution.

In this connection it is well to remember that mere dilution does ot kill pathogenic bacteria. It may prevent explosive epidemics, ut it is not to be relied upon to prevent all cases of typhoid fever. he amount of polluting material (sewage) is considerable, but Lake Iuskegon acts as a sedimentation basin. The amount of water vailable for dilution in Lake Michigan is large; all these facts have erved to protect Muskegon in the past, at least for the major porion of the year. The present intake is only about 5,000 feet from e mouth of the river, and the population is increasing. In July, 910, the citizens voted in favor of a bond issue of $300,000 for aterworks improvement. In spite of the obvious necessity it is oubtful if any method of water treatment or purification will be arried out.

The rate of typhoid fever in Muskegon from 1889 to 1905 was 19 deaths per 100,000. Since 1904 it has been as follows:

Typhoid fever deaths per 100,000: 1904, 28.7; 1905, 28.7; 1906, 33.4; 1907, 14.3; 1908, 33.4; 1909, 0; 1910, 24.

There has been a tendency to increase since 1903, but Muskegon has been fortunate in escaping a higher death rate for typhoid fever when one considers the relative positions of the sewers and water-works intakes. The intakes have been protected, as indicated above,

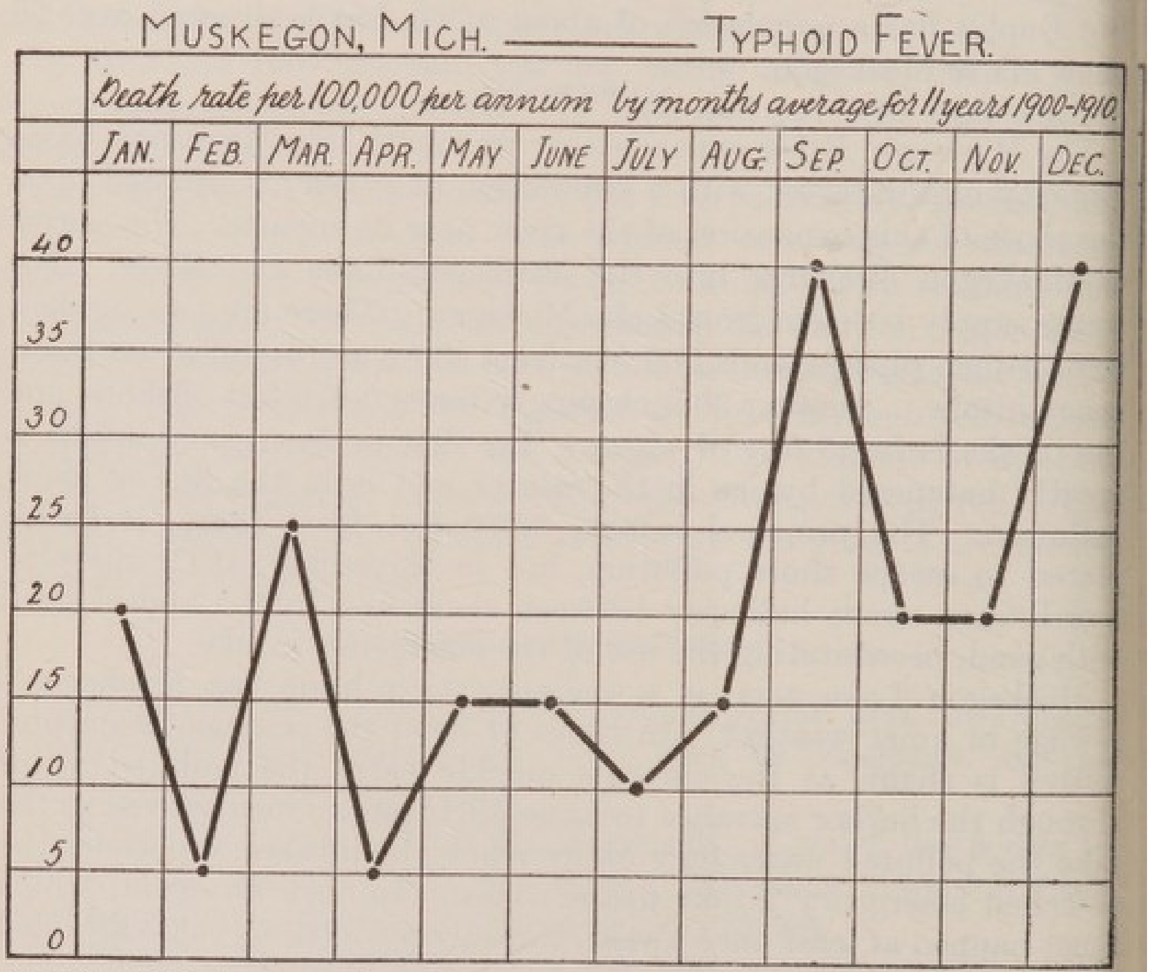


CHART 53.—The Muskegon seasonal prevalence curve for typhoid fever shows a pronounced peak in March.

but the water supply is menaced greatly at times by Muskegon's own sewage, especially in time of flood.

The abnormal typhoid prevalence in March, shown on Chart 53, is due entirely to outbreaks in 1901, 1902, 1903, and 1904, which were probably due to water.

Study of the seasonal prevalence of typhoid in Muskegon shows nothing from 1905 to 1910 which would indicate that water was responsible for the typhoid fever deaths. However, conditions are such that disaster may happen, especially during floods and storms, and this menace will steadily increase as the city grows.

MAP 25.—Muskegon, Mich. The river expands into Muskegon Lake before discharge into Lake Michigan. This expansion acts as a sedimentation basin for the city's sewage. The position of the waterworks intake in relation to the harbor entrance is shown.

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GRAND RIVER DRAINAGE BASIN.

Grand River rises in the southern part of Jackson County, in the southeast-central part of Michigan, flows northward to Lansing, thence northwestward to the central part of Ionia County, and finally westward to Grand Haven, Mich., where it enters Lake Michigan. Its length by general course is about 200 miles, but following the bends and angles the distance is at least 300 miles. The total drainage area is about 5,570 square miles. The drainage basin is fairly regular in outline and shape. At Grand Rapids, which is at the head of navigation, the stream passes over a limestone ledge, making a considerable fall at Grand Ledge. About 12 miles west of Lansing there is a similar descent over sandstone. Below Grand Rapids the flow is very sluggish. In the upper half of this stretch the immediate banks of the river are high, forming natural levees; below Lamont bayous and swamps are common between the river banks and the foothills bordering the valley.

The valley of the river proper is narrow; gravel bluffs from 50 to 60 feet high stand close to the stream in some places. The northwestern and southeastern portions of the drainage basin are thickly interspersed with small lakes, a number of which have no surface outlet.

The sources of the river have an elevation of about 1,000 feet; at Lansing the elevation is about 820 feet; at Grand Rapids it is about 590 feet; at the mouth of the river the elevation is 581 feet; the total descent is therefore about 400 feet, which produces a rather low average fall.

The basin contains no noteworthy forested areas, all timber having been cut off some time ago.

The stream flow of the Grand River is indicated by the following table taken from the records of the United States Geological Survey.

TABLE 33.—*Monthly discharge of Grand River, Grand Rapids, Mich., for period Apr. 1, 1901–Dec. 31, 1905, except March, 1903.*

[Drainage area, 4,900 square miles.]

Months.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.
January	12,000	1,630	4,140
February	14,700	1,520	5,300
March	26,500	2,300	7,800
April	20,900	2,480	6,920
May	10,200	2,260	4,550
June	49,300	1,690	6,200
July	13,300	1,180	4,530
August	6,400	1,040	2,560
September	7,090	1,360	3,200
October	8,950	730	3,650
November	6,540	1,760	3,140
December	7,430	1,370	3,490
For the period	49,300	730	4,610

From the standpoint of obviating nuisance, the flow is ample to care for the pollution of 386,000 persons, even if discharged at one place, but water carriage of pathogenic bacteria for considerable distances can take place without offense to sight or smell.

Population of Grand River drainage basin, by counties.

Counties.	Population, 1910.	Counties.	Population, 1910.
Kent	159,000	Eaton (part of)	8,000
Ionia	33,000	Montcalm (part of)	24,000
Barry	22,000	Gratiot (part of)	7,000
Clinton	23,000	Shiawasee (part of)	11,000
Ingham	53,000	Jackson (part of)	13,000
Ottawa (part of)	33,000		
		Total	386,000

The total population on the drainage area is 386,000 persons, indicating a density of about 70 persons to the square mile. The Grand River drainage basin has the following urban population:

City or village.	Population.	City or village.	Population.
Grand Rapids	112,571	Belding	4,119
Lansing	31,229	Hastings	4,383
Jackson	31,433	Grand Ledge	2,893
Grand Haven	5,856	Eaton Rapids	2,094
Ionia	5,030	Mason	1,742
Greenville	4,045		
		Total	205,395

Subtracting an urban population of 205,000, there remains a rural population of 181,000, or less than 33 persons to the square mile. The sewage pollution of the Grand River from the rural population resident on its watershed is of small moment compared with the large volume of untreated sewage discharged into the river by the sewered cities and towns along its banks.

JACKSON.

The city of Jackson which has a population of 31,433 is situated on the Grand River in the center of Jackson County. The waterworks supply is from wells in sandstone which are from 200 to 400 feet in depth. The wells do not flow, but the water rises to within 2 to 6 feet of the surface. By using a siphon at a level of 17 feet below the natural head the 12 wells give a combined yield of 6,500,000 gallons per day.

The State prison has an independent supply likewise from deep wells in the sandstone. Jackson has a sewage disposal plant and is 140 miles above Grand Rapids the only city using the river as a source of supply.

LANSING.

Lansing the capital of Michigan has 31,000 inhabitants and is situated on the Grand River about 90 miles above Grand Rapids.

The entire sewage of Lansing is discharged untreated into the Grand River. The water supply is from deep wells. The water main passes under the river. There is said to be usually a pres-

MAP 26.—The Grand River Drainage Basin.

sure of 70 pounds in the pipe, and if so it seems unlikely that any contamination takes place from this source.

Typhoid-fever rates in Lansing have been high in certain years.

Years.	Deaths per 100,000.	Years.	Deaths per 100,000.
1900	72.8	1906	76.7
1901	34.4	1907	17.3
1902	10.9	1908	58.2
1903	62.1	1909	12.7
1904	62.1	1910	50.0
1905	42.4		

The seasonal prevalence of each year, except 1904 and 1908, would suggest that water was not responsible for the majority of the cases. In fact, the disease was most common in summer and autumn, and the bulk of the cases occur among the poor.

On January 8, 1908, 10,000 people were attacked in Lansing with a disease similar to that which has been called winter cholera in Erie, Pa., Escanaba, Mich., and other places. The symptoms were

nausea, vomiting, diarrhea, and in severe cases, collapse. The attack was short in duration and there was practically no mortality. Practically all of those afflicted lived in the southern part of the city. East Lansing, which has an independent water supply, had no increase in diarrhea. For some time Lansing had been supplied by two pumping stations.

Examination by the State board of health of water from the main pumping station showed the water to be pure. Examination of water from the south station showed *B. coli* in 1 c. c. samples, although the bacterial counts were low. The water from the south station was discontinued by order of the State board of health, and the water supply has apparently been safe ever since. How the contamination reached the south supply is not explained in the State board of health reports. An unusual amount of typhoid fever occurred in Lansing during February and March following the "winter cholera."

GRAND RAPIDS.

Grand Rapids is an important manufacturing city, with a popula-

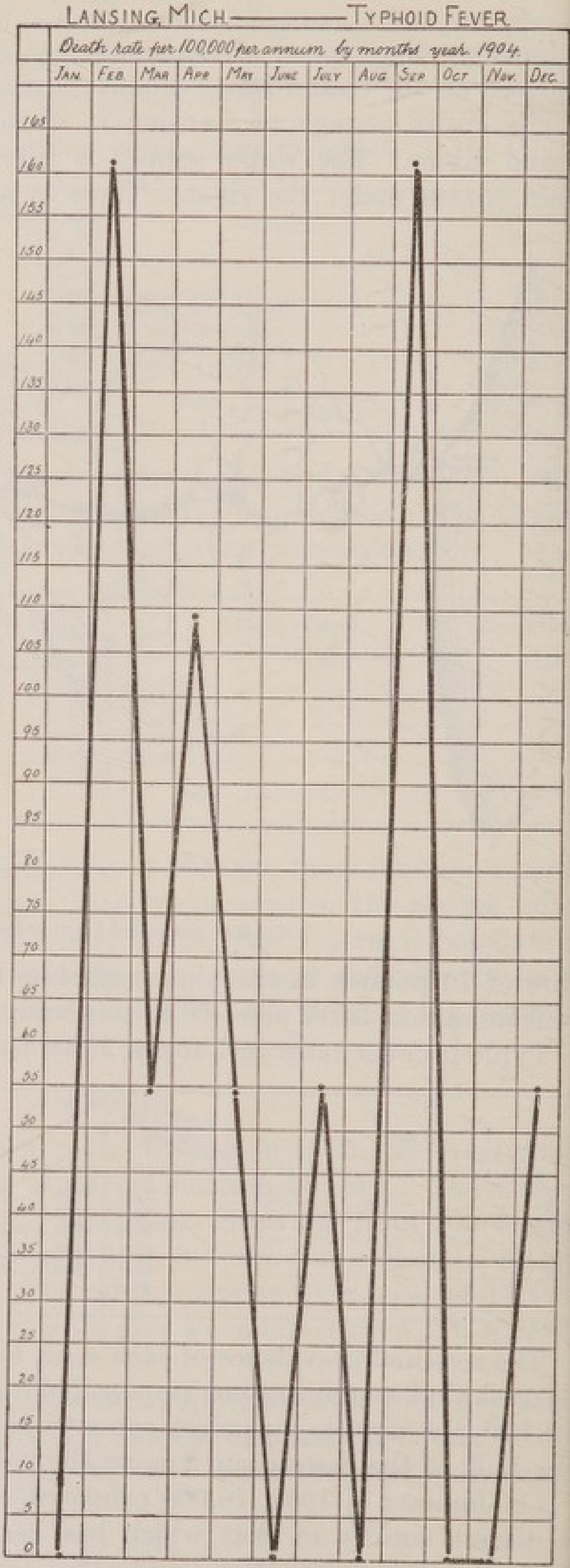


CHART 54.—There was an explosive outbreak of typhoid fever in Lansing in February, 1904, very suggestive of polluted water.

on of 112,000. It contributes the largest quota of sewage pollution the Grand River. The entire sewage, including night soil, is discharged into the river without treatment of any kind.

The water supply of Grand Rapids may be said to be from three istinct sources: (1) The municipal supply from the Grand River, nfiltered; (2) Hydraulic Water Co. daily capacity of 3,500,000 gallons; (3) private wells, mostly shallow and often grossly contami-

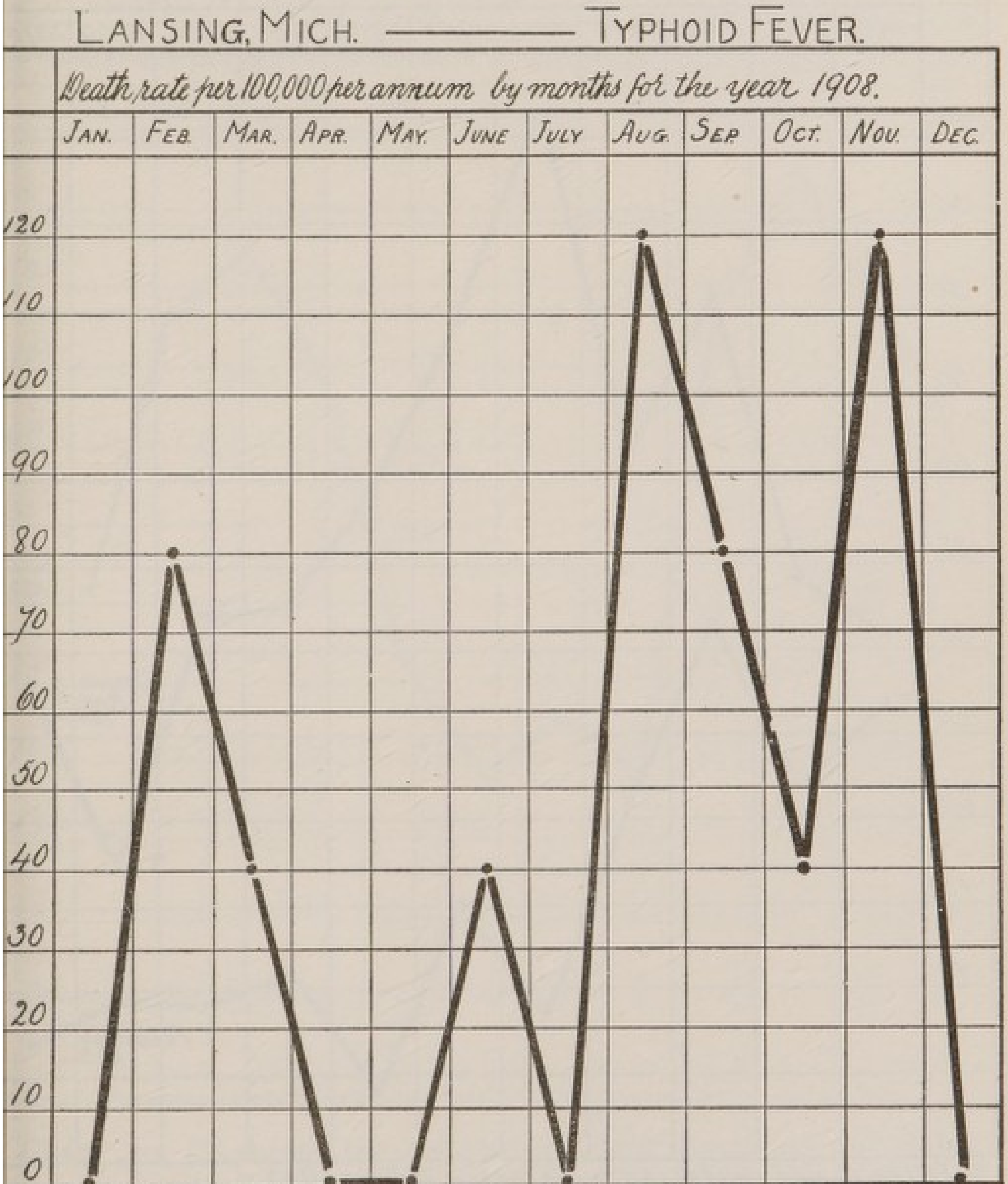


CHART 55.—The year 1908 resembles 1904 in Lansing, the typhoid-fever curve indicating an explosive outbreak in February.

ated. The majority of the population depend upon the municipal r Grand River supply. The hydraulic company probably supplies ot more than 8,000 persons. It is estimated that there are nine to ten housand wells in Grand Rapids. The hydraulic company's supply s a groundwater supply collected through 20-inch tile pipe running

through gravel. It is probably safe, but supplies a comparatively small proportion of the population.

The Grand River is a polluted stream and the municipal supply has been furnished unfiltered. Probably 50,000 persons depend upon

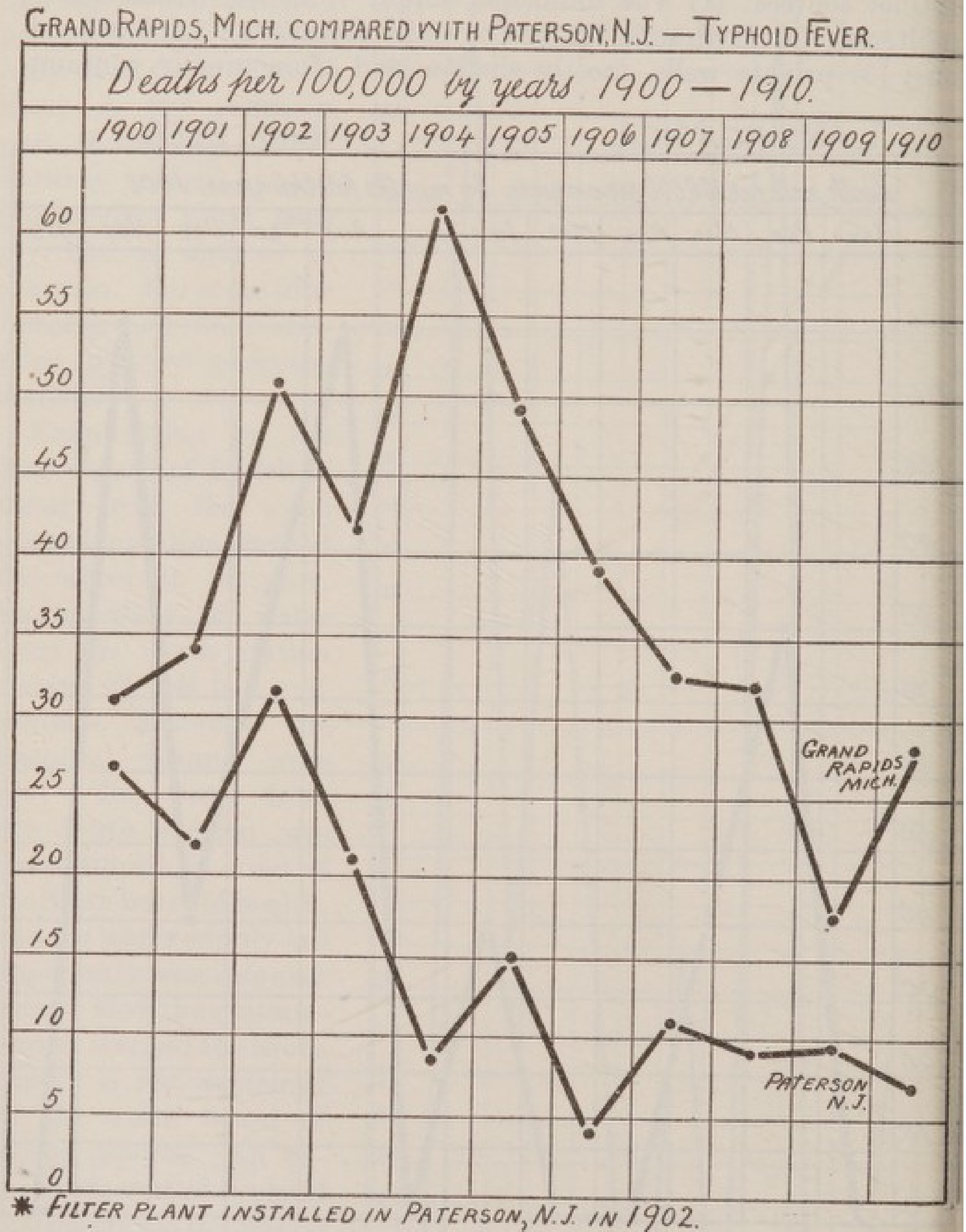
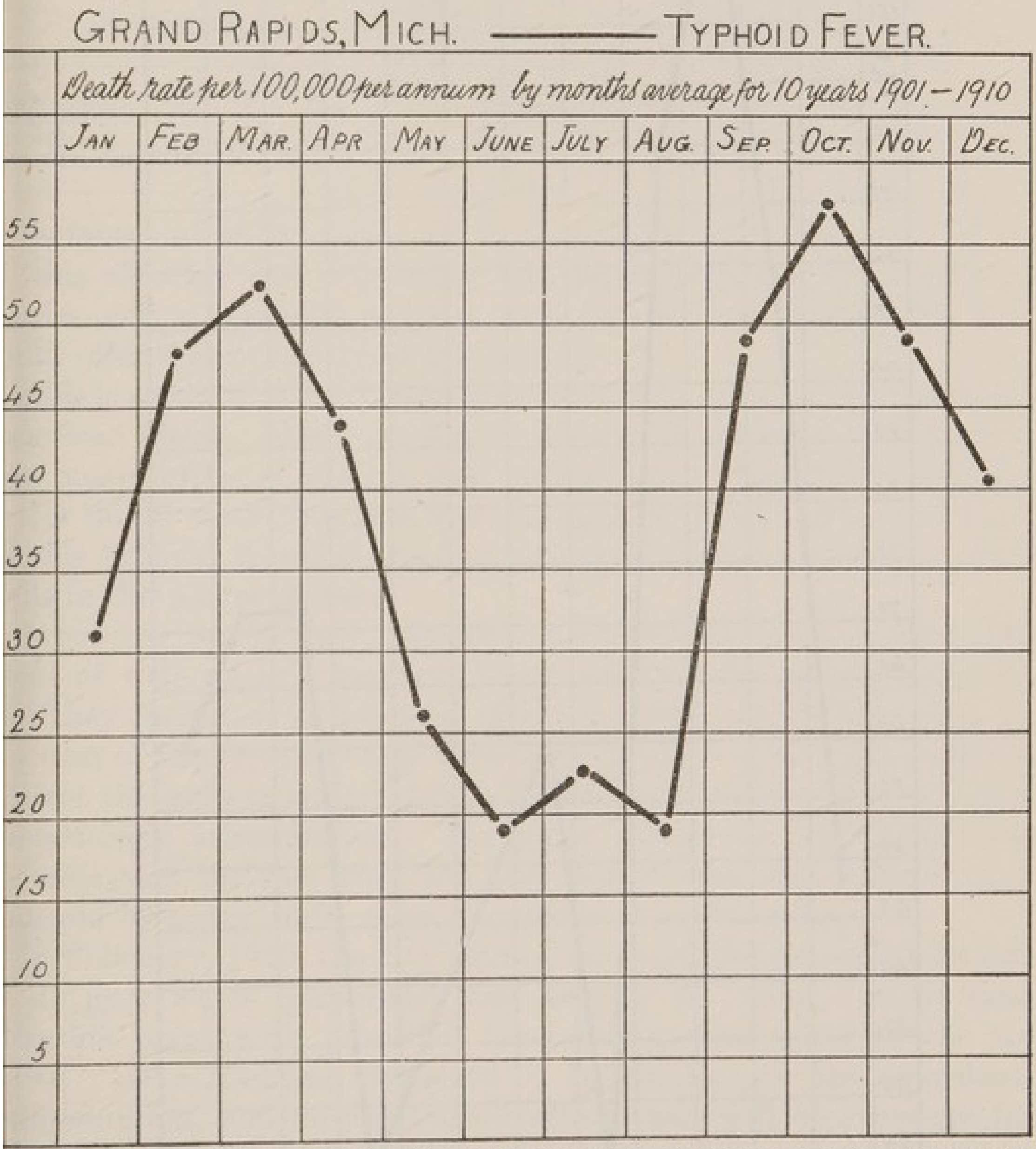


CHART 56.—Showing the high rate for typhoid fever in Grand Rapids compared with Paterson, N. J.—a city with a safe water supply.

the shallow wells, which are by far the most dangerous supply in Grand Rapids.

Chart No. 56 shows the high rate of typhoid fever in Grand Rapids since 1900, compared with Paterson, N. J. A filter plant was in-

alled in Paterson in 1902. The gradual decline of typhoid in Grand apids from the very high rates which prevailed previous to 1906 attributed by the health officer to the advice given and generally ccepted to boil all drinking water. In spite of this reduction the ate is still much too high and in 1910 showed an upward tendency. uring the first six months of 1911 the typhoid death rate per 00,000 was 32.



HART 57.—The seasonal prevalence of typhoid fever in Grand Rapids also indicates water-borne infection.

Chart No. 57 shows the peculiar seasonal prevalence of typhoid ever in Grand Rapids for the past 10 years. March exceeds all onths except October. February and April are also abnormally igh.

Chart No. 58 shows in greater degree this peculiarity during 1904, hich was the worst typhoid fever year in the decade. March had he highest rate, April next, and February next, all three having ates than September, October, or November.

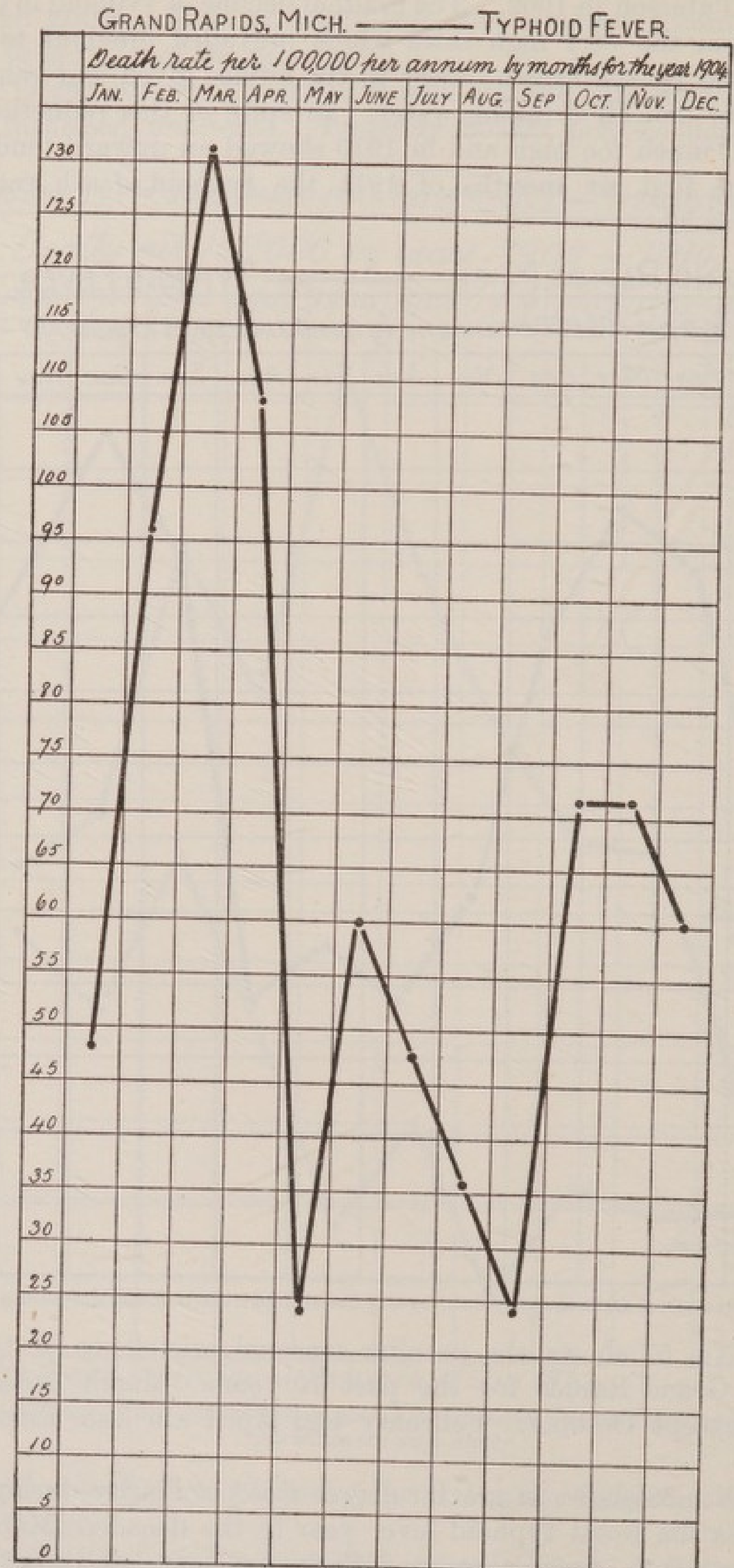


CHART 58.—The abnormal prevalence of typhoid fever in winter and spring in Grand Rapids is accentuated in the year 1904.

In investigating typhoid fever cases the majority were usually ›und to be users of well water and in many instances the insanitary ıtdoor privy was an accompanying menace because of its close ·oximity to the well.

In 1907 an investigation of typhoid fever in relation to water used ıowed the following:

Source of supply.	Number of cases.	Source of supply.	Number of cases.
ells	298	Boiled city water	2
ring water	51	Unknown	7
y water	35		
draulic Water Co	5	Total investigated	398

In 1908 out of 192 cases only 5 were users of city water. In spite this showing the city water was from a known contaminated ›urce and a campaign against wells promised little until the city ›uld offer a pure supply as a substitute.

Milk is a factor in the Grand Rapids typhoid rate as in other large merican cities. However Grand Rapids has carried milk inspecon much further than some cities with lower typhoid fever rates but etter public water supplies, and the greatest single factor in Grand apids typhoid is polluted water, especially the water from shallow ells in the poorer districts.

According to the data collected by the health office in 1907, the sers of well water comprised about one-half the total population ıd they furnished 75 per cent of the typhoid, and in 1908 only 2½ er cent of the typhoid cases were users of city water. The evidence ainst the wells in Grand Rapids was definite and included repeated ıcteriologic examinations. The great obstacle to the elimination wells was the fact that the city supply was also polluted and elieved by many to be more dangerous than the wells.

In February, 1910, the city council accepted the recommendations its pure water commission and decided to install a rapid sand tration plant with provision for softening the water to the solled "Lake Michigan Standard." In addition to the coagulant, dimentation, and mechanical filtration, there will be provision for ing hypochlorite of lime when necessary to insure a safe water at l times.

The installation of a filtration plant and its effective operation will ıable the city to carry on conscientiously a vigorous campaign ainst shallow wells and insanitary privies. The property owners' fusal to accept city water not only perpetuated the well problem, ıt also, on account of lack of water, prevented the substitution of ısh closets for insanitary outdoor privies. In Grand Rapids the ·oblem is very similar to that in Toledo, and the solution is the

same. The installation of a safe municipal supply is the first step. It will not effect a great immediate reduction of typhoid fever, but the substantial reduction will follow when by means of this safe public water supply the shallow well and insanitary privy are eliminated.

GRAND HAVEN.

The population of Grand Haven in 1910 was 5,856. Only about 10 per cent of the population is tributary to sewers, the great majority depending upon cesspools and privies. The water supply is from shallow wells, but seems to be safe, as the typhoid death rate per 100,000 for 20 years has been below 14.

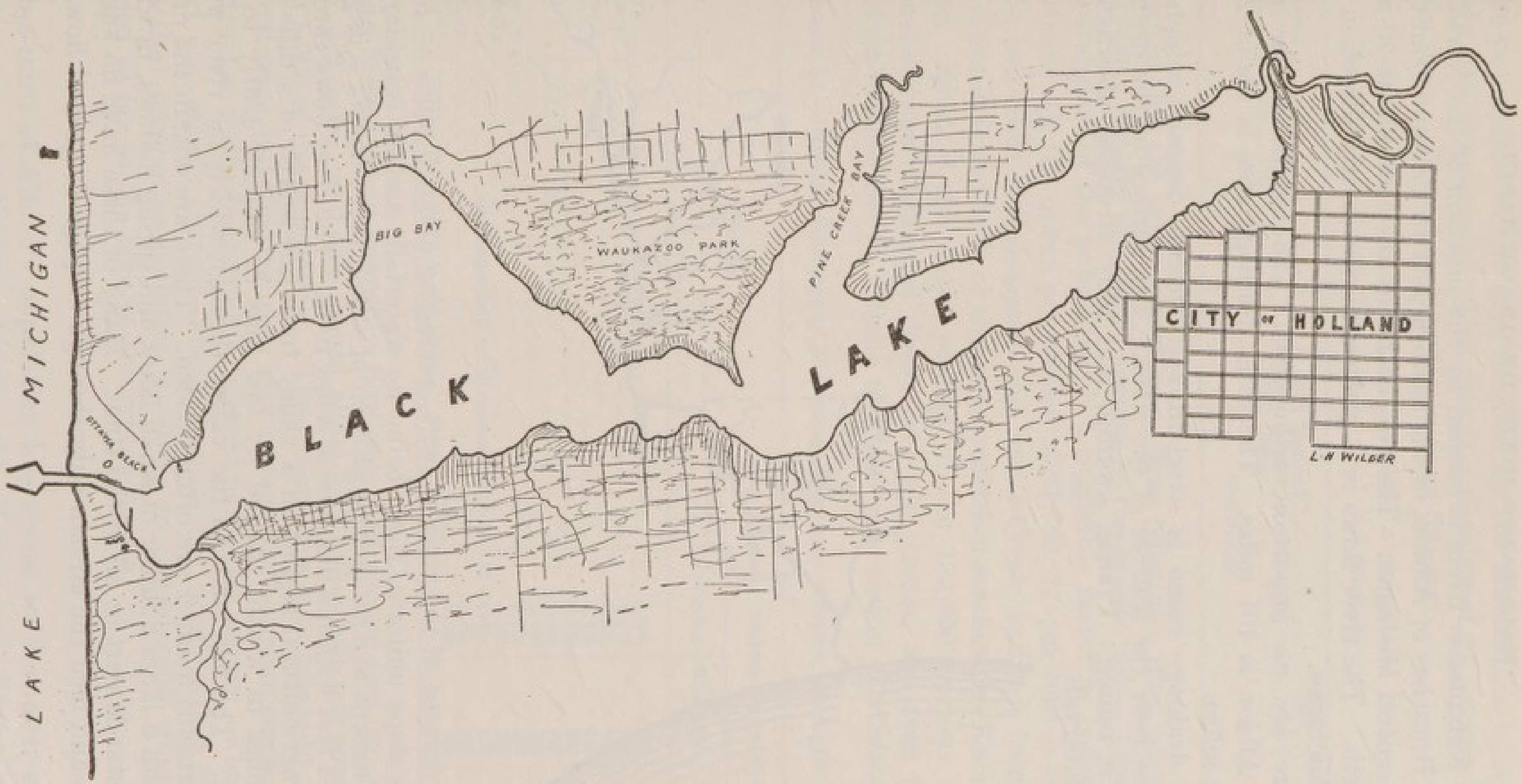
HOLLAND.

Holland has a population of 10,490. It is situated 5 miles from the shore of Lake Michigan in the southwest corner of Ottawa County, at the head of Black Lake. Black Lake is navigable and gives Holland an excellent harbor. Holland's water supply is from shallow wells about 25 feet deep. Their purity depends upon the exclusion of surface pollution and prevention of soil pollution in the vicinity. A good flow of safe water can be obtained by going through the 29 feet of beach sand and 84 feet of clay to a water-bearing stratum of sharp gravel and silt. Unfortunately the water so obtained is saline. In the event of growth, Holland will be eventually obliged to go to Lake Michigan for a public drinking supply. Extension of the present shallow-well system may suffice for some years, and it is possible that deeper drilling might yield unobjectionable water.

Any considerable growth of the city would overtax the present wells and increase the chances of contamination. The only protection now afforded consists in the character of the soil. Rainfall and pollution on the surface of the sand is more likely to filter through rather than drain over the surface to the open wells.

Under any conditions contamination of the present supply must be regarded as possible. Holland has several factories, including a sugar factory and tannery; about half the population has access to the sewers. Sewage amounts to about 300,000 gallons. This with the wastes from a large tannery and sugar factory is passed through septic tanks and discharged into Black Lake.

Holland with Ottawa Beach attracts many summer visitors. Typhoid fever rates in Holland for 16 years, 1889–1905, gave an average of 29 deaths per 100,000 population. Average for 1906–7 and 1908 has been but 10 per 100,000.



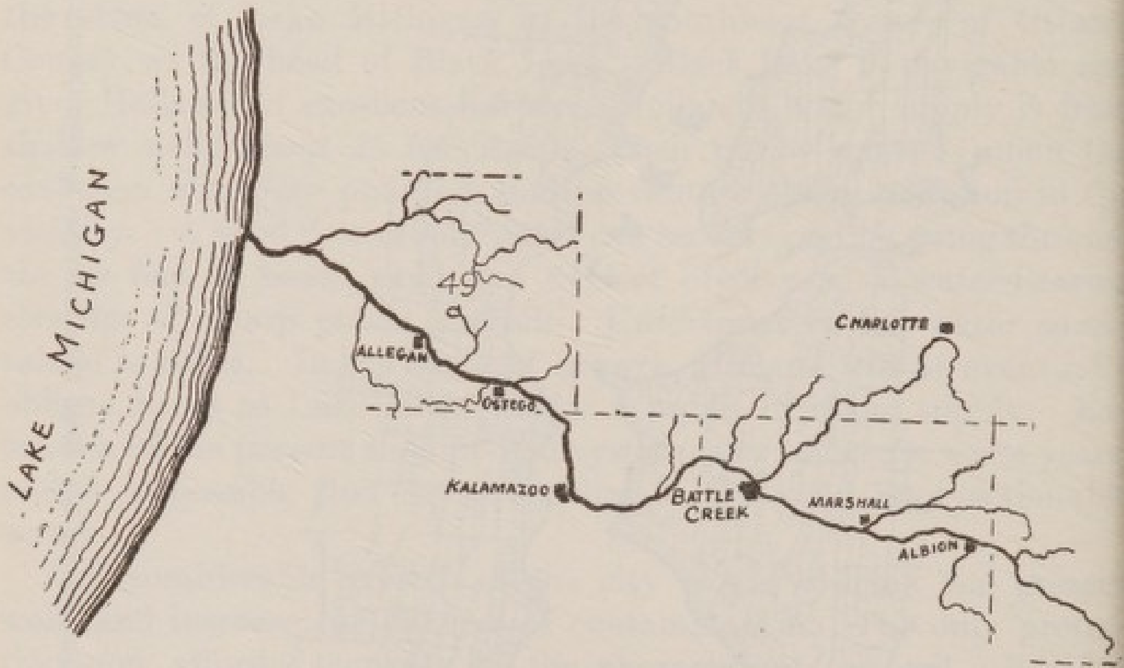
MAP 27.—Holland, Mich., showing how Black Lake intervenes between the city and Lake Michigan.

KALAMAZOO RIVER DRAINAGE BASIN.

The Kalamazoo River is formed by the junction of the North and South Branches of Albion, in the eastern part of Calhoun County, in south-central Michigan. The two branches are each about 20 miles in length. The river flows in a general northwesterly direction into Lake Michigan.

There are no important tributaries. The length of the river below Albion is 101 miles. The total drainage area is about 2,000 square miles.

The drainage basin is overlain with glacial deposits, which are thinnest near the sources of the river. The surface of the drainage basin is rolling. Prairie, swamp, and hilly stretches alternate at short intervals.



MAP 28.—The Kalamazoo River Drainage Basin.

The current of the river is swift, averaging about 3 miles an hour, and its slope uniform, there being no waterfalls and no considerable rapids except at two points, at each of which there occurs a descent of 3 or 4 feet within a distance of a few rods. The river flows through a rich agricultural region, in a valley from one-fourth of a mile to 2 or 3 miles in width, backed by low hills or sloping gently to the upland. The flat lands in the valley through which the river winds in a tortuous manner are often flooded. There are within the drainage basin a large number of small lakes and spring hollows, in which water stands part or all of the time. Many of these have no surface outlets and feed the stream only through seepage or ground flow.

The population of the area drained by the Kalamazoo is approxi-nately 135,000 persons. This means a density of 67 persons to the quare mile. The urban population is as follows:

Cities.	Population.	Cities.	Population.
Calamazoo	39,437	Marshall	4,236
Battle Creek	25,267	Allegan	3,419
Albion	5,833	Otsego	2,812
		Total urban	81,004

Subtracting the urban population, there remains a rural population of 54,000, a density of only 27 persons to the square mile. Obviously the rural part of the population is a negligible factor in pollution of the river. Of the urban population of 81,000, 77 per cent is resident n the two cities of Kalamazoo and Battle Creek, and it is from these two cities that the bulk of the gross pollution reaches the Kalamazoo River. Even if the entire sewage of the 135,000 persons on the watershed was discharged direct into the stream, the even flow of the river is sufficient in volume to insure prevention of nuisance.

TABLE 34.—*Monthly discharge of Kalamazoo River near Allegan, Mich., for 1907.*

Months.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.
January	3,520	1,270	1,820
February	1,870	866	1,320
March	3,340	845	1,760
April	3,520	882	1,630
May	2,670	820	1,530
June	1,450	529	1,110
July	1,410	182	994
August (29 days)	1,100	323	736
September	1,330	288	828
October	1,460	578	1,030
November	1,630	568	1,020
December	3,400	338	1,340

The lowest mean monthly flow was 736 second-feet in August, 1907 (29 days), and this would allow 5.45 cubic feet per second for each 1,000 of the population. The stream flow is sufficient to obviate the nuisance, but the pollution with sewage by the urban communities renders the water dangerous for a great part of its course. The rather rapid and steady current (about 3 miles per hour) makes it probable that dangerous pollution at times in considerable quantity is carried as far as the lake at the river's mouth.

ALBION.

One-third of Albion's population has access to the sewer system. The sewage is discharged into the Kalamazoo River without treatment.

Albion's pollution is quite distant from the mouth of the river, and no towns on the river use river water as a public supply. These facts minimize the danger from the sewage of this small city (population 5,833). Albion has a water supply from flowing wells which is probably uncontaminated. In recent years Albion has suffered little from typhoid fever, only two deaths being recorded in four years, 1905–1908.

MARSHALL.

Like Albion, Marshall is distant from Lake Michigan, and its amount of sewage does little damage because the inhabitants of cities and towns below Marshall do not use river water for drinking purposes. Marshall's water supply is derived from deep wells in sandstone, and is probably pure. There is storage for 235,000 gallons in a standpipe 100 feet high. The population of Marshall is 4,236.

BATTLE CREEK.

The population of Battle Creek in 1910 was 25,267. The public water supply is from Goguac Lake and Minges Brook, a surface supply which is undoubtedly contaminated at times. Goguac Lake is used extensively as a summer resort, and yet water is furnished without filtration to the consumers. One-third of the population still depends upon surface wells, and these shallow wells must be considered a dangerous factor in Battle Creek's typhoid.

Battle Creek has had a high typhoid rate for many years.

Deaths per 100,000, typhoid fever: Average, 16 years (1889–1905), 34.6; 1906, 33.3; 1907, 24; 1908, 38.7; 1909, 34.

Chart 59 shows too many cases have occurred in January, February, March, and April, suggesting water as a factor.

In Battle Creek about one-third of the population depends upon privies. Battle Creek has about 28 miles of sewers to which about 15,000 people are tributary. These sewers discharge by 17 outlets into Kalamazoo River and its tributary, Battle Creek. There is no treatment of the sewage.

KALAMAZOO.

Kalamazoo had a population of 39,437 in 1910. It is situated on the Kalamazoo River about 20 miles below Battle Creek. Seventy-five per cent of the population have access to the sewers, which are mostly on the separate plan. There are about 70 miles of sewers, discharging by six outlets into the Kalamazoo River. Kalamazoo has a public water supply from wells. There is a large central well 32 feet deep and 22 feet in diameter, surrounded by 13 tubular wells which flow into it. The tubular wells are from 80 to 120 feet deep. The wells are entirely in sand and gravel, passing through no impervious stratum, but the water seems to be of excellent quality.

Kalamazoo has had a rather low prevalence of typhoid compared with other Michigan cities, and it is probable that the water supply is uncontaminated. The average typhoid rate for 10 years, 1900–1909, was 26.6 deaths per 100,000, and in 1909 the rate was only 7.6.

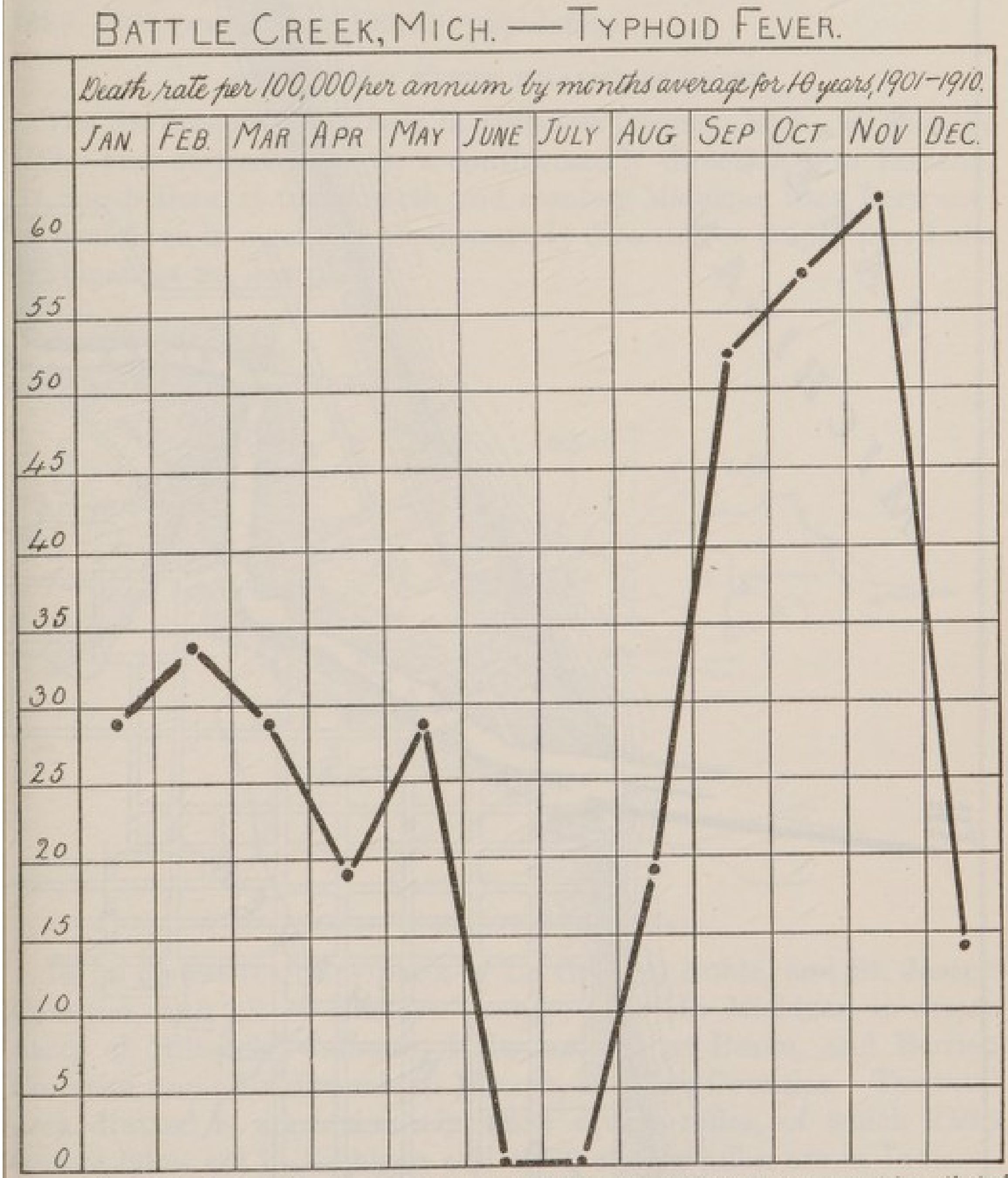


CHART 59.—Battle Creek, Mich., has a seasonal prevalence for typhoid fever quite different from that of cities with safe water supplies.

BLACK RIVER BASIN.

The Black River drains a very small area in Van Buren and Allegan Counties. The only community of importance on this watershed is the city of South Haven, situated at the mouth of Black River.

SOUTH HAVEN.

The city of South Haven has a resident population of 3,577. The transient population in summer exceeds this. Most of the transients

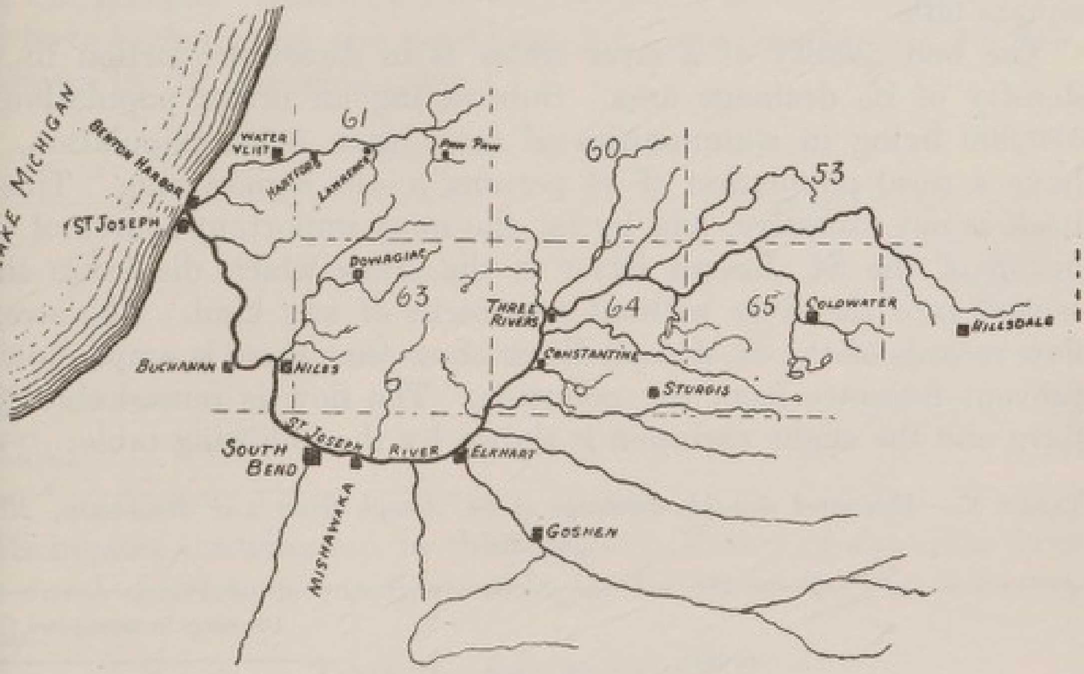
and excursionists come to South Haven by boat from Milwaukee and Chicago. The main trunk sewer of South Haven empties into the

MAP 29.—South Haven, Mich., showing the relation between the harbor entrance and the waterworks intake.

Black River at its mouth. The water supply is taken from Lake Michigan about 1,600 feet beyond the piers at the river's mouth and a little to the south of the mouth of the river. Undoubtedly the water is polluted with sewage at times and is manifestly unfit for drinking purposes. The typhoid fever death rate for 17 years, 1889–1906, was 48 per 100,000 population.

ST. JOSEPH RIVER DRAINAGE BASIN.

The St. Joseph River rises in Hillsdale County, Mich., at Bunday Hills, and at first flows in a southwesterly direction into Indiana. At South Bend it turns north and reenters Michigan near Bertrand. It then flows in a general northwesterly direction to empty into Lake Michigan at St. Joseph.



Map 30.—St. Joseph River Drainage Basin.

In its course it drains parts of La Grange, Noble, and St. Joseph Counties, and all of Elkhart County, Ind. In Michigan it drains parts of Hillsdale, Calhoun, Kalamazoo, Van Buren, and Berrien Counties, and all of Branch, St. Joseph, and Cass Counties. The total area drained is approximately 4,586 square miles, of which 2,916 square miles are in Michigan and 1,670 square miles are in Indiana. The drainage basin contains more than 400 small lakes, varying in surface area from one-eighth of a square mile to 6 square miles. Of these approximately 100 are in Indiana and 300 in Michigan.

The drainage basin lies in a completely glaciated region and is overlain with diversified drift deposits. The current of the river from South Bend to its mouth was formerly reversed, and this valley formed an outlet for the waters of Lake Michigan, which turned to the southwest through Kankakee River at South Bend, and thus reached the Mississippi through Illinois River.

The basin of the St. Joseph, in Michigan, contains relatively little marsh land not artificially drained and relatively little uncleared land. About a third of the lakes, however, are without visible outlets. The proportion of undrained lakes in Indiana is smaller and the swamp lands are much more extensive.

Elkhart River, one of the principal Indiana tributaries of the St. Joseph, drains an area of about 500 square miles, which contains large lakes and extended swamps, the principal fall of the stream occurring in its passage from marsh to marsh.

The country drained is a populous agricultural region and includes the famous fruit belt. It also receives the drainage of several cities and large towns. The total population in the drainage basin is approximately 335,000, which gives a density of 73 persons to the square mile.

The bad quality of a river water is in direct proportion to the density of its drainage area. Subtracting an urban population of 130,000 living in communities of more than 5,000 population, we have a rural population of 44 persons to the square mile. This in itself is not excessive, and by far the most important source of pollution of the St. Joseph River is the cities which discharge their sewage into the river without treatment of any kind. The stream flow records of the St. Joseph River show that there is ample flow to prevent nuisance from the pollution. The flow is remarkably uniform and the slight variation is shown by the following table:

TABLE 35.—*Estimated monthly discharge of St. Joseph River near Buchanan, Mich., for 1905.*[1]

Months.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.
March	8,122	2,451	4,784
April	6,249	3,432	4,688
May	10,260	3,558	6,080
June	4,837	2,472	3,534
July	4,853	1,749	2,994
August	2,928	991	2,075
September	3,432	1,406	2,308
October	3,087	1,297	2,223
November	3,481	1,846	2,617
December	3,561	2,188	3,038

[1] From United States Geological Survey Reports.

Allowing $3\frac{1}{2}$ second-feet for each 1,000 of the population would require a stream flow of 1,172 cubic feet per second to avoid nuisance. Upon this basis of calculation, and from the standpoint of nuisance only, the St. Joseph should have no trouble in caring for the pollution of 335,000 people.

Sewage pollution of a stream is objectionable, not only because of uisance which offends the senses, but also because of the possibility f infection being transmitted by means of the water from place to lace. This latter menace is of far greater importance than any mere uisance which is offensive to sight or smell.

The greatest danger at present to be anticipated from sewage pol- ıtion is the spread of typhoid fever. A small amount of infectious naterial may be carried quickly from one place to another by the urrent before dilution or sedimentation are effected. The time fac- or in pollution is all important. Even with great dilution, if the ime necessary to permit of death of the pathogenic organisms has ot elapsed, infection of persons may occur. There has been plenty f typhoid fever in Indiana counties of La Grange, Noble, Elkhart, nd St. Joseph. Although the central and southern Indiana coun- ies have higher rates, the rural rates for these counties are not low, s shown by the following table:

TABLE 36.—*Rural rate.*

Counties.	Deaths per 100,000, average for 5 years, 1904–1908.
a Grange	26.41
oble	18.6
lkhart	23.8
t. Joseph	25.8

Michigan's contribution to the specific pollution of the river from he rural districts is inconsiderable, as indicated by the following able:

TABLE 37.—*Rural typhoid rates.*

Counties.	Typhoid fever, deaths per 100,000.				
	1904	1905	1906	1907	1908
ranch	11.04	7.7	15.6	....	16.0
t. Joseph	4.3	17.3	8.7	4.4	13.3
ass	30.0	10.1	10.2	10.3	26.1
errien	10.1	20.2	38.4	16.1	22.2

The table shows a low average rural rate, but at times the rate was ıbove 25 in Berrien and Cass Counties.

In addition to the rural typhoid, some of the following urban com- nunities have had high typhoid rates and at such times contribute langerous pollution to the river or its tributaries.

TABLE 38.—*Urban communities contributing sewage to the St. Joseph River.*

Cities.	Population, 1910.	Cities.	Population, 1910.
Cold Water, Mich	5,945	Niles, Mich	5,156
Three Rivers, Mich	5,072	Dowagiac, Mich	5,088
Goshen, Ind	8,514	Benton Harbor, Mich	9,185
Elkhart, Ind	19,282	St. Joseph, Mich	5,936
Mishawka, Ind	11,886		
South Bend, Ind	53,684	Total	129,748

The influence of Coldwater and Three Rivers on the dangerous pollution of the St. Joseph River is slight. They are quite distant from the mouth of the river, and the typhoid fever rates in St. Joseph County and in these towns in particular are very low. Only one-third of Coldwater's population depends upon privies—the other two-thirds depend upon sanitary sewers and cesspools. There are two storm and one combined sewer outlets into the Coldwater River, but the sewage of the sanitary or separate system is passed through septic tanks, the effluent discharging into the Coldwater River, which is a tributary of the St. Joseph.

Elkhart and South Bend have large populations, and have had at times very high typhoid fever rates.

The following table shows the deaths from typhoid fever per 100,000 in South Bend and Elkhart for nine years:

TABLE 39.—*Deaths per 100,000 from typhoid fever.*

Cities.	Average 9 years, 1901–1909	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
South Bend	22.4	29.4	28.3	14.9	16.8	27.8	17.9	19.6	23.0	33.9	16.7
Elkhart	36.2	32.1	56.4	55.1	47.9	52.6	11.4	5.6	5.5	60.0	10.3

DOWAGIAC.

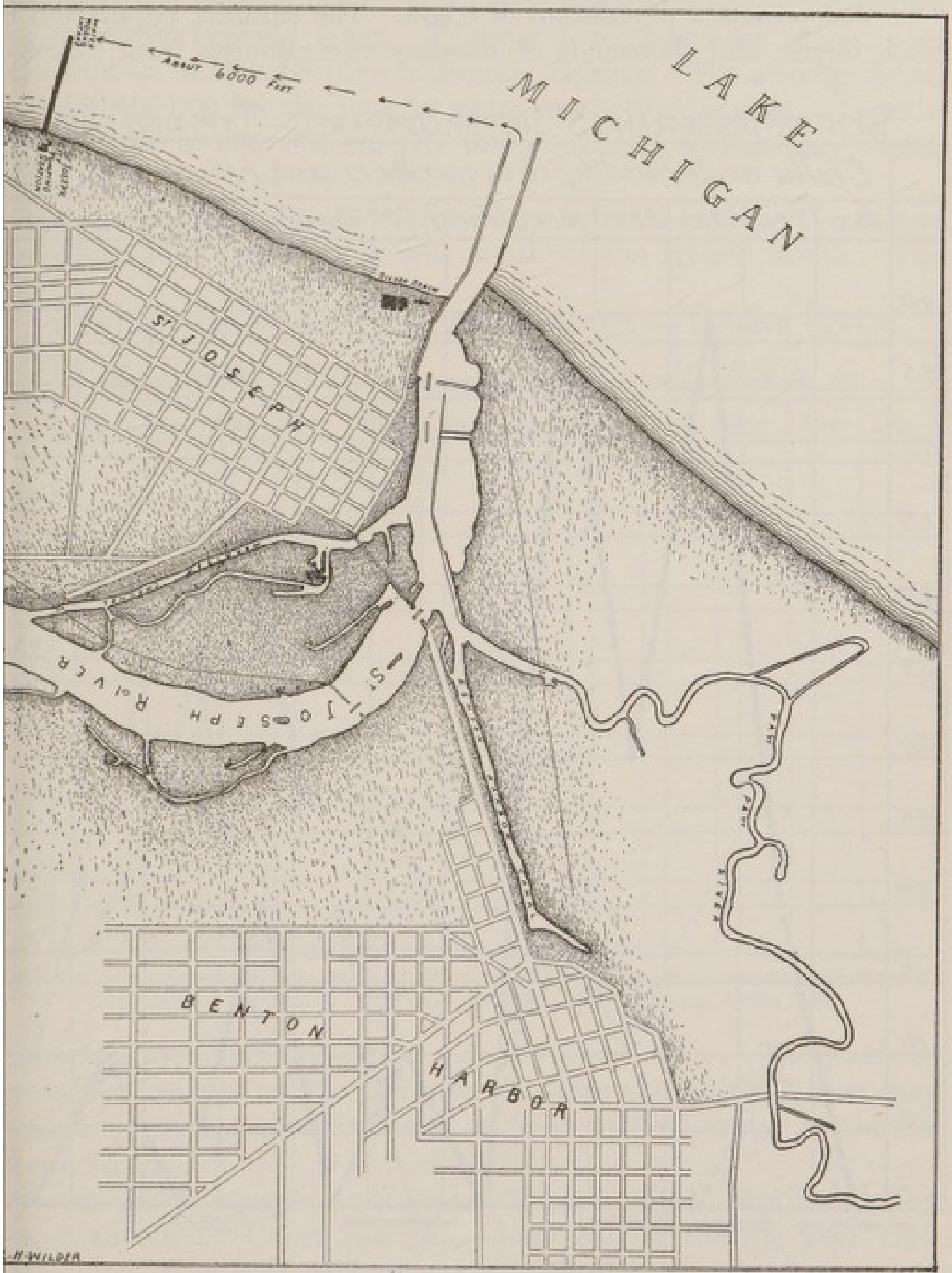
The population of Dowagiac is 5,088. About 25 per cent of the population has access to sewers which discharge into the Dowagiac Creek. The water supply is from wells, and considerable typhoid has been reported in the city. The typhoid deaths per 100,000 average 22.

NILES.

Niles has a population of 5,156. There are about 1,500 persons who have access to the sewers. The sewers discharge into the St. Joseph River. The water supply is from wells and from Barron Lake, a source subject to contamination. The typhoid rate for years has averaged about 30 deaths per 100,000 population.

BENTON HARBOR.

Benton Harbor's population was 9,185 in 1910. There is a large ummer influx of visitors. The water supply of Benton Harbor has been classed as pure and is derived from deep wells. It is in close



AP 31.—St. Joseph and Benton Harbor, Mich., showing relation of the waterworks intake of St. Joseph to the mouth of the grossly polluted river.

elation with St. Joseph, and many of Benton Harbor's temporary ummer residents go to St. Joseph and possibly at times drink St. oseph's water.

In Benton Harbor the average typhoid fever death rate for 20 years up to 1908 was only about 15 per 100,000. In 1909 and 1910 the rate was about 22 deaths per 100,000.

ST. JOSEPH.

St. Joseph has a population of 5,936. The summer population is much larger, and thousands of one-day excursionists from Chicago

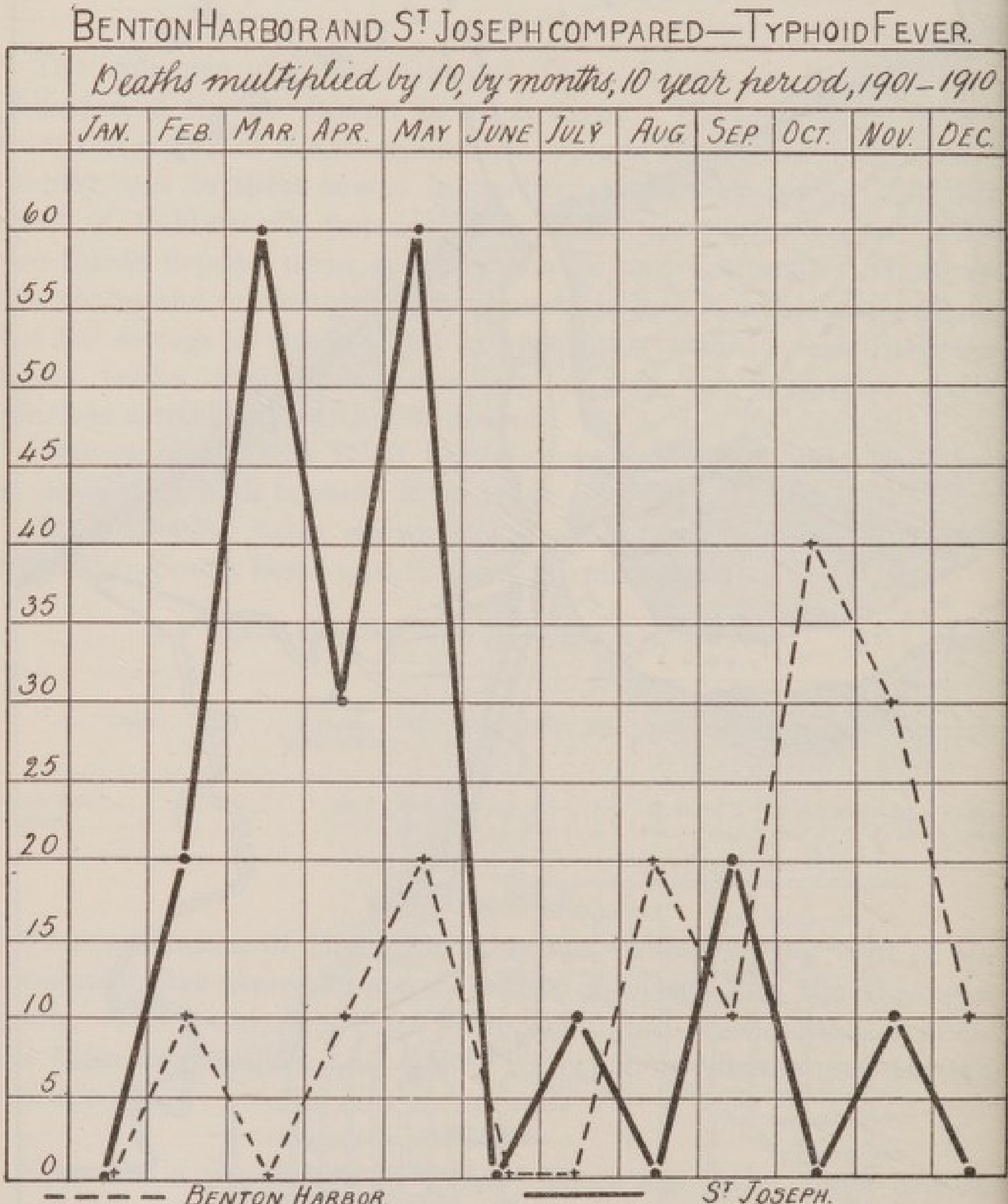


CHART 60.—The greatest prevalence of typhoid fever in St. Joseph, Mich., is in February, March, April, and May. The contrast with Benton Harbor is striking.

and other large cities in neighboring States come to St. Joseph in the summer months. Excursion trains run regularly from Indiana cities north to St. Joseph during the summer months and carry thousands of people each season to the bathing beaches. The intake

ipe of the St. Joseph water works is 1,500 feet offshore and about ,000 feet south of the mouth of the grossly polluted St. Joseph River. The stay of many of the summer visitors at St. Joseph is hort, sometimes only a few hours, but long enough to drink the angerous St. Joseph water and carry back to Indiana or Illinois he germs of typhoid fever. Typhoid fever has been much more revalent in St. Joseph than in Benton Harbor. The average death ate per 100,000 for the past 10 years, 1901–1910, was 40. In 1910 he rate rose to 100, due entirely to an outbreak in February, April, nd May.

The sewers of St. Joseph all discharge into the river. The water-orks intake is less than a mile south of the river's mouth. The

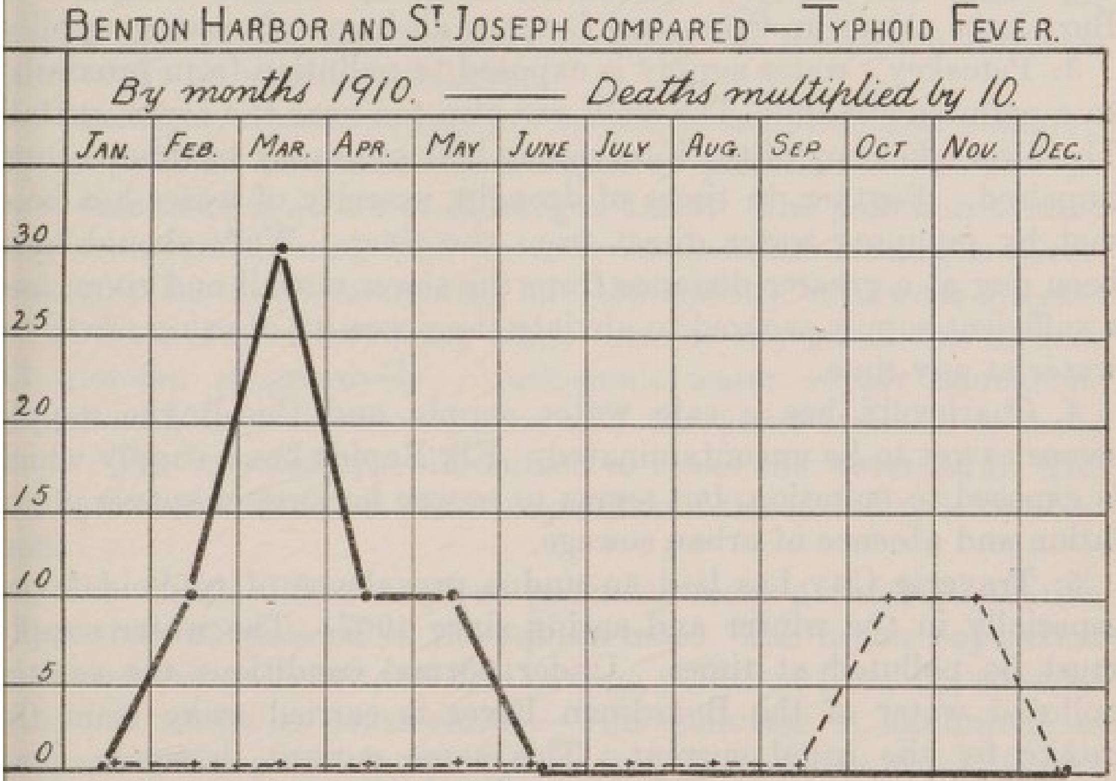


CHART 61.—Contrasting the sister cities, St. Joseph and Benton Harbor, in seasonal prevalence of typhoid fever during 1910. (St. Joseph, solid line; Benton Harbor, dotted line.)

take is only 1,500 feet offshore in 16 feet of water. The water at he intake can not escape pollution at times and this pollution may e especially dangerous in times of flood or high water in the St. oseph River.

The excessive prevalence of typhoid fever in March, April, and May well shown by Chart No. 60. Chart No. 61 for the year 1910 ows an outbreak of typhoid fever in St. Joseph, with its greatest tensity in March. It is interesting to compare the twin cities of enton Harbor and St. Joseph. Benton Harbor's supply has been om deep wells. Evidence of surface contamination has occa-onally been found, but in general the Benton Harbor supply has

been safe. New deep wells have recently been added and the water though having a high mineral content is safe bacteriologically. On the other hand St. Joseph's water supply is polluted with the sewage of both cities, and probably grossly polluted in the winter and spring months. Note the high prevalence of typhoid fever in St. Joseph in the first half of the year. In Benton Harbor, as might be expected, the typhoid curve reaches its height in October.

CONCLUSIONS.

1. The water supply of Mackinac Island may be classed as safe. Care should be taken to prevent the use of other supplies.

2. Cheboygan and Harbor Springs, and the intervening resorts on the "inland Lake Route," Mullet Lake, Topinabee, Indian River, Burt Lake, Alanson, Oden, and Conway all have safe water supplies.

3. Petoskey's water supply is exposed to pollution from proximity to a polluted stream. The wells are also too near the sewer outfall. The filter efficiency of the intervening lake sand may in time become impaired. Further, in times of drought, scarcity of water has been met by pumping water direct from the river. Wells should have been dug at a greater distance from the sewer outfall and river, and a sufficient supply secured to obviate the necessity of using raw river water at any time.

4. Charlevoix has a safe water supply and the Boyne supply seems as yet to be uncontaminated. Elk Rapids has a supply which is exposed to pollution, but seems to escape because of sparse population and absence of urban sewage.

5. Traverse City has had an undue prevalence of typhoid fever, especially in the winter and spring since 1907. The water supply must be polluted at times. Under normal conditions the sewage polluted water of the Boardman River is carried away from the intake by the usual current. This same current, however, may carry pollution to the intake from the hospital sewer situated to the west of the intake.

Under abnormal weather conditions currents undoubtedly are produced from east to west which would carry without difficulty the polluted Boardman River water to the intake.

It is the plain duty of the municipality of Traverse City to make its water supply safe at once. This can be done cheaply by the use of hypochlorite of lime. If further purification is desired to remove turbidity, filtration can be resorted to. The sewage disposal question is secondary, and the present system of disposal by dilution may suffice for years, provided the very necessary treatment or filtration of the public water supply is instituted without delay.

6. Manistee has a water supply which may be classed as safe. Much remains to be done in the work of eliminating insanitary

rivies and shallow wells. The typhoid fever rates have been low
cepting the years 1907 and 1908. The high rates in these years
ere due to excessive prevalence from August to October. The low
tes in winter months and the low yearly rates for the years, except-
g 1907 and 1908, must be ascribed to the influence of a good water
pply.

7. Ludington's water supply is exposed to pollution from Lake
arquette, which receives the entire sewage discharge of the city.
his pollution is especially liable to occur following heavy rains
d floods in the Pere Marquette River. In quiet weather Lake
arquette acts as a sedimentation basin for Ludington's sewage and
fords protection to the intake.

Ludington should install a temporary hypochlorite plant for
eating the public water supply at once. If desired, a filtration
ant could be substituted later.

8. Muskegon's water supply is exposed to pollution and undoubt-
ly is polluted at times. The degree of pollution is modified by
e sedimentation action of Muskegon Lake. The pollution is most
kely to occur following high water or floods in the Muskegon River.
uskegon has been fortunate, but the menace is always present
d disaster may occur at any time. As the city grows this menace
ll increase progressively. Muskegon's water supply should be
eated with hypochlorite of lime and the plant installed without
lay. The hypochlorite will suffice to make the water safe. The
stallation of a filtration plant may follow if the turbidity is trouble-
me.

9. The Grand River receives pollution from a rural population
less than 33 persons to the square mile. The urban population
the watershed is 205,000 and sewage pollution from the sewered
ies and towns is considerable. This pollution is minimized as
menace to the public health by the fact that no city except Grand
apids uses the river water as a source of supply. The sewage of
and Rapids, the greatest single source of pollution, has 40 miles
river flow for purification before discharge into the lake. The
arest waterworks intake to the mouth of the Grand River is Mus-
gon, 12 miles north. It is likely that the raw water at Muskegon
not greatly affected, if at all, by the discharge of the Grand River.

10. The water supply of Jackson is from deep wells in sandstone
d is safe. Jackson has a sewage disposal plant and is 140 miles
ove Grand Rapids, which is the only city using Grand River as a
urce of water supply.

11. Lansing's sewage goes untreated into the river. Lansing
s a safe water supply from deep wells. The only dangerous fea-
re of the Lansing supply lies in the fact that the water main passes
der the river. There is said to be a pressure of 70 pounds in the

main and consequently pollution of the water supply is unlikel from the river water.

12. Grand Rapids discharges its sewage into the Grand River, an recently a legal decision confirmed the right of Grand Rapids to us the river for purposes of sewage disposal. Grand Rapids has su fered severely from typhoid fever and this high prevalence has ha an interstate significance in the past. The greatest single factor i this high typhoid rate has been the contaminated shallow well There are also many insanitary privies. The elimination of these wel and privies necessitates a pure public water supply, which up to th present Grand Rapids did not possess. The installation of a moder filter plant is under way and Grand Rapids will soon have a saf public water supply. The health commissioner will then be in position to push vigorously the campaign against the shallow wel and insanitary yard privies.

Two things are essential in converting a polluted river water int a safe public water supply—a modern filter plant and expert supe vision. It is to be hoped that Grand Rapids will not neglect th latter requisite.

13. The present water supply of Holland is exposed to little po lution, because of the porous character of the soil. Increase c population will eventually force Holland to go to Lake Michigan fo an adequate public water supply. When this occurs the Lak Michigan water must be rendered safe by appropriate treatmen

14. Kalamazoo River drainage basin receives an insignifican amount of pollution outside of the sewage of Albion, Marshal Battle Creek, and Kalamazoo. None of the cities use the river a a source of water supply. Albion and Marshall contribute sma quantities of sewage to the Kalamazoo. Both cities have saf water supplies. Battle Creek takes its water supply from Minge Brook and Goguac Lake. This supply is exposed to contamination, a Goguac Lake is used as a summer resort. One-third of the popula tion depends upon shallow wells. The typhoid fever rate has bee high, with undue prevalence in January, February, March, and Apri The sewage of the city is discharged untreated into the Kalamazoo Battle Creek needs badly a safe water supply, and a campaign agains the shallow wells and insanitary privies.

Kalamazoo discharges its sewage untreated into the river. Th public water supply is probably uncontaminated. Typhoid feve rates have been comparatively low in Kalamazoo. The effect of th discharge of Kalamazoo River on the sanitary quality of Lake Michi gan water is a negligible quantity, except within a few miles of th mouth, at Saugatuck. The nearest waterworks intake is at Sout Haven, 20 miles south, which is probably unaffected from this source

15. South Haven's water supply can not escape pollution at times om South Haven's own sewage, and the public water supply should rendered safe by the use of hypochlorite of lime or by filtration.

16. The rural population on the drainage area of the St. Joseph iver is not excessive, but the sewage from urban communities with aggregate population of 130,000 is discharged untreated into the ream. The largest single contribution of sewage comes from uth Bend, but many miles of river flow make this a negligible antity at the river's mouth. The most dangerous pollution is used by the sewage of Benton Harbor and St. Joseph, near the outh of the river. This causes pollution at the St. Joseph water-orks intake. The polluted water of the St. Joseph River probably s no further effect on the water of Lake Michigan, as the nearest aterworks intakes, except St. Joseph, are South Haven, 23 miles rth, and Michigan City, 33 miles south.

17. Benton Harbor's water supply is from deep wells and may be assed as safe.

18. St. Joseph has a water supply exposed to contamination, and is undoubtedly polluted at times by the sewage of Benton Harbor d St. Joseph. The municipality should take immediate steps to stall a plant for treating the public water supply with hypochlorite lime, or by other adequate measures necessary to render the water fe at all times.

V. LAKE HURON, ST. CLAIR RIVER, LAKE ST. CLAIR, AND THE DETROIT RIVER.

LAKE HURON AS A SOURCE OF WATER SUPPLY.

As a source of water supply Lake Huron is ideal. Its enormous torage capacity insures storage for years of the amount of water lowing into it. In other words, if all inflow were stopped, it would ake years for this great basin to empty itself by losing daily the resent average daily flow through its only outlet, the St. Clair River. This fact of enormous storage, with the sedimentation and reat dilution afforded, narrows the question of sewage pollution to ne of local significance, so far as Lake Huron is concerned.

Owing to the enormous volume of water in Lake Huron and to the mall size of the communities situated thereon sewage pollution does ot alter the general quality of the lake water, except for a few miles n the vicinity of the sewer outfalls. The sewage of the cities in the aginaw Valley constitutes an exception. The polluted Saginaw River, emptying into Saginaw Bay, renders the water of Saginaw Bay nfit for drinking purposes without treatment or filtration. This ollution at certain seasons would be evident because of currents nd the shallowness of the bay for many miles. Outside of Saginaw Bay, and Thunder Bay in the vicinity of Alpena's sewers, the water f Lake Huron receives only a negligible quantity of pollution, and hould be of excellent quality.

T. CLAIR RIVER, LAKE ST. CLAIR, AND THE DETROIT RIVER AS SOURCES OF PUBLIC WATER SUPPLIES.

The water of Lake Huron, entering the St. Clair River, is relatively ure. Within comparatively narrow limits (about 70 miles) this nternational waterway, between Port Huron and the mouth of the Detroit River, receives the pollution of about 1,000,000 people. The vatershed is largely clay near the waterway, and surface pollution s washed into the streams quickly without the opportunity for urification afforded by a porous soil. The result is that at certain easons of rain and flood there is no part of the international water-vay between Port Huron and the mouth of the Detroit River which an furnish safe drinking water without filtration or other treatment.

Even if the sewage of Port Huron, Sarnia, Detroit, Windsor, and ther cities was eliminated from the problem, the water of the St.

Clair River, Lake St. Clair, or Detroit River could not be depended upon to furnish a safe water without filtration or treatment every day in the year. Following heavy rains, thaws, and floods the character of the water would be dangerous at times because of the surface washings of this large and populous area washed into a comparatively short stretch of running water.

The most favorable point for securing a good raw water is naturally above Detroit's sewer outfalls and below Lake St. Clair. This point avoids the nearest and largest single source of pollution (Detroit sewage) and allows the longest possible time of transit from the second largest single source (Port Huron), besides benefiting by the action of a great natural sedimentation basin (Lake St. Clair).

This point has virtually been selected for Detroit's waterworks intake. Even this favorable location is exposed to pollution and is undoubtedly polluted at times.

COAST STREAMS FROM THE STRAITS OF MACKINAC TO THUNDER BAY.

The coast streams from the straits of Mackinac to Thunder Bay are insignificant and drain a sparsely settled country. The largest community on this part of the lake shore has only 700 inhabitants. The present pollution is a negligible quantity.

THUNDER BAY RIVER DRAINAGE BASIN.

Thunder Bay River rises in the southern part of Montmorency County, in the northeastern part of the lower peninsula of Michigan, and flows in a generally northeasterly direction to within about 15 miles of its mouth, where it turns and flows southwestward, emptying into Thunder Bay at Alpena. The important tributaries on the right or south bank beginning at the sources are: Upper South Branch and South Branch. Nenelon River is a tributary of the South Branch. On the left or north bank there is only one tributary, the North Branch. The total length of the river, not following the bends, is about 50 miles.

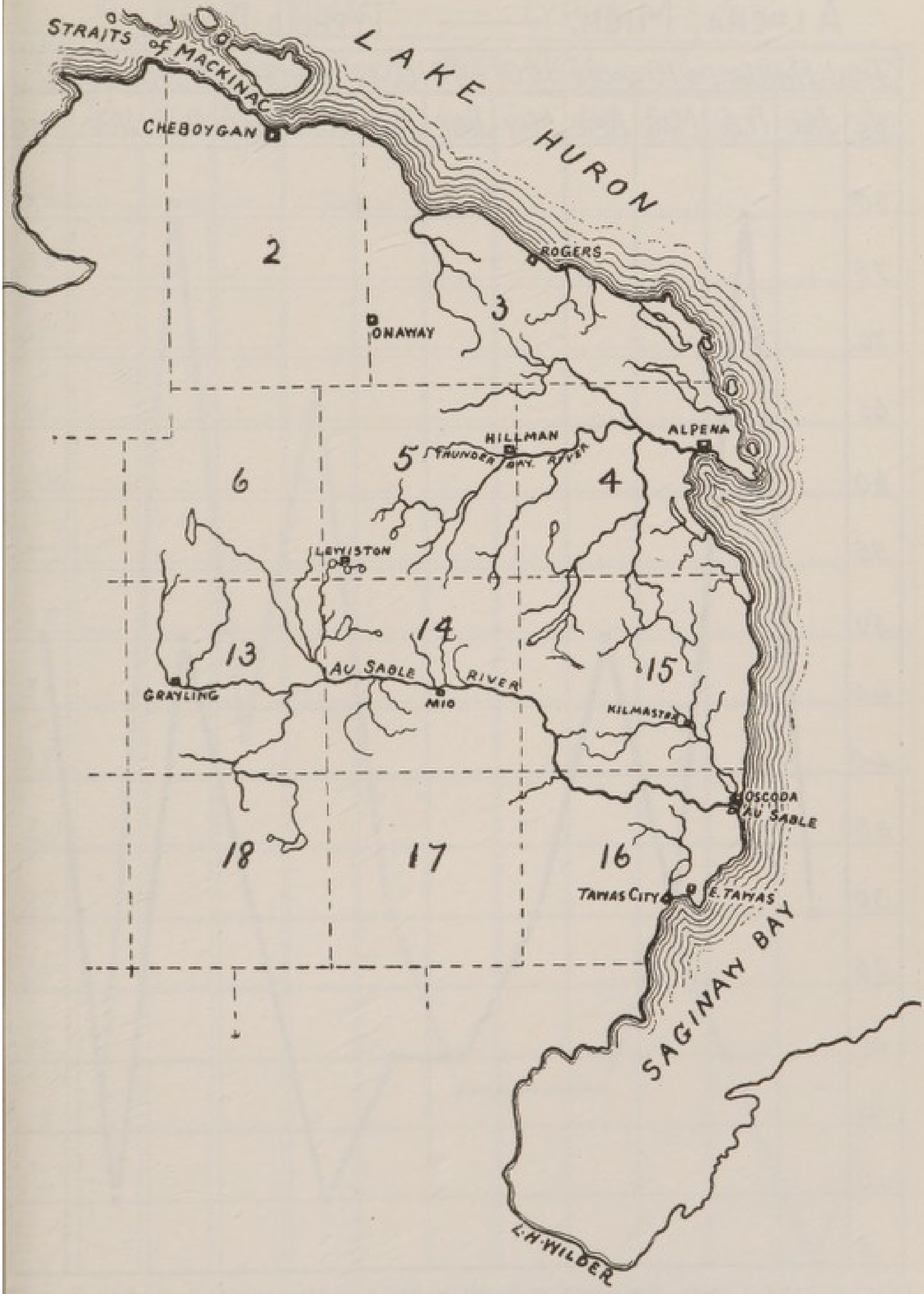
The upper portions of the drainage basin are in general level or undulating, the central part is rolling and hilly, and the lower portion is level, with shallow sand ridges. The elevation of the sources of the river is approximately 1,200 feet; the elevation of the mouth is 581 feet.

This drainage basin was formerly heavily timbered with Michigan pine. Most of the pine has been cut, but a large number of conifers, hardwoods, white birch, and cedar remains, so that this area may be said to be forested rather than cleared.

The only community of importance in the basin of the Thunder Bay River is Alpena.

ALPENA.

The city of Alpena has a population of 12,706 and is situated on Thunder Bay at the mouth of Thunder Bay River. Its sewage and



MAP 32.—Coast streams and watersheds from the Straits of Mackinac to Saginaw Bay.

lluted soil washings empty into the river. There are a few deep d some shallow wells, but the main water supply is pumped from

Thunder Bay. In 1905 the city purchased the plant of a private water company which had been installed in 1879. The plant had a considerable mileage of wooden mains and was in poor condition.

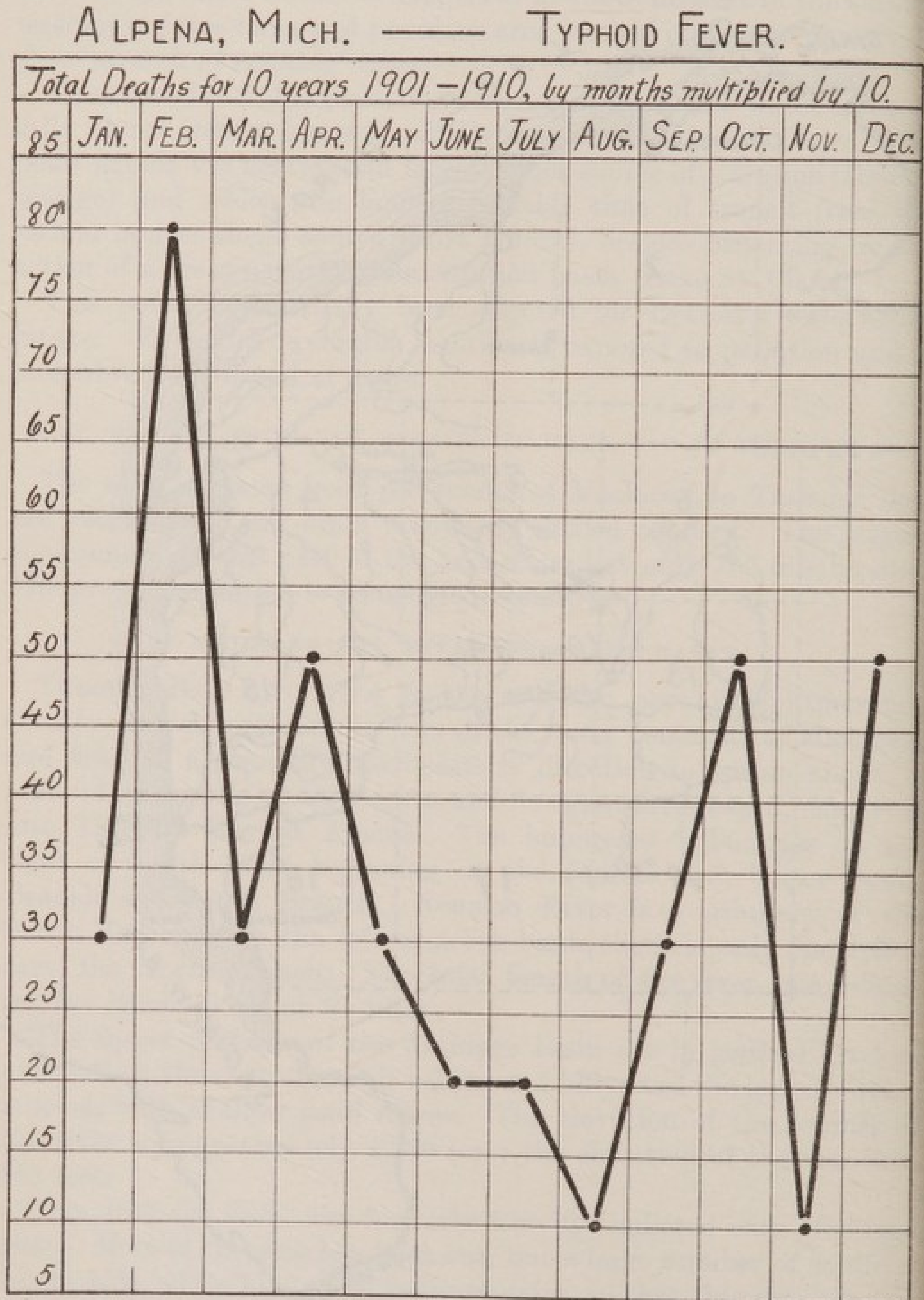


CHART 62.—Alpena, Mich. The month of greatest typhoid prevalence is February and the peaks for December and April equal that of October.

During the past five years Alpena has had an excessive typhoid fever rate, and there is reason to believe that the sewage pollution of

ts water supply was, in part at least, responsible. Chart 62 shows yphoid fever deaths per 100,000, multiplied by 10 to represent cases by months for 10 years, 1901–1910. In the month of February

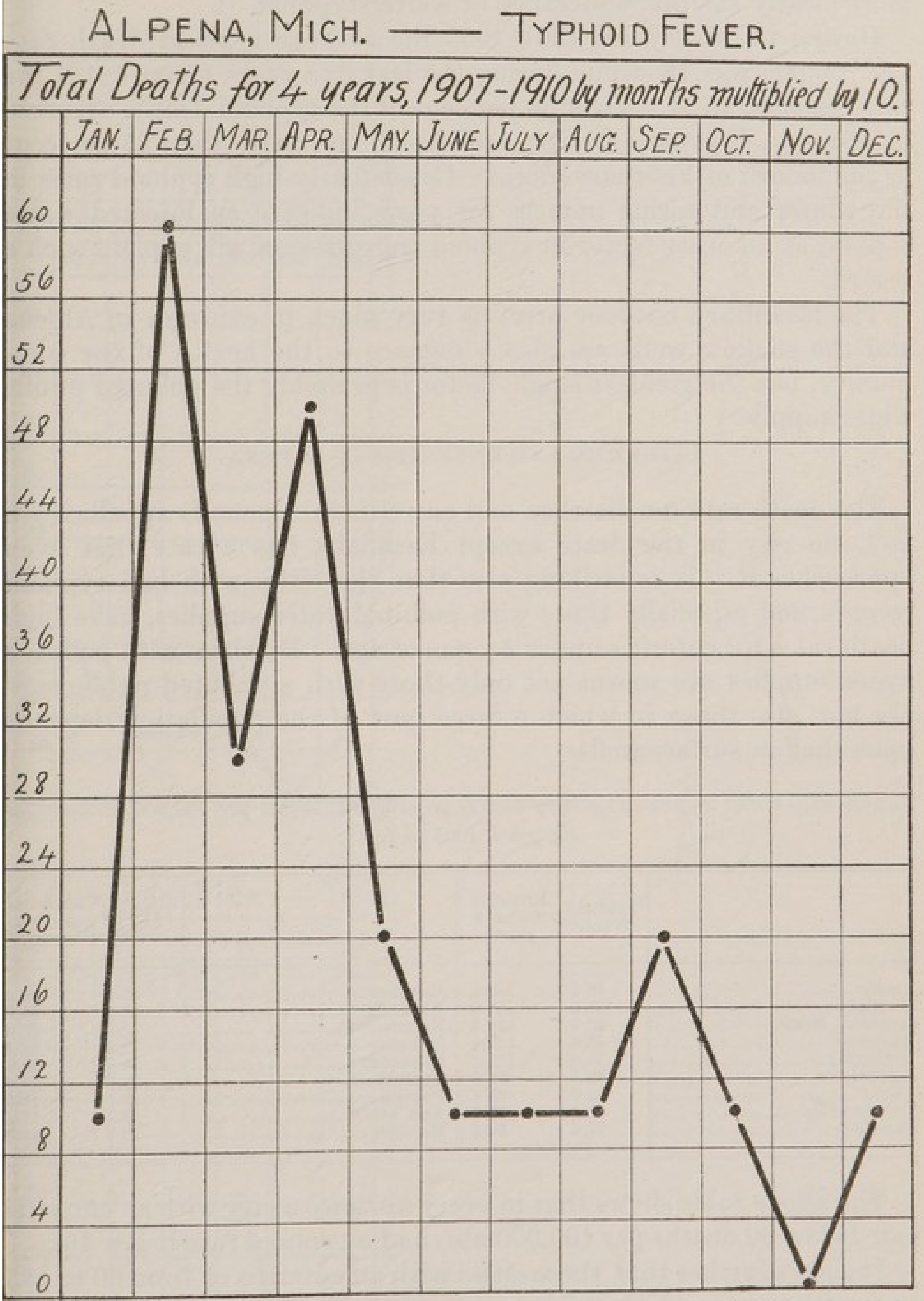


CHART 63.—Alpena, Mich. Typhoid fever, 1907 to 1910. The excessive prevalence in February, March, and April is notable.

occurred by far the highest typhoid mortality, indicating that the infection reached the victims in December or January. April is the

second worst month, indicating an infection in late February or March. The typhoid rate has been steadily increasing in Alpena, and chart No. 63 for the period of four years, 1907–1910, shows even more clearly the preponderance of winter typhoid.

During the five years 1901–1905 the average typhoid death rate per 100,000 was 18, while during the last five years (1906–1910) the rate has risen to 51. Over 50 per cent of the typhoid deaths occurred in January, February, March, and April, and more than 25 per cent in the month of February alone. Consistently high typhoid rates in the winter and spring months for years indicate an infected water supply, as no other factor in typhoid transmission will explain such a record.

The insanitary outdoor privy is very much in evidence in Alpena and the shallow wells are also a menace to the health of the community, but the greatest single factor is probably the polluted public water supply.

DIARRHEA AND ENTERITIS IN ALPENA.

The death rate for diarrhea and enteritis in Alpena is appalling; in fact, no city in the State except Escanaba has a rate that even approaches it. It is striking also that the cities with bad typhoid records, and especially those with polluted water supplies, have high death rates for enteritis under 2 years of age. By cities with polluted water supplies are meant not only those with a polluted public supply but also those in which a large part of the population depends upon shallow surface wells.

TABLE 40.—*Cities of from 12,000 to 50,000 population, deaths per 100,000, average for six years, 1905 to 1910.*

	Typhoid fever.	Enteritis under 2 years.		Typhoid fever.	Enteritis under 2 years.
Alpena	46.7	162.6	Lansing	33.3	56.6
Escanaba	136.0	185.0	Battle Creek	31.3	44.0
Sault Ste. Marie	52.3	134.6	Kalamazoo	29.5	59.0
Ironwood	43.5	124.5	Jackson	28.3	45.5
Ishpeming	15.6	113.0	Muskegon	24.7	59.8
Port Huron	42.0	78.6	Saginaw	24.6	42.0
Flint	43.0	63.0	Pontiac	24.5	44.0
Traverse City	42.0	53.5	Ann Arbor	22.1	18.6
Bay City	37.3	56.3	Manistee	20.8	48.0

The above table shows that in every instance a city with an enteritis rate below 60 deaths per 100,000 also had a typhoid rate below 40.

It shows further that those cities with an enteritis of from 60 to 185 had, with the exception of Ishpeming, typhoid rates above 40 and ranging as high as 136.

Chart No. 64 shows Alpena compared with Ann Arbor and Pontiac, cities of the same class.

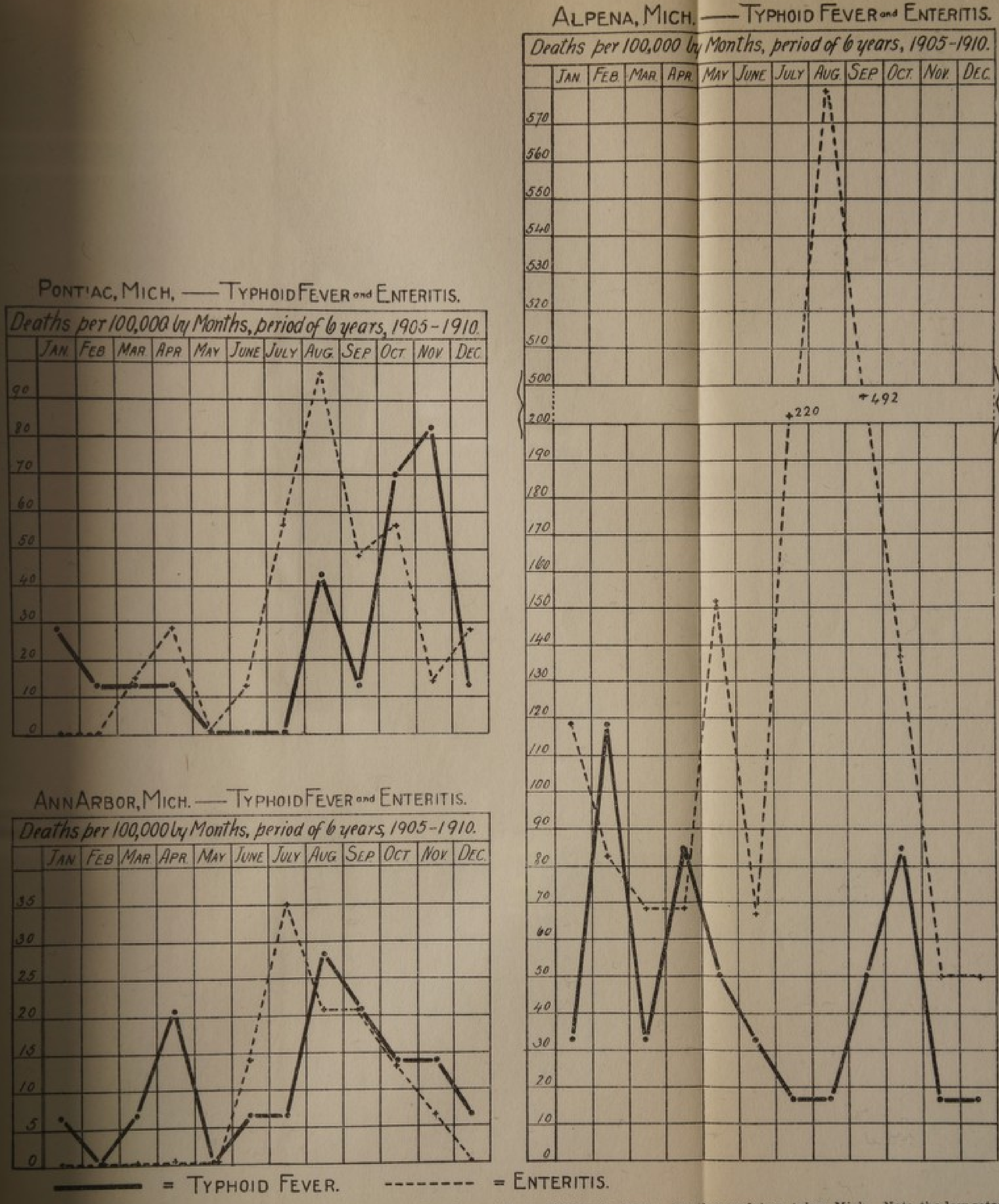


CHART 64.—Showing the relation between the curves for typhoid and enteritis in children in Alpena, Pontiac, and Ann Arbor, Mich. Note the low rates in Ann Arbor and Pontiac for both typhoid and enteritis in winter and spring. The contrast with Alpena is striking.

37958°—12. (To face page 220.)

The dotted line represents enteritis under 2 years of age and the solid line typhoid fever. The chart is based on death rates per 100,000 population per annum by months for a period of six years from 1905 to 1910. The excessive prevalence of enteritis and typhoid in Alpena should be noted, especially during the winter and spring months. It should also be noted that the enteritis curve corresponds in seasonal prevalence to the typhoid curve.

Although enteritis of children is a summer and autumnal disease, whenever there is winter typhoid there is also "winter" enteritis.

From the standpoint of prevention of mortality, and especially of infant mortality, it matters little whether these deaths recorded as diarrhea and enteritis are really typhoid, bacillary dysentery, or some other disease. The pertinent fact stands out prominently that this terrible mortality can be reduced enormously by the application of those measures which are necessary for the reduction or eradication of typhoid fever. It is necessary to have a safe water supply, a proper disposal of sewage, and to wage a campaign for the elimination of the insanitary privy and the dangerous shallow well.

AU SABLE RIVER DRAINAGE BASIN.

The drainage basin of Au Sable River lies in the northeastern part of Michigan. The river rises in the heart of the plateau region in the central part of northern Michigan, in the southern part of Otsego County, flows southward along the western side of Crawford County to Grayling, then turns and flows eastward across Crawford and Oscoda Counties, thence southeastward, and joins Lake Huron at Au Sable. The South Branch and the North Branch are the principal tributaries. The river is about 100 miles in length, not following the bends, and its total drainage area comprises about 2,010 square miles.

Along the lower 20 miles of the river the drainage basin is narrow, having an average width of about 5 miles; but farther up it is somewhat regular in shape, being about 40 miles long by about 30 miles wide. In its wider portion the basin consists chiefly of sand and gravel plains with undrained hollows. The elevation of the sources of the river is about 1,250 feet; at Bamfield, about 40 miles from the mouth, following the river, the elevation is approximately 850 feet and the elevation at the mouth is 581 feet.

This district was at one time noted for its white pine, but the area is now almost entirely cleared of its valuable native timber and is in great part covered with scrub conifers.

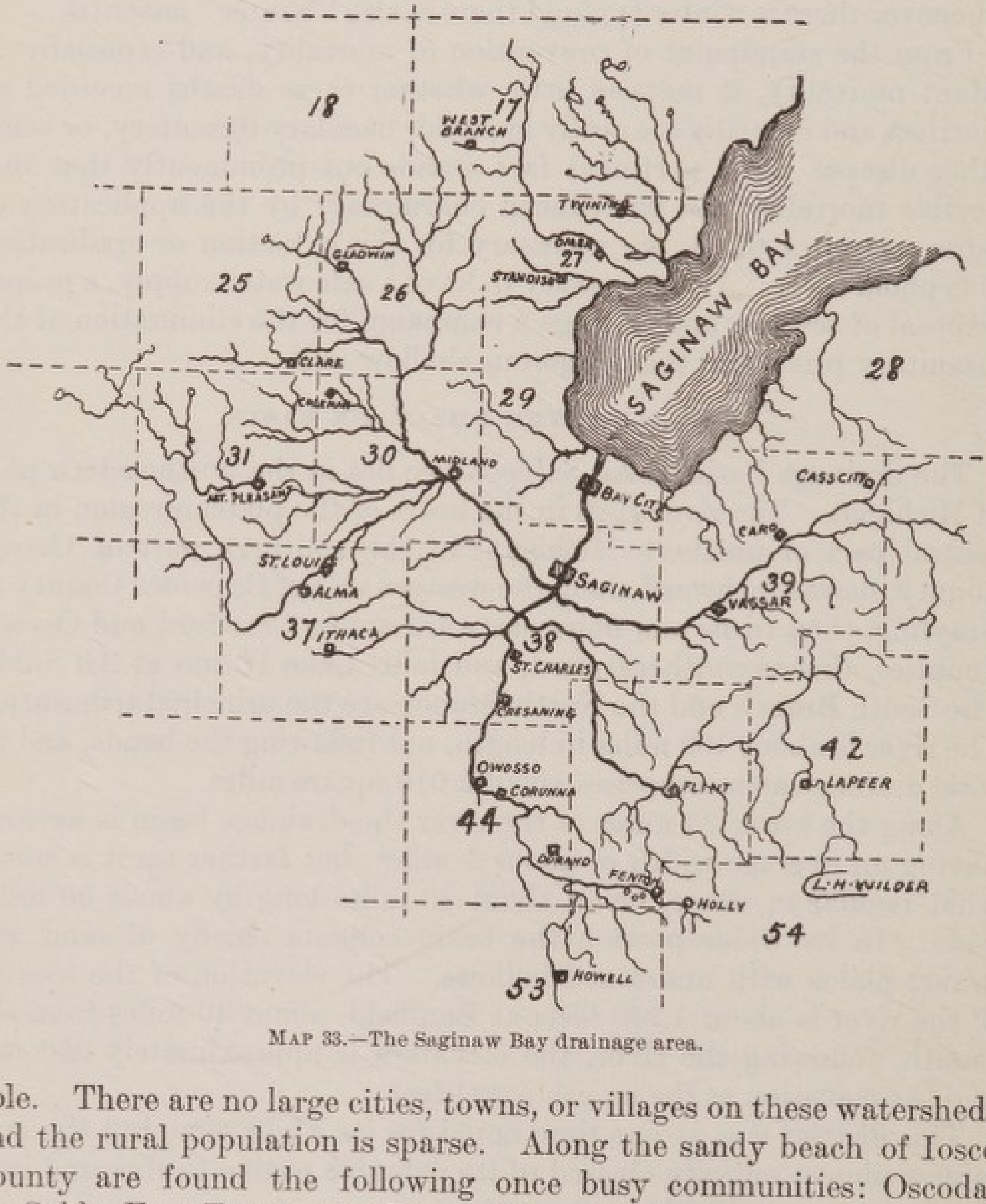
There are no cities or towns of importance in this drainage basin. The sparse rural population is scattered widely over a very sandy area, and present pollution from this source need not be considered.

THE SAGINAW BAY DRAINAGE AREA.

This drainage area may be subdivided into: (*a*) Coast streams of minor importance, including the Rifle Rivers; and (*b*) Saginaw River Basin.

COAST STREAMS.

The pollution of Saginaw Bay by the coast streams, including the Au Gres, Rifle, Pigeon, and Point aux Barques Rivers, is inconsider-



MAP 33.—The Saginaw Bay drainage area.

able. There are no large cities, towns, or villages on these watersheds and the rural population is sparse. Along the sandy beach of Iosco County are found the following once busy communities: Oscoda, Au Sable, East Tawas, and Tawas City. Their population is becoming less, and their importance declining rapidly with the falling off in the lumber industry.

City or village.	Population in decades.		
	1910	1900	1890
Au Sable	648	1,116	4,328
Oscoda	864	1,109	3,593
East Tawas	1,452	1,736	2,200
Tawas City	1,061	1,228	1,544

The amount of pollution from these decadent cities can be disregarded.

THE SAGINAW RIVER BASIN.

The Saginaw River is formed by the union of three streams—the Shiawassee, the Tittabawassee, and the Cass Rivers.

The drainage basin of the Saginaw River lies in the north-central part of Michigan, surrounding Saginaw Bay. The Saginaw is formed by three rivers—the Tittabawassee, which is the most northern; the Shiawassee, which extends to the south; and the Cass, which drains the eastern part of the basin. The Tittabawassee River rises in the southwestern part of Ogemaw County, flows southward to the central part of Midland County near Midland, then southeastward, and joins Saginaw River a few miles above the city of Saginaw. It receives the waters of Tobacco, Salt, and Pine Rivers, and Chippewa River, which discharges into the Pine. The Shiawassee River rises in the central part of Livingston County and flows northward into the Saginaw River. This river is really the main stream of the drainage basin, as it is a direct continuation of Saginaw River. Its principal tributaries are the Bad and Flint Rivers, the latter draining a larger area than the Cass River. Cass River, the smallest of the three tributaries that form the Saginaw, is formed by the union of the North and South Branches. Considering the South Branch as the main stream, the river rises in the western part of Sanilac County, flows northward until it crosses into Tuscola County, then southwestward into the Saginaw about opposite the mouth of the Tittabawassee. It has no important tributaries.

Saginaw River proper is only 20 miles long. The Tittabawassee and the Shiawassee are about 80 miles in length, and the Cass is about 75 miles long. None of these measurements takes into account the short bends and angles. The total drainage area of Saginaw River comprises about 6,260 square miles; of this area about 2,620 square miles belong to the Tittabawassee, about 2,420 square miles to the Shiawassee, and about 994 square miles to the Cass.

This drainage basin, like most of the river basins in Michigan, is covered with glacial drift and presents a flat surface, varied only by the valleys which the larger streams have cut from 10 to 30 feet below the plain. The depth of the surface deposits is not everywhere uni-

form, varying from a thin film to a layer 500 feet thick, but being in most places about 80 to 100 feet in thickness. To the southeast the drift coating is very thin, the maximum being about 40 feet, but toward the west it becomes thicker.

The sources of the Tittabawassee are about 900 feet above sea level and at Midland the elevation is about 600 feet. Saginaw Bay is about 581 feet above sea level. The elevation of the sources of the Shiawassee is about 920 feet; at Coruna the elevation is about 740 feet. The sources of the Cass are at an elevation of about 800 feet; at Vassar the elevation is about 610 feet The slope of the Saginaw River is so small that fluctuations in the elevation of Saginaw Bay caused by strong winds sometimes reverse the current in the river.

This section of Michigan has been about cleared of its timber, and the entire area is largely under cultivation, but some lumbering is still being done on the Tittabawassee.

Population of the Saginaw River Basin.

Counties.	Estimated population.	Counties.	Estimated population.
Gladwin	8,500	Shiawassee, part of	16,000
Midland	14,000	Livingston, part of	8,000
Isabella	23,000	Lapeer, part of	18,000
Saginaw	89,000	Tuscola, part of	17,000
Genesee	64,000	Sanilac, part of	11,000
Bay, part of	50,000		
Clare, part of	4,500	Total estimated population	337,000
Gratiot, part of	14,000		

With an area of 6,260 square miles the density of population would be 53 persons to the square mile. However, about 50 per cent of this total population is resident in 12 communities.

Urban population of the Saginaw River Basin.

Cities or villages.	Population, 1910.	Cities or villages.	Population, 1910.
Saginaw	50,510	Midland	2,527
Bay City	45,166	Howell	2,338
Flint	38,550	Fenton	2,331
Owosso	9,639	Durand	2,315
Mount Pleasant	3,972	Caro	2,272
Lapeer	3,946		
Alma	2,757	Total urban	166,323

If we subtract the urban population from the total we have a rural population of 171,000, a density of only about 27 to the square mile—manifestly too sparse a population to menace greatly the purity of the streams. On examining the list of urban communities given above it will be noted that 134,000 of the urban population is resident in the cities of Bay City, Saginaw, and Flint, and the sewage pollution from these cities is a factor of paramount importance in the consideration of sanitary conditions in the Saginaw River Basin.

OWOSSO.

The city of Owosso has a population of 9,639. It i situated on the Shiawassee River. The public water supply is from artesian wells and is pure. About 40 per cent of the population use the public supply; the rest use shallow wells. Typhoid fever rates in Owosso are relatively low. The average for 16 years, 1889–1905, was 24.4. In the last few years the rates have been higher.

Deaths per 100,000, typhoid fever: Average 16 years (1889–1905), 24.4; 1906, 10.7; 1907, 10.5; 1908, 31.3; 1909, 31.3; 1910, 31.3.

Owosso has sewers to which about 3,000 people have access, but about three-fourths of the population still depends upon privies. The sewage is discharged by four principal outlets and several smaller ones into the Shiawassee River without treatment of any kind.

FLINT.

The city of Flint has a population of 38,550 (1910), and is situated on Flint River at the mouth of Thread Creek. The public water supply is taken from Flint River above the city and delivered unfiltered. The amount used for drinking purposes is problematical. There are many deep wells in Flint and a great part of the public supply is used for manufacturing, fire purposes, and lawn sprinkling. In spite of the fact that deep wells are numerous and the public water supply is regarded with suspicion, there is no doubt that many people do use the public supply for drinking and domestic purposes.

For 16 years (1889–1905) Flint had an average typhoid rate of 25 deaths per 100,000 population. The rates since have been much higher.

Typhoid fever deaths per 100,000: Average, 16 years (1889–1905), 25; 1906, 38.5; 1907, 44; 1908, 67.6; 1909, 54; 1910, 105.

The pollution of the river by the sewage of Flint is considerable. There are nearly 40 miles of sewers discharging by 27 outlets into Flint River and Thread Creek. There is no sewage treatment.

Chart No. 65 shows the steady rise of the typhoid fever rate since 1905. The present excessive prevalence (1910) of typhoid fever in Flint is probably greater than in any similar city in the registration area of from 30,000 to 40,000 population. Such notorious typhoid centers as Niagara Falls, N. Y., and Escanaba, Mich., had lower rates than Flint for 1910.

Chart No. 65 also shows the relation between typhoid fever and the deaths in children under 2 years recorded as enteritis or diarrhea. It will be observed that the deaths from enteritis have increased coincidently with the typhoid increase which began in 1905.

The reasons for the abnormally high rate in Flint should be ascertained by the State and local authorities at once. In 1910 the rate

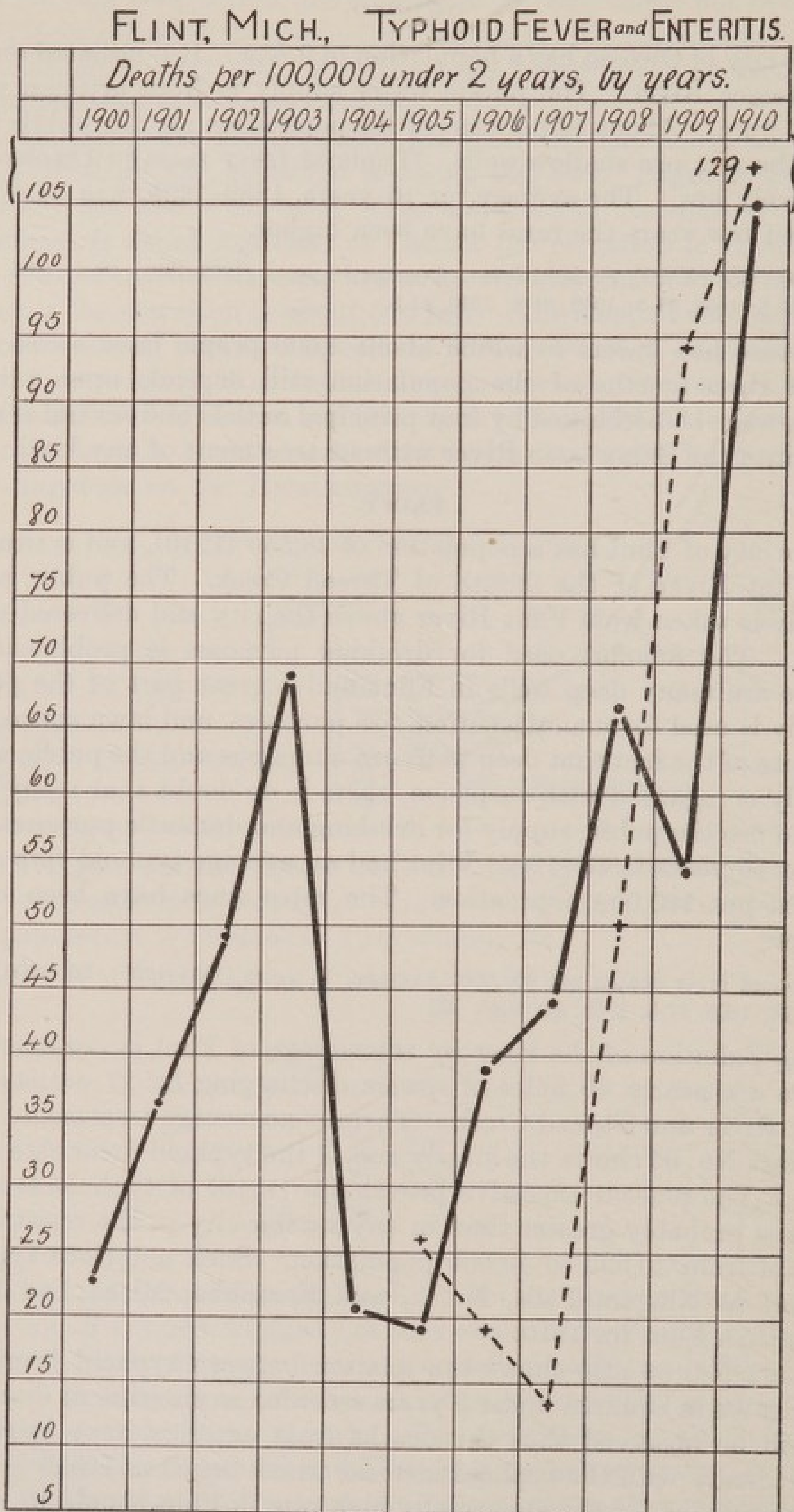


CHART 65.—Showing the relation between typhoid fever and enteritis in Flint, Mich., as evidenced by the steady synchronous increase in both diseases since 1907. The dotted line represents enteritis.

was over 105 deaths per 100,000. Flint's rapid growth in the past decade is undoubtedly the most important factor in the great increase of typhoid fever prevalence. For the purpose of the present investigation the important and pertinent facts are that there is an excessive prevalence of typhoid fever in Flint and that the untreated sewage and drainage of Flint reaches the Saginaw River by way of the Flint River to pollute the water supplies of the cities situated below.

Chart No. 66 shows the close relation in seasonal prevalence between typhoid fever and enteritis. Flint is in great need of a pure public water supply and a proper sewerage system. In addition, a campaign of education should be conducted and a vigorous campaign against the insanitary outdoor privies started as soon as possible. It would be advantageous also to have an investigation to determine the real cause of the excessive mortality of children under 2 years from what is called enteritis.

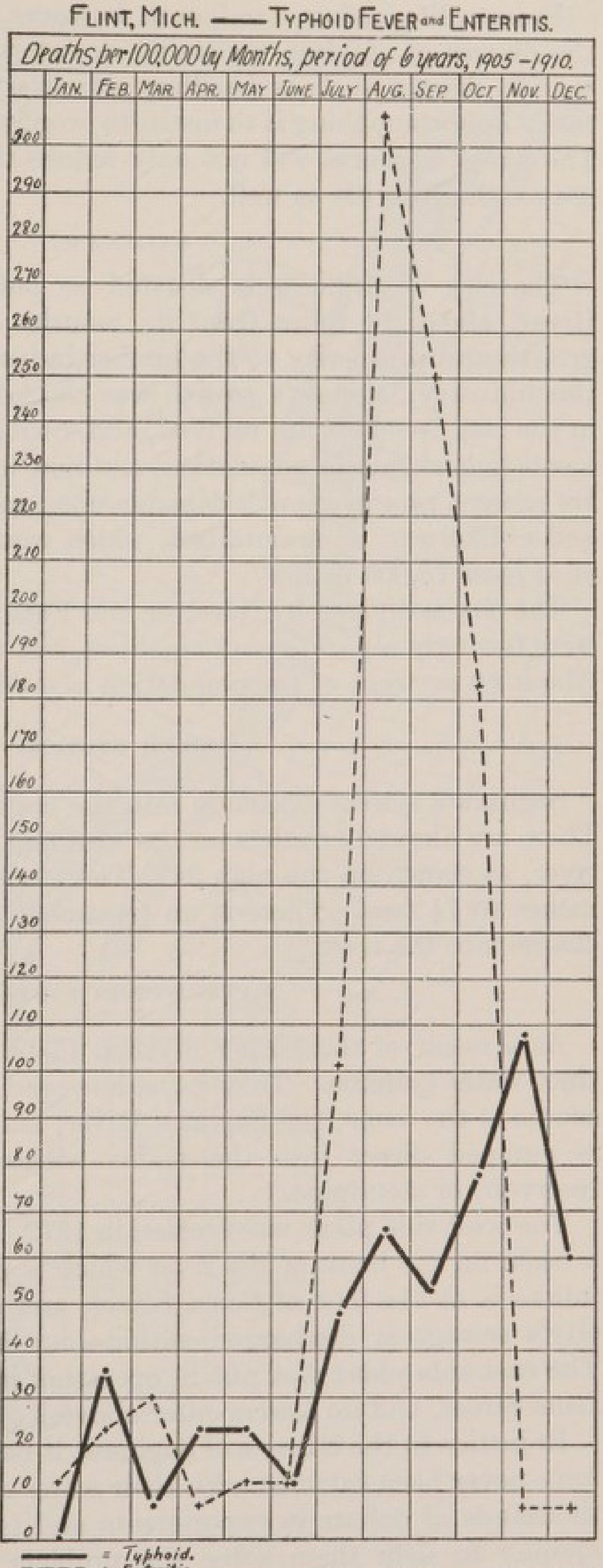


CHART 66.—Seasonal prevalence of typhoid fever and enteritis, in Flint, Mich. The distribution by months is similar in both diseases.

From a life-saving standpoint, however, it matters little whether the disease of children registered as enteritis is really enteritis or a specific disease such as bacillary dysentery or typhoid fever. The really important thing is to institute prophylactic measures promptly. The same measures will not only reduce the typhoid fever but will reduce the enteritis as well.

SAGINAW.

The city of Saginaw is situated on both banks of the Saginaw River, about 16 miles from its mouth. It owed its early rapid growth and prosperity to the lumber industry. With the decline of this industry Saginaw's growth was checked from 1890 to 1900, but in the last decade it has revived, and, owing to new industries, made a substantial gain in population, and now has a population of 50,510. Its present rate of growth depends upon solid, substantial industries and is likely to be maintained, which would result in a population of at least 75,000 in 1930.

The city is divided by the river into East and West Saginaw, which were formerly separate municipalities, but united in one city in 1890. About 60 per cent of the population is resident on the east side.

SEWER SYSTEM.

Saginaw's sewers discharge into the Saginaw River or its bayous. There are about 12 outlets on the west and 14 on the east side of the river, as shown on the map 34. These outlets vary in size from 12 inches to 7½ feet. There is no treatment of the sewage before discharge into the river.

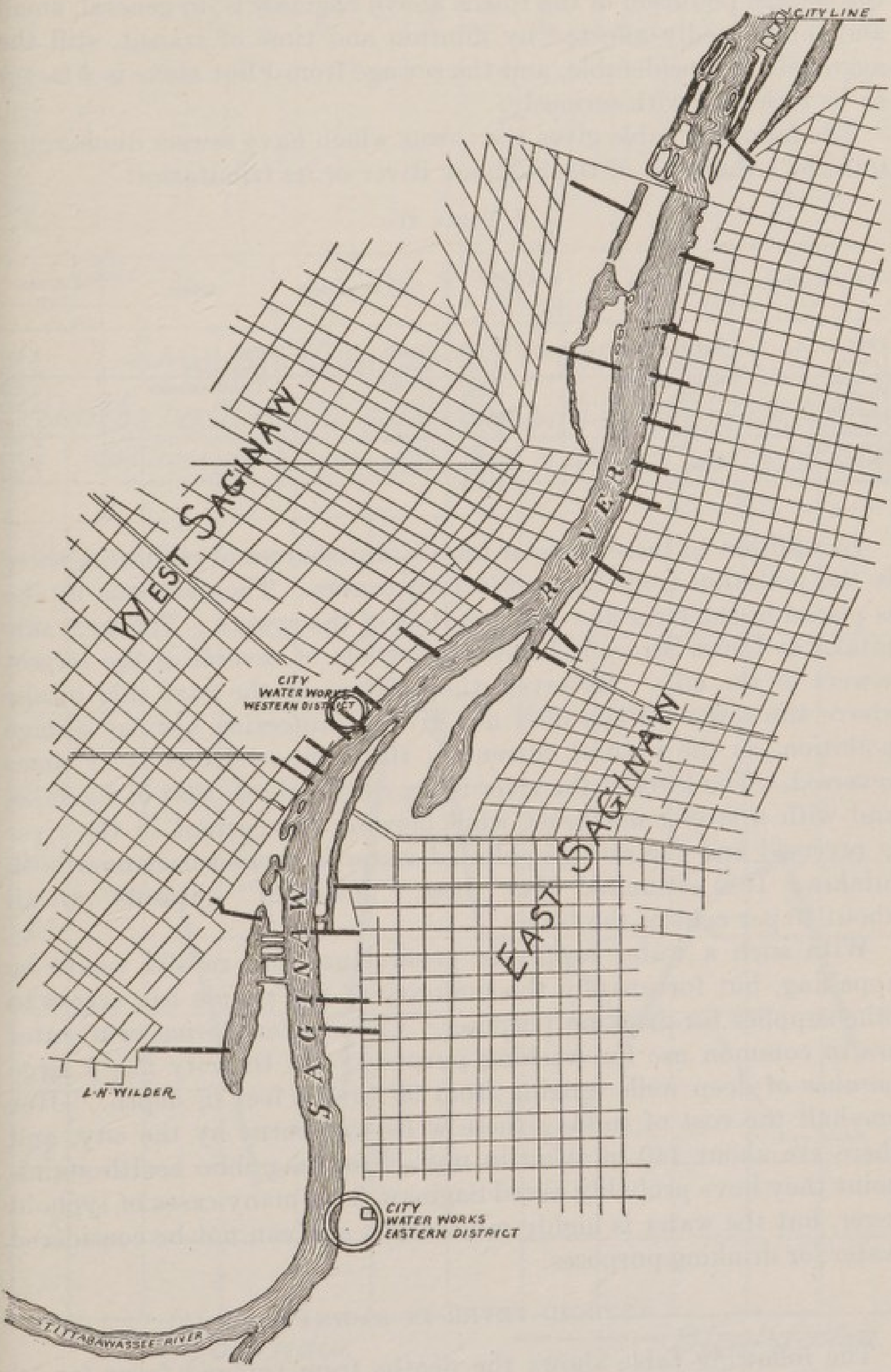
WATERWORKS SYSTEM.

As a result of the former division the city has inherited two distinct water systems. They have, however, points in common. The source is the same, the Saginaw River, and in both cases the water is pumped direct into the mains without sedimentation basins, reservoir, or standpipe.

The west side plant was erected in 1872. The water is taken from a basin on the bank of the river which is protected by piling. The intake is at the foot of Court Street, and a large proportion of the city's sewage is discharged within four blocks above the intake. The east side plant was put in operation in 1873. The intake is at Lane Street, and no sewers enter above it.

In justice to the citizens of Saginaw, it must be admitted that they have never been satisfied with their water supply. They have spent thousands of dollars in experiments and tests and have had expert opinion to help them solve the problem. It has finally become apparent to everyone that to obtain a satisfactory supply for a city

of such size in the Saginaw Valley other sources than groundwater must be sought, and the future supply will probably be from the Saginaw or Tittibawassee Rivers, filtered by mechanical filtration.



MAP 34.—City of Saginaw, Mich., showing sewer outlets. Waterworks and intakes are indicated by circles.

Sources of pollution of Saginaw's water supply consist of the sewage and wastes from communities upon the Flint, Cass, Tittibawassee, and Shiawassee Rivers, and the sewage of Saginaw itself. While the sewage pollution of the towns above Saginaw is, in general, small and undoubtedly affected by dilution and time of transit, still the aggregate is considerable, and the sewage from Flint alone is a factor to be reckoned with seriously.

The following table gives the towns which have sewers discharging into the tributaries of the Saginaw River or its tributaries:

TABLE 41.

City or village.	River.	Population.	City or village.	River.	Population.
Flint	Flint	38,550	Holly	Cass	1,537
Lapeer	do	3,946	Mount Pleasant	Chippewa	3,972
Owosso	Shiawassee	9,639	Midland	Tittabawassee	2,527
Fenton	do	2,331	Clare	do	1,350
Durand	do	2,315	St. Louis	do	1,940
Corunna	do	1,384	Alma	Pine	2,757
Chesaning	do	1,363	Caro	Cass	2,272
Howell	Cass	2,338	Vassar	do	1,659
Ithaca	do	1,876			

In addition to these more or less distant sources of pollution, there is the pollution from Saginaw's own sewers. The east side intake is placed in the river above the outlets of the sewers. The west side intake at Court Street is below the outlets of several of the largest sewers in the city. However, the position of the east side intake above the sewer outlets does not give it protection against sewage pollution, as the natural current in the Saginaw River is at times reversed. The level of the river is very little above that of the lake, and with a strong northeast wind blowing the current in the river is reversed and the sewage-polluted water is carried back over both intakes. It is estimated that these "upstream" currents prevail about 10 per cent of the time.

With such a water supply in general use the results would be appalling, but fortunately the majority of the people has access to othe supplies for drinking purposes. Cisterns for storing rain water are in common use for washing purposes, and the city has a large number of deep wells ranging from 90 to 140 feet in depth. Over one-half the cost of sinking these wells was borne by the city, and there are about 140 of them in use. From a public health standpoint they have probably saved Saginaw from many cases of typhoid fever, but the water is highly mineralized and can not be considered water for drinking purposes.

TYPHOID FEVER IN SAGINAW.

The following table shows the deaths from typhoid fever for 10 years, 1901–1910, by months:

TABLE 42.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1901	1	1	......	......	......	2	......	1	3	1	2	2	13
1902	1	1	......	......	......	......	......	1	......	1	......	......	4
1903	......	2	......	......	......	1	1	......	......	......	1	......	5
1904	1	3	4	......	6	2	1	1	2	1	......	3	24
1905	1	4	......	......	......	2	2	1	1	2	......	2	15
1906	......	3	1	......	1	1	1	......	1	2	1	1	12
1907	1	......	1	......	......	......	1	2	3	......	1	1	10
1908	1	......	......	......	1	2	......	2	......	3	4	......	13
1909	1	2	1	1	2	1	1	1	......	......	2	1	13
1910	......	......	......	2	1	......	2	1	4	......	1	......	11
Total, by months	7	16	7	3	11	11	9	10	14	10	12	10	120

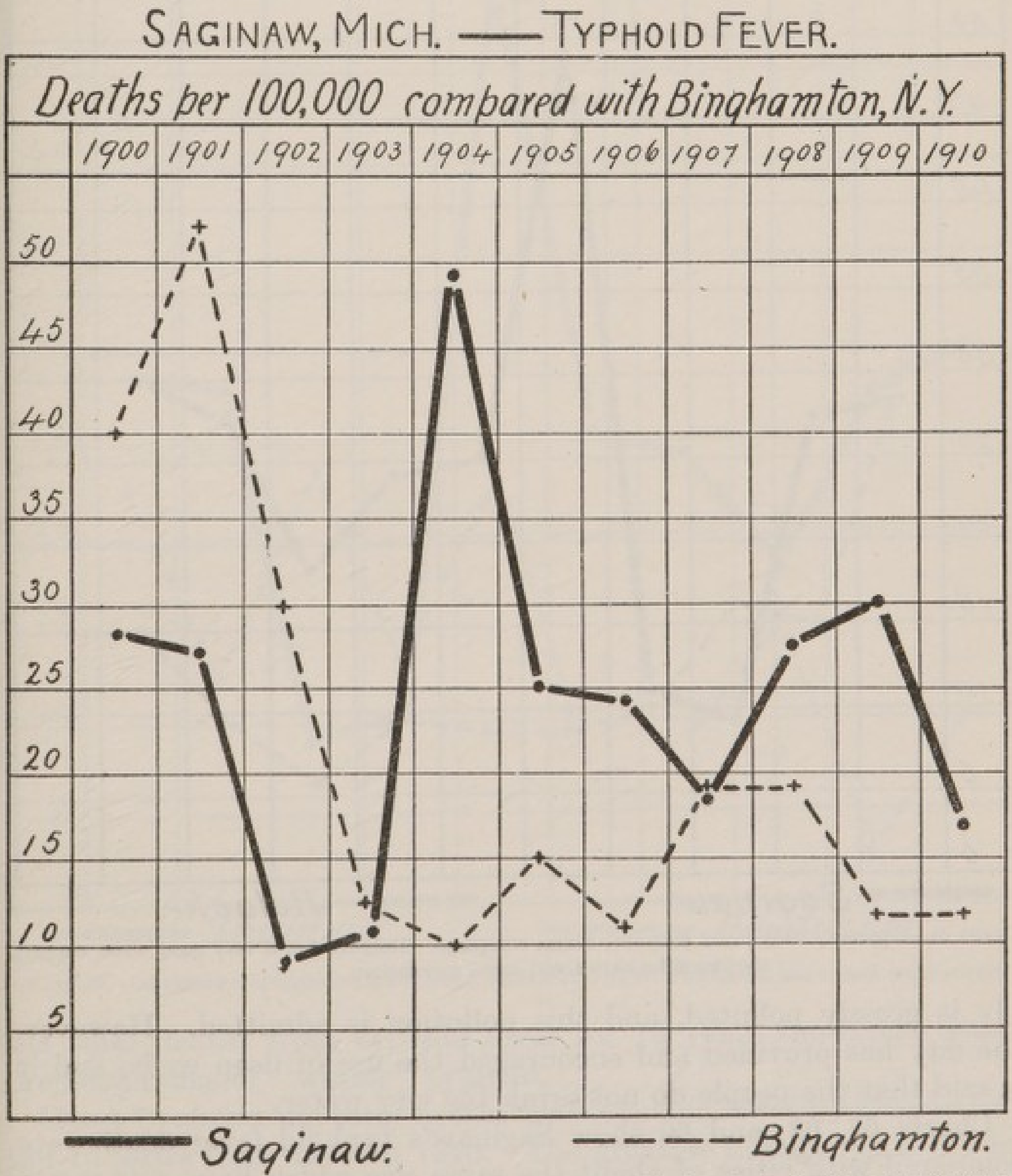


CHART 67.—Binghamton, N. Y., contrasted with Saginaw, Mich. Binghamton had a filter plant installed in 1902–3.

For 16 years prior to 1905 Saginaw had an average typhoid death rate of 20 per 100,000 population. In 1904 the rate jumped to 49.3, and has been consistently high every since, except in 1907, when the rate feel to 18.1.

The rate is altogether too high for a city like Saginaw, where economic and sanitary conditions are fairly good, and indicates that something is wrong with the water supply. The public water sup-

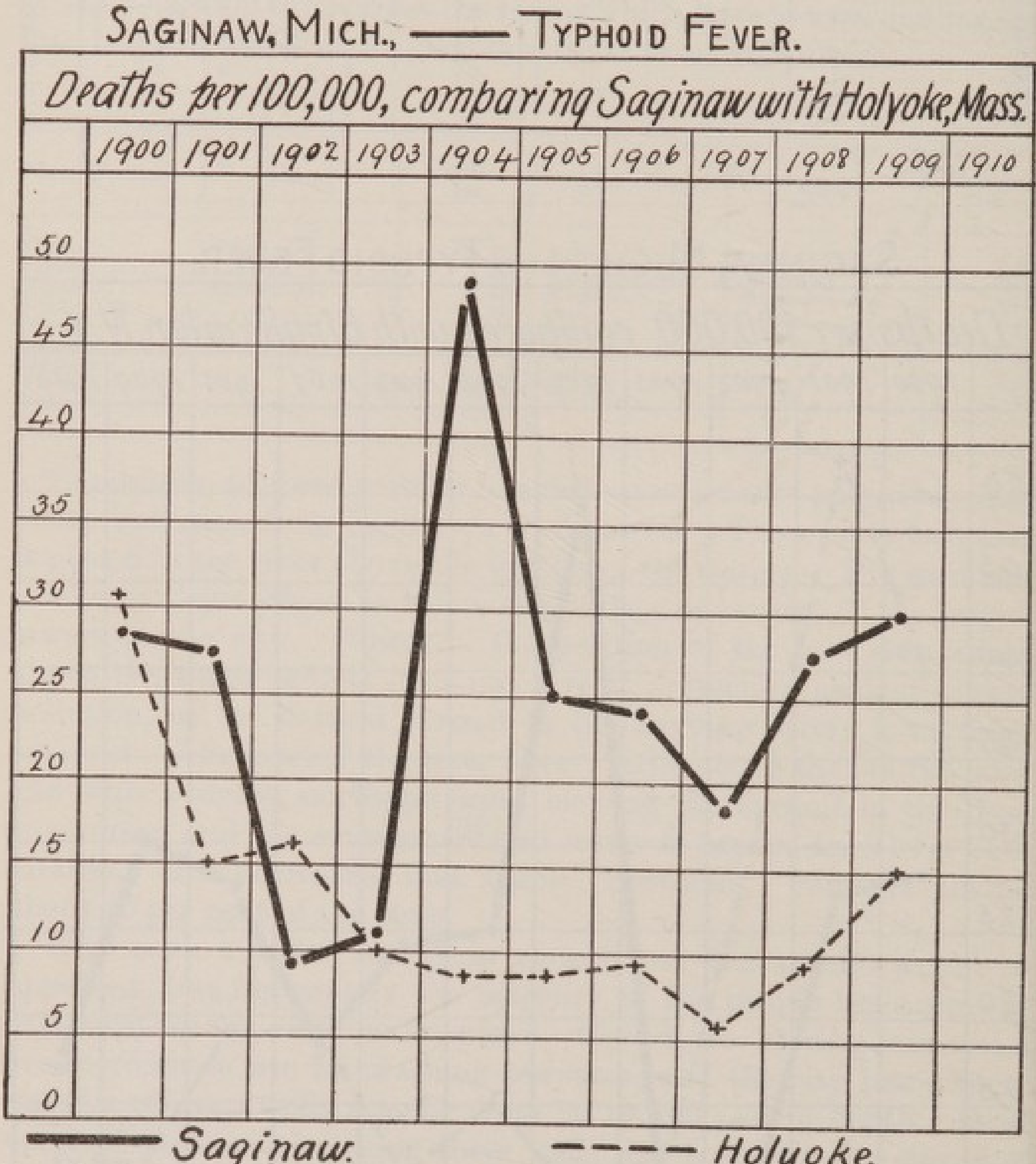


CHART 68.—Saginaw, Mich., and Holyoke, Mass., compared. Holyoke has a very good water supply; the two cities have about equal populations.

ply is grossly polluted, and this pollution is admitted. However, the city has provided and encouraged the use of deep wells, and it is said that the people do not drink the city water.

Charts 67, 68, and 69 show Saginaw's typhoid fever death rate compared with cities of about the same size which have safe water supplies.

It will be noted from the table of deaths by months that in the years when an excessive number of typhoid deaths were recorded, the majority of these occurred in the winter and spring. In fact,

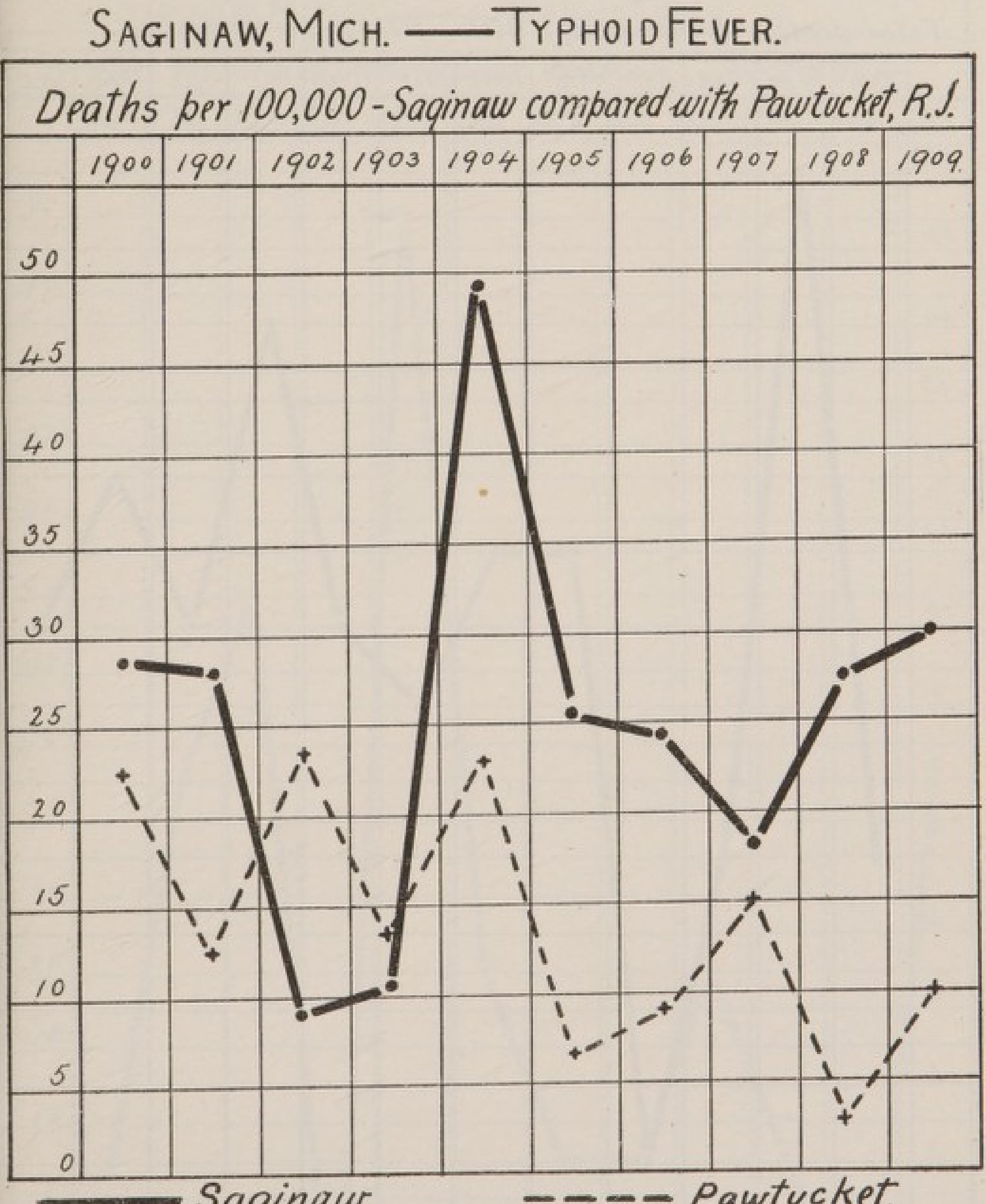


CHART 69.—Comparison of Saginaw, Mich., with Pawtucket, R. I. Pawtucket has a good water supply.

the total deaths from typhoid fever for 10 years shows the same preponderance of "winter" typhoid.

Chart 70 shows the total deaths from typhoid fever by months for the 10 years from 1901 to 1910. The greatest number occurred in February.

Chart 71 shows even more clearly the part played by winter and spring typhoid in 1904, the worst typhoid year of the decade. To indicate the date of infection the apices of the typhoid curve in

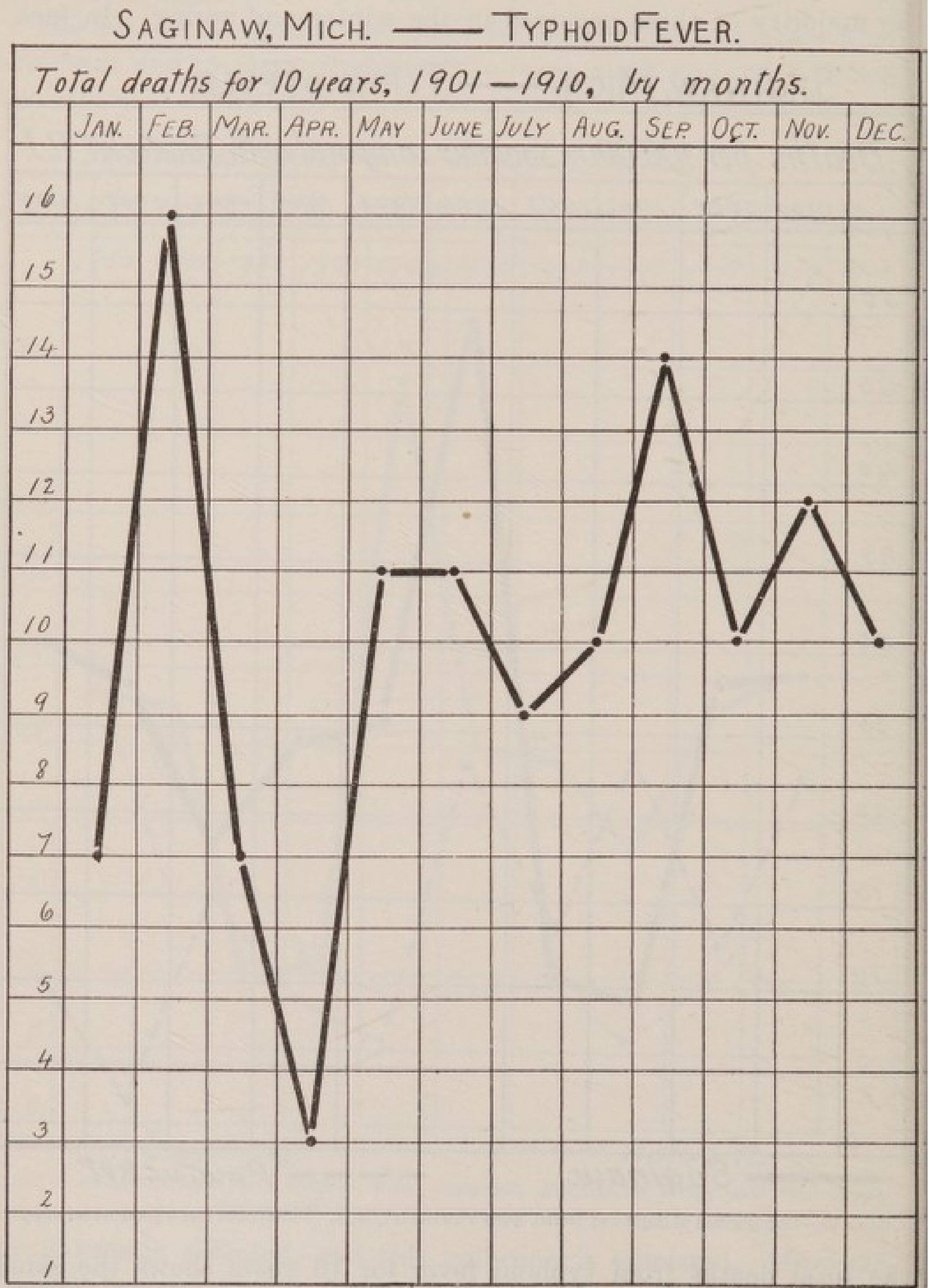


CHART 70.—The seasonal prevalence chart of typhoid fever in Saginaw shows February to have the greatest number of deaths.

March and May should be moved back about six weeks, as the chart is made from typhoid deaths.

BAY CITY.

Bay City has a population of 45,166. It is situated on the Saginaw River, occupying both banks to within 2 miles of its mouth. Its early history, like that of Saginaw, was closely associated with the

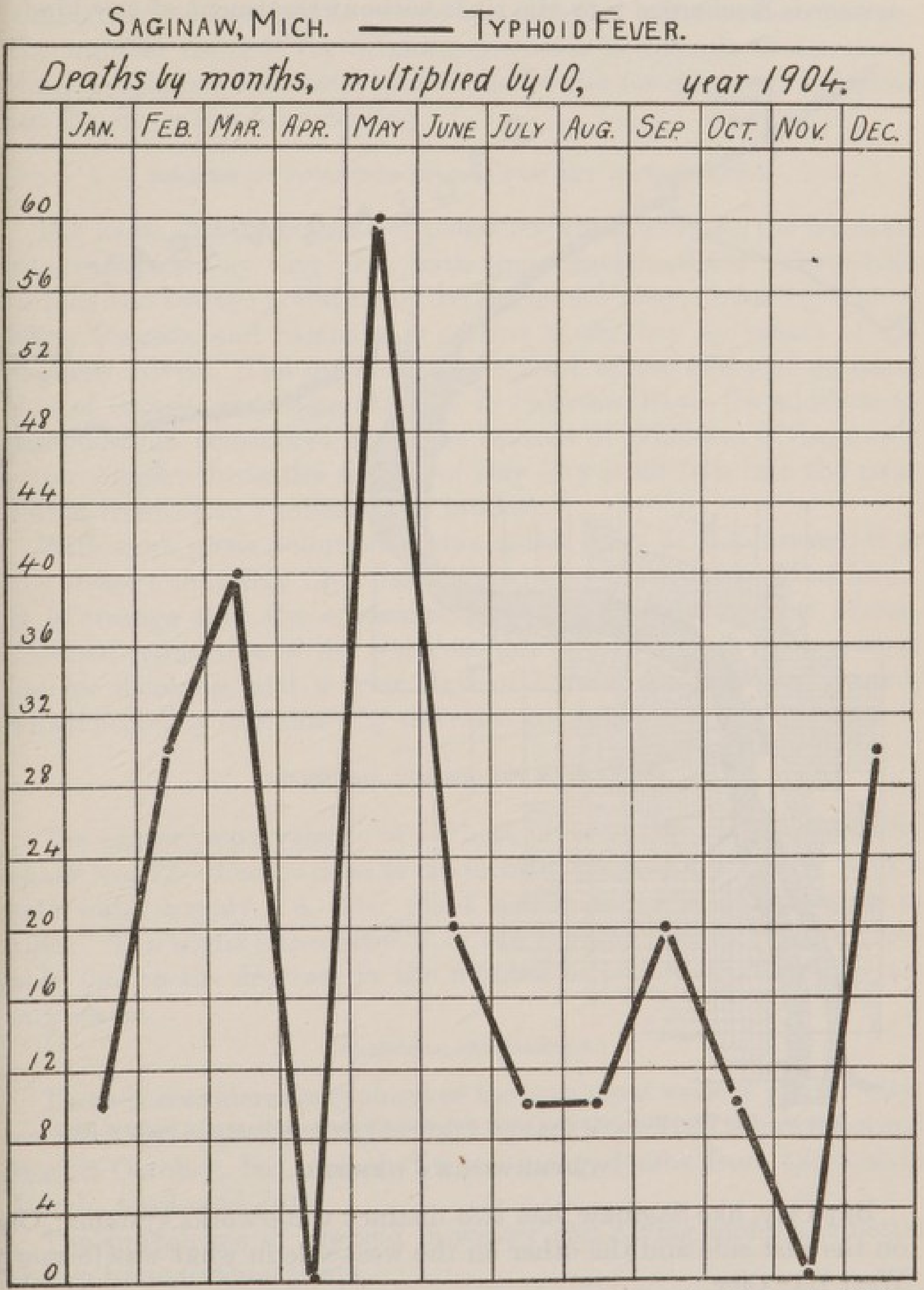
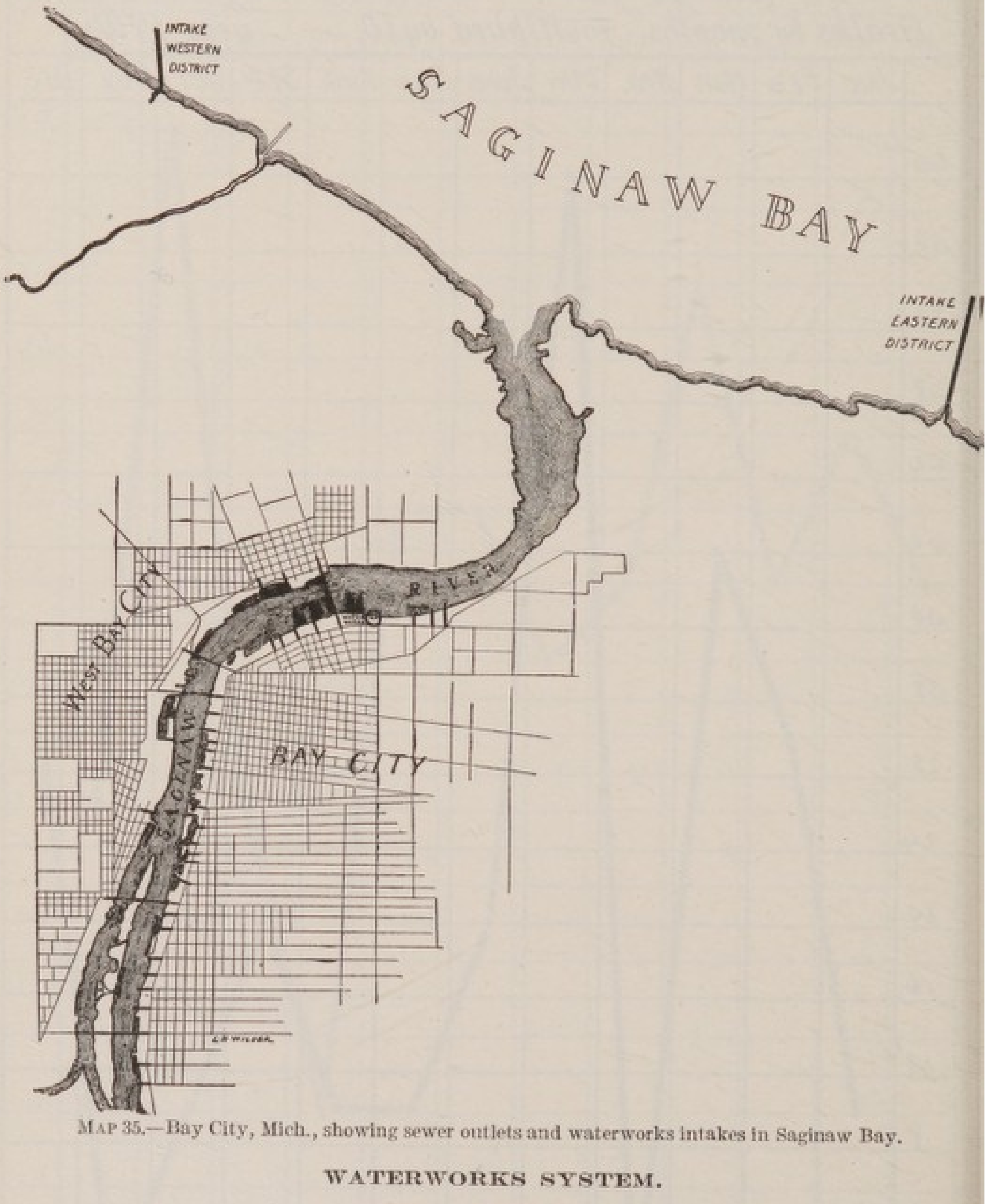


CHART 71.—The monthly distribution in 1904 shows a great preponderance of deaths from typhoid fever in the winter and spring months.

lumber industry. Bay City proper is on the east bank, and what was formerly West Bay City lies across the river.

SEWER SYSTEM.

The entire sewer system of Bay City discharges into the Saginaw River. There are 29 outlets on the east and 6 on the west side of the river. These outlets vary in size from 2 to 5 feet. The crude sewage is discharged into the river without treatment of any kind.



MAP 35.—Bay City, Mich., showing sewer outlets and waterworks intakes in Saginaw Bay.

WATERWORKS SYSTEM.

Bay City, like Saginaw, has two distinct waterworks systems: One on the east side and the other on the west side in what was formerly West Bay City.

The east side intake is situated in Saginaw Bay, $3\frac{1}{2}$ miles east of the mouth of the river and 1 mile offshore in 4 feet of water. The water flows by gravity to the city limits and is then pumped into the

mains. The west side intake is also in Saginaw Bay, 3 miles west of the mouth of the river, and is one-half mile offshore in 9 feet of water. The west side pumping station is on the bay shore, and the water is pumped from there into the mains.

About 70 per cent of the people have the city water in their houses. The number using it for drinking purposes is difficult to ascertain. Many people use well water and bottled water for drinking, and some use the city water after boiling.

SOURCES OF POLLUTION OF THE BAY CITY WATER SUPPLY.

The same distant sources of pollution which affected the Saginaw intakes affect Bay City also, with some modifications. The whole surface and sewage pollution of the Saginaw Valley, including that of Flint, Owosso, and Saginaw, is carried to the bay by means of the Saginaw River. The modifications consist of the effect of dilution, time of transit, and sedimentation in Saginaw Bay. In addition to the pollution considered above as sources of pollution of Saginaw's water supply, the entire sewage of Bay City itself falls into the river within from 5½ to 7 miles of the intakes.

With such gross pollution within a few miles of the intakes, it is not strange that Bay City has suffered severely from typhoid fever. It is strange that the epidemics have not been even more severe. The bad reputation of the water no doubt prevents its more general use for drinking, and a great deal of bottled spring water is used, which probably explains why the rates are not higher.

TYPHOID FEVER IN BAY CITY.

The excessive prevalence of typhoid fever in Bay City is shown by chart No. 72. Comparison is made with Binghamton, a city with a safe water supply. A filter plant was installed in Binghamton in 1902. The slight improvement in the typhoid rate in 1910 is probably due to the decrease in the number of people drinking the raw city water.

SEASONAL PREVALENCE.

There is considerable typhoid of the autumnal variety in Bay City, and the aggregate by months for 11 years 1900–1910 shows a normal rise in October, but also shows too many deaths from typhoid in March, April, and June.

The prevalence of typhoid in winter and spring months is better shown by individual years.

Chart No. 74 shows the deaths by months for three years, 1907–1909, multiplied by 10 to represent cases. The deaths in April during this period equal those of September, and June has the next highest number.

One thousand nine hundred and four also illustrates the atypical typhoid curve of Bay City. The majority of the deaths in this year occurred in the three months, January, April, and May. In addition to this winter and spring typhoid, there was a normal rise in the number of deaths from typhoid in October.

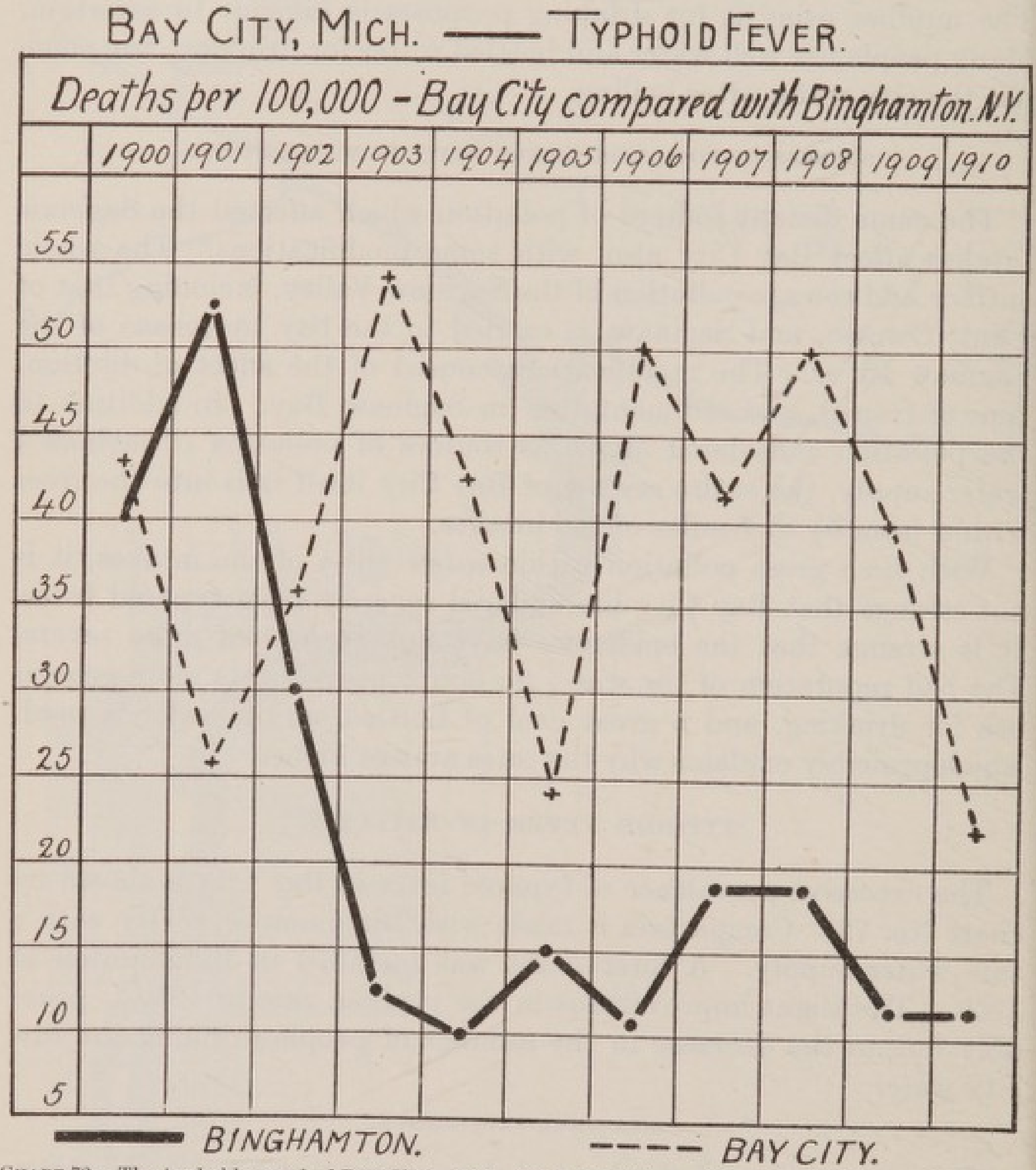


CHART 72.—The typhoid record of Bay City., Mich., compares unfavorably with Binghamton, N. Y.—a city with safe water supply since 1903.

THE RELATION OF THE WATER SUPPLY TO THE HIGH TYPHOID RATES IN SAGINAW AND BAY CITY.

It is said that the people of Saginaw and Bay City do not drink the sewage-polluted public water supplies. In general this may be true, but there is no doubt that poor and ignorant people do drink such water and that it is used for many things besides lawn sprinkling, as, for example, washing of milk cans, cooking utensils, vegetables, etc.

It is an extremely dangerous thing for a municipality to permit a grossly polluted water to enter its mains, even if the people are advised not to drink it. There are in every community scores of persons who who are irresponsible from a sanitary standpoint and must be protected against themselves. The city water is always most convenient

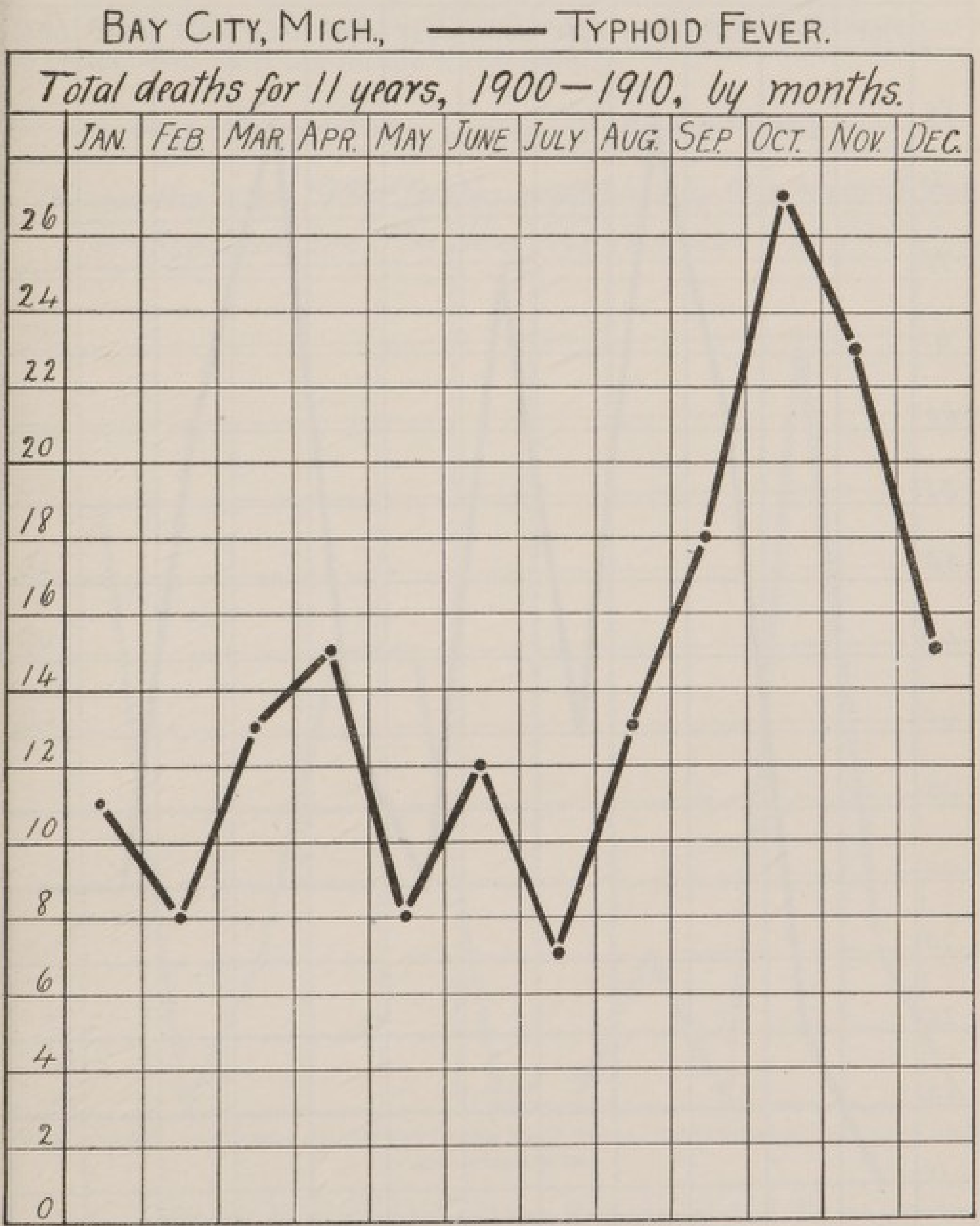


CHART 73.—The monthly distribution of typhoid deaths for 10 years shows that there are too many deaths from typhoid in the first half of the year, and especially in March and April in Bay City, Mich.

and the careless, ignorant, or lazy are very likely to use it instead of going some distance to pump water or buying bottled water, which many of them can ill afford. Further, the furnishing of bad water has another indirect bearing upon the public health by encouraging the use of wells and insanitary outdoor privies. Many of the shallow

wells are contaminated, and distrust of the public supply causes the citizens to persist in using the water from dangerous, shallow wells.

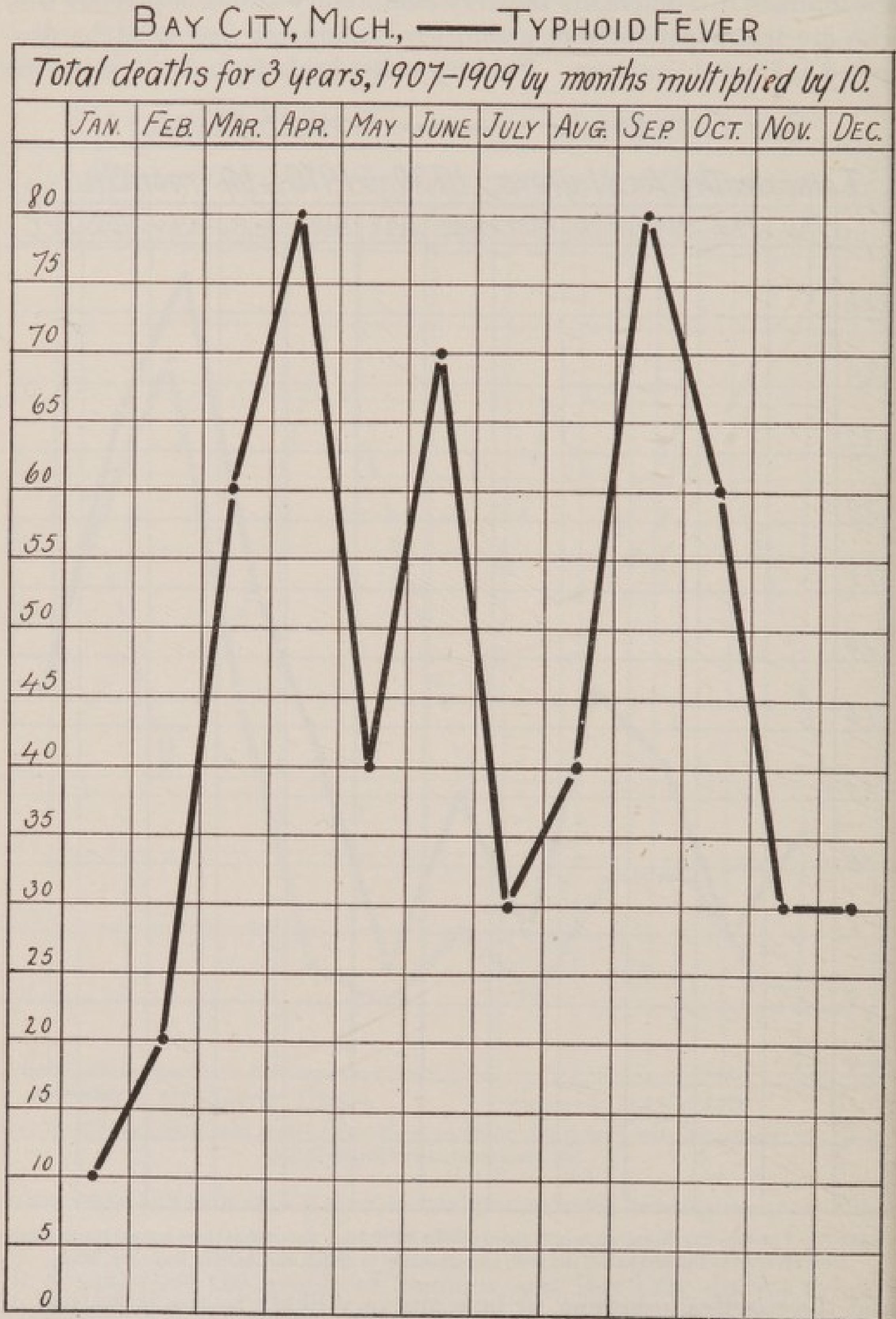


CHART 74.—The condition shown in Chart 73 is accentuated in Chart 74. March and April for the years 1907 to 1909 equalled September and October in typhoid mortality.

A sewage polluted, unfiltered water is not only dangerous in itself, but its unsightly appearance causes a large part of the population to

depend entirely upon well water. While the deep wells may be considered safe there are many shallow wells in use, especially in the districts where the outdoor privy is common.

A large part of the citizens will not install a polluted water supply in their homes, consequently this lack of water prevents the installation of flush closets and perpetuates the problem of insanitary privies. In Bay City 30 per cent and in Saginaw 62 per cent of the houses have no connection with the public water supply.

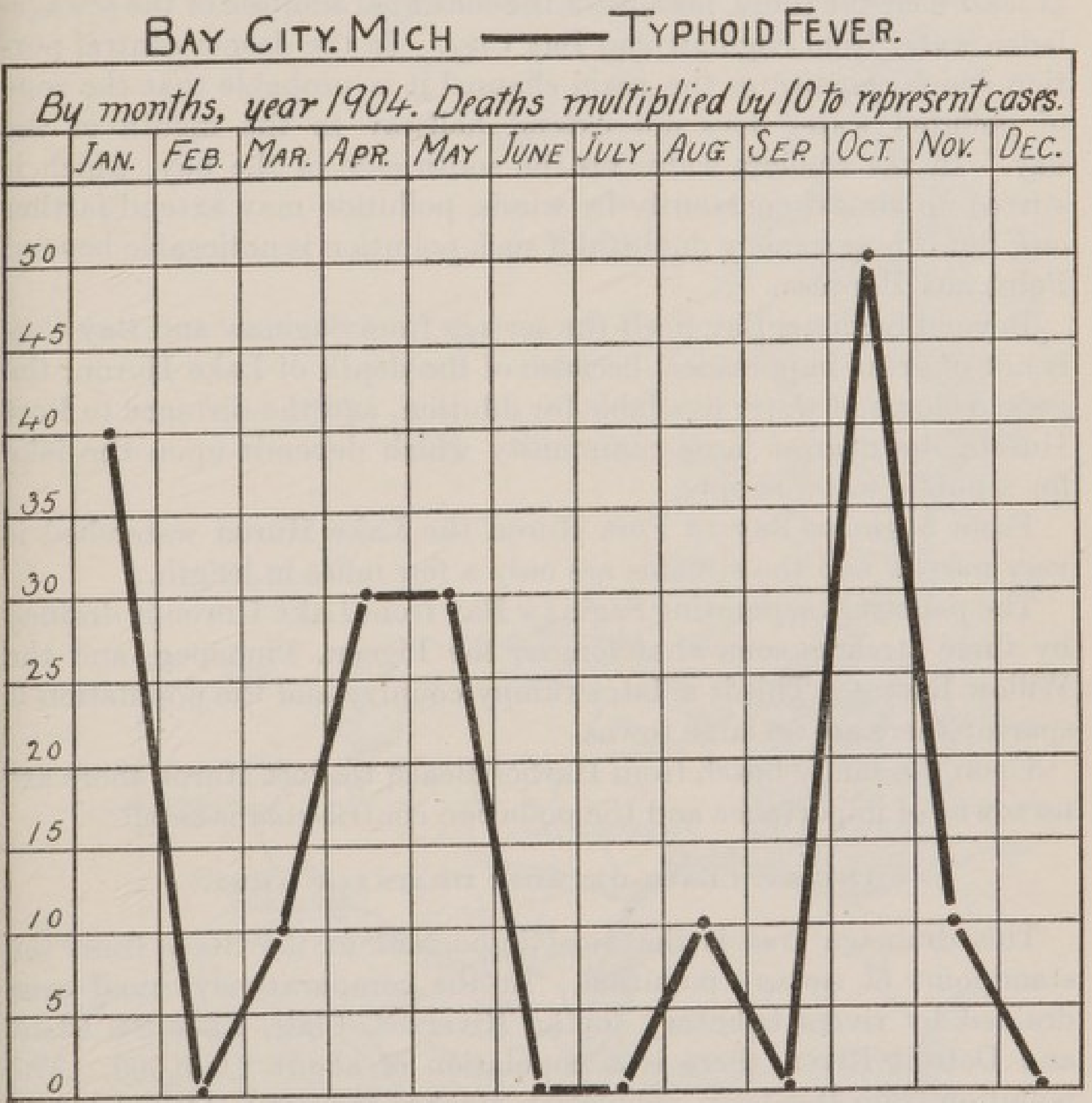


CHART 75.—The very irregular curve in Bay City for 1904 is shown. Again there are high rates in winter and spring months.

The conclusion is unavoidable that if Saginaw and Bay City had safe public water supplies the typhoid fever rate would make a very different showing. Not only would the number of cases and deaths decrease, but excessive prevalence of the disease in winter and spring would no longer be the rule. With a safe public supply, a vigorous

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campaign against shallow and contaminated wells could be inaugurated and much could be done to substitute the modern flush closet for the insanitary outdoor privy.

EFFECT OF THE POLLUTION CARRIED BY THE SAGINAW RIVER UPON SAGINAW BAY AND LAKE HURON.

Saginaw Bay is in reality an ernomous sedimentation basin for the polluted water of the Saginaw River, but it is not able to purify itself, at least near the shore, because of the continual addition of the sewage-laden water from Saginaw and Bay City. In the deeper central portion which constitutes the main channel it is probable that the zone of polluted water does not extend halfway to the mouth of the bay. In the shallow water on the south side of the bay, which is stirred up almost constantly by winds, pollution may extend farther out, but it is extremely doubtful if such pollution is noticeable beyond Point aux Barques.

Beyond Saginaw Bay itself the sewage from Saginaw and Bay City is not of great importance, because of the depth of Lake Huron, the great volume of water available for dilution, and the distance to Port Huron, the nearest large community which depends upon the lake for a public water supply.

From Saginaw Bay to Port Huron the Lake Huron watershed is very narrow and the streams are only a few miles in length.

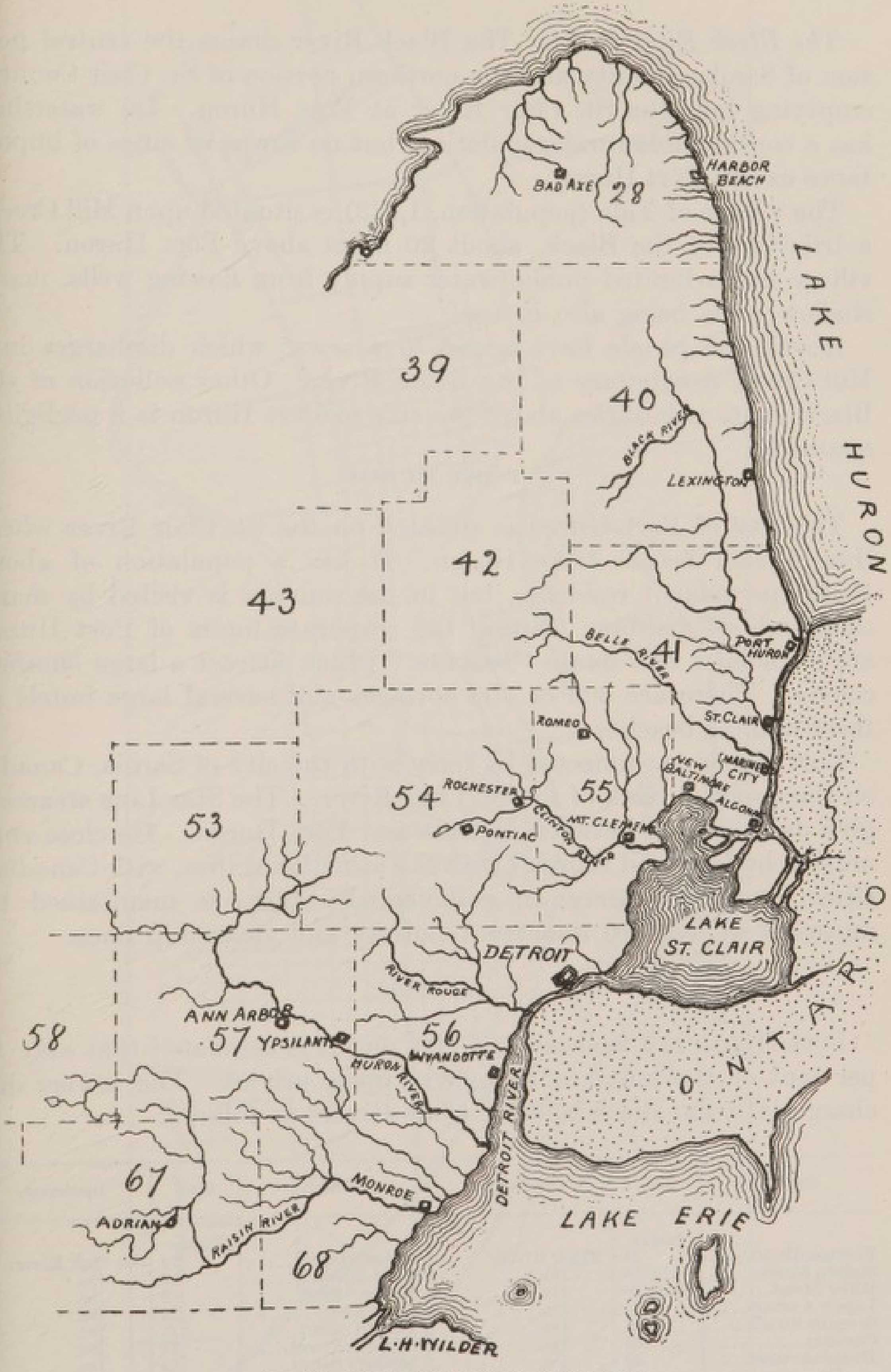
The peninsula separating Saginaw Bay from Lake Huron is drained by three streams somewhat longer, the Pigeon, Pinnepog, and the Willow Rivers. This is a flat, swampy country and the population is sparse; there are no large towns.

Upon the sandy beach from Harbor Beach to Port Huron there are no towns of importance and the pollution contributed is small.

THE ST. CLAIR-DETROIT DRAINAGE AREA.

This drainage area is the most important in the State from the standpoint of sewage pollution. In the comparatively small area drained by rivers tributary to the River St. Clair, Lake St. Clair, and Detroit River, there is a population of about 1,000,000. The pollution from this large population reaches the navigable interstate and international waterway within comparatively narrow limits. The distance between Port Huron and the mouth of the Detroit River is only about 70 miles.

The St. Clair-Detroit drainage area may be subdivided as follows: River St. Clair, including Black River basin, Pine River basin, and Belle River basin; Lake St. Clair, including Clinton River basin; Detroit River, including River Rouge basin, Huron River basin, and River Raisin basin.



MAP 36.—The St. Clair-Detroit drainage area.

The Black River basin.—The Black River drains the central por tion of Sanilac County and the northern portion of St. Clair County emptying into the St. Clair River at Port Huron. Its watershe has a considerable rural population, but no towns or cities of impor tance except Port Huron.

The village of Yale (population, 1,223) is situated upon Mill Creek a tributary of the Black, about 20 miles above Port Huron. Th village has a limited public water supply from flowing wells, man shallow wells being also in use.

About 100 people have access to a sewer which discharges int Mill Creek, a tributary of the Black River. Other pollution of th Black or its tributaries above the city of Port Huron is a negligibl quantity.

PORT HURON.

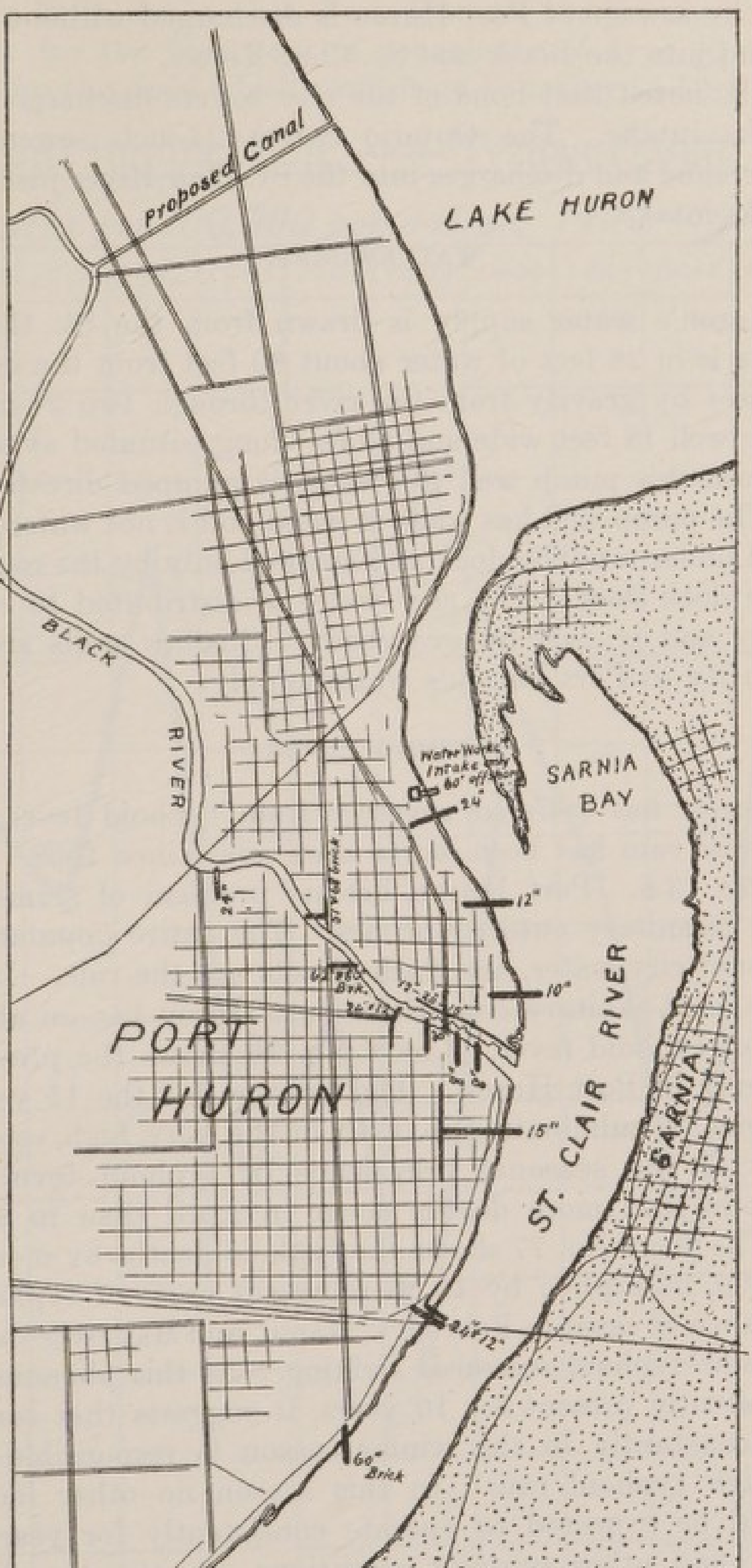
The city of Port Huron is situated on the St. Clair River wher that stream leaves Lake Huron. It has a population of abou 19,000 permanent residents, but in the summer is visited by man thousands of visitors. Within the corporate limits of Port Huro are included a half dozen "beaches," which attract a large summe colony. There are 300 or 400 cottages and several large hotels a these bathing beaches.

Port Huron is connected by ferry with the city of Sarnia, Canada on the opposite bank of the St. Clair River. The Star Line steamer give daily service between Detroit and Port Huron. Its close con nection by boat and railroad with the other lake cities, with Canadia cities, and with American commercial centers is maintained b means of at least 10 important railway and steamship lines.

SEWERS.

Port Huron is a well-sewered city and it is estimated that only 10 per cent of the inhabitants depend upon privies. The sewers dis charge into the Black and St. Clair Rivers as follows:

Outlet.	Size.	Discharge.	Outlet.	Size.	Discharge.
	Inches.			*Inches.*	
Fourteenth Street	24	Black River.	Ontario Street	24	St. Clair River.
Suffern Street	51 by 68	Do.	Bard Street	12	Do.
Miller Street	62 by 80	Do.	Butler Street	10	Do.
Lapier Avenue	24	Do.	Quay Street	10	Do.
Seventh Street	12	Do.	Fourth Street	15	Do.
Customs	30	Do.	Seventh Street	24	Do.
Huron Avenue	12	Do.	Military Street	12	Do.
Do	30	Do.	Tenth Street	60	Do.
Do	15	Do.	South Park	12	Do.
Fourth Street	8	Do.	Do	15	Do.
Third Street	8	Do.			



MAP 37.—Port Huron, Mich., showing sewer outlets, waterworks intake, and proposed canal (under construction) for flushing Black River.

The entire sewage of Port Huron is discharged without treatment of any kind into the Black and St. Clair Rivers.

It will be noted that none of the city sewers discharge above the waterworks intake. The Ontario Street 24-inch sewer turns at Lincoln Avenue and discharges into the St. Clair River just below the waterworks intake.

WATERWORKS.

Port Huron's water supply is drawn from the St. Clair River. The intake is in 28 feet of water about 60 feet from the dock. The water passes by gravity from the river through two 24-inch mains to a pump well 18 feet wide and 50 feet long, situated at the water's edge. From this pump well the water is pumped directly into the mains. The pump well has walls of wood and is not water-tight. It is situated under a public dock and covered only by the rough planking of the dock floor. The city water is distributed to every part of the city and is used by everybody. Shallow wells are a negligible quantity in Port Huron's water supply.

TYPHOID FEVER.

Port Huron has suffered severely from typhoid fever, and the typhoid fever rate has been worse each year since 1908. The rate in 1910 was 73.5. Port Huron has no problem of slums, shallow wells, and insanitary outdoor privies. The entire population drink the unfiltered city water, and flush closets are the rule. In spite of these very good sanitary conditions Port Huron has an abnormally high rate of typhoid fever. Chart No. 76 shows the prevalence of typhoid fever in Port Huron. The average for the 11 years, 1900 to 1910, was 39, culminating in 1910 in the very high rate of 73.5. The study of the seasonal prevalence of typhoid fever in Port Huron shows that more deaths occur in April than in any other month. The chart No. 77 shows the typhoid deaths by months from 1900 to 1909, multiplied by 10 to represent cases of typhoid. The preponderance of cases in February, March, and May over the number in the regular typhoid season is striking. As this phenomenon has been consistently present for 10 years, it suggests that some factor operating constantly in the winter season is responsible for Port Huron's high typhoid rate. In this season no other factor than water could be expected to operate consistently for years. Flies, vegetables, and other summer conditions are at once eliminated. Privies are not a factor in Port Huron, shallow wells are a rarity, and the use of the public water supply is general. The possiblity of milk causing an outbreak in the winter or spring months must be admitted, but milk outbreaks would not occur in March and April each year for a period of many years.

There is little doubt that Port Huron's public water supply is responsible for the high rate of prevalence of typhoid fever, and especially for the cases which occur from February to April. In fact,

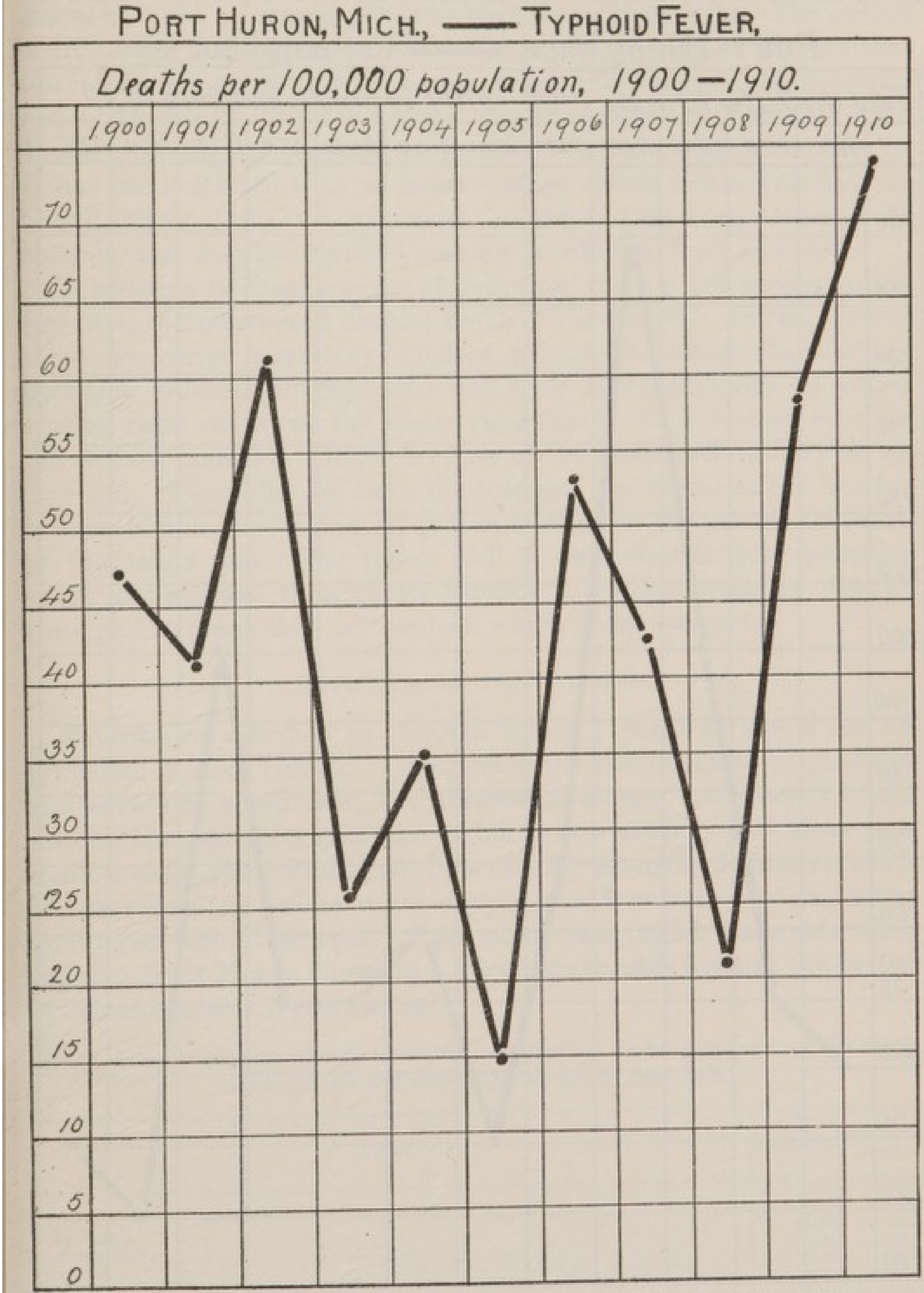


CHART 76.—Port Huron, Mich., showing the increase in typhoid fever in 1909 and 1910.

the analyses made by the State board of health have shown repeatedly evidence of fecal contamination of the Port Huron water supply.

The sewer outlet nearest the intake discharges into the St. Clair River about 40 yards below the intake. There is a strong current in

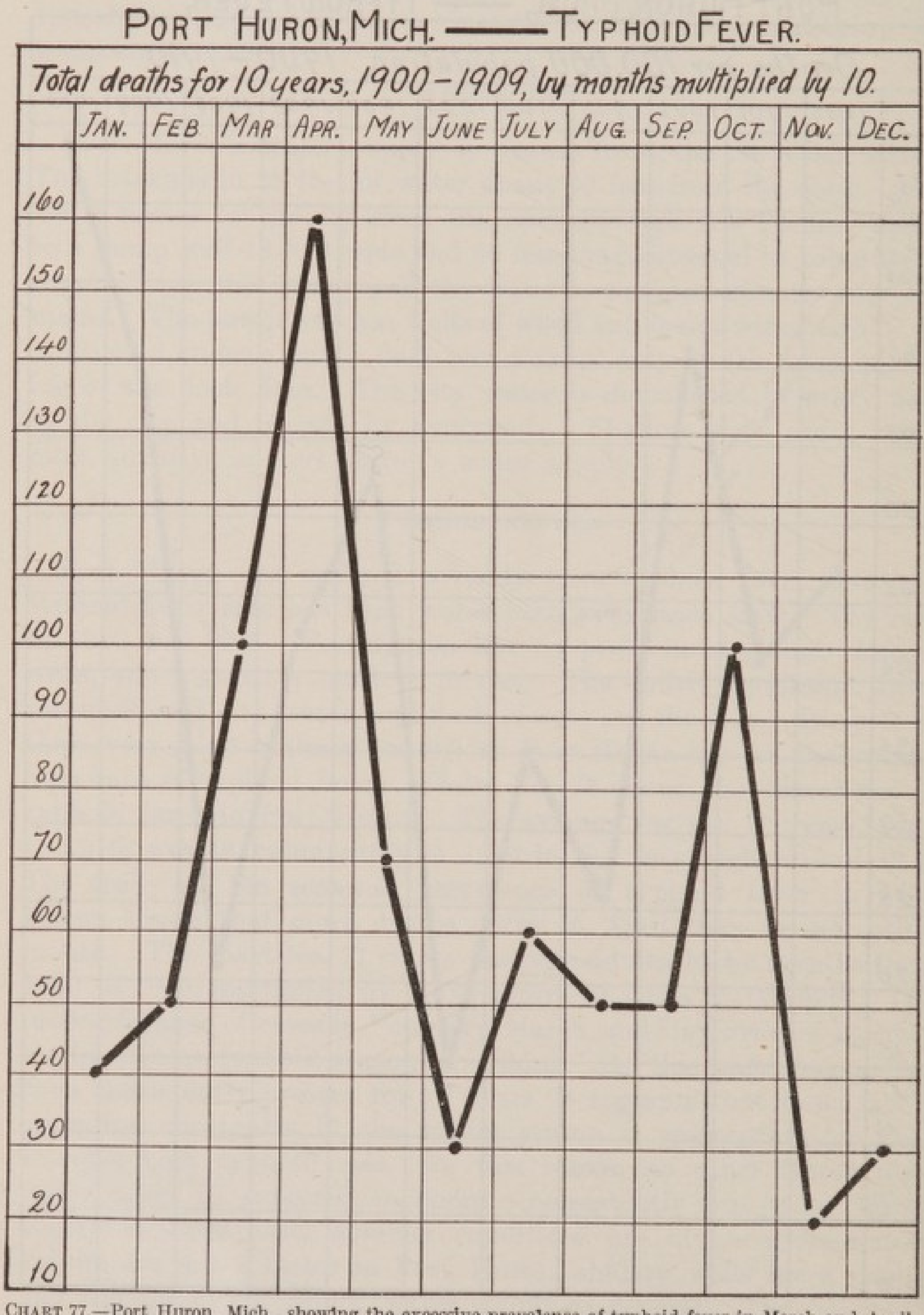


CHART 77.—Port Huron, Mich., showing the excessive prevalence of typhoid fever in March and April.

the main channel which is not effected by winds to any extent, and which would carry pollution downstream at all times in the year, but currents in the shallower water near the shore are changeable and

deceptive. The sewer discharges near the shore, and the intake is only 60 feet from the dock. It is possible that sewage pollution might be carried back over the intake by a surface current near the shore, induced by strong winds or gales from the south. The outfall of this sewer is altogether too close for safety, in view of the fact that the intake is only 60 feet offshore. While there are no public sewers above the intake, there is a sewer discharging in front of the Grand Trunk property, a comparatively short distance above the intake. It has been claimed that no house sewage enters this sewer, but the health officer, Dr. Cotè, informed the writer that house sewage did enter it, and that he intended making an effort to have it closed.

In addition to these sources of pollution, there is the surface drainage from the unsewered district north of the intake. In this district there are some insanitary outdoor privies and cesspools, and the pollution washed directly into the river is considerable at times. During rains or thaws the water runs rapidly to the river carrying the surface pollution with it because of the nonporous quality of the clay soil. The pollution from the cottages and hotels at the beaches is considerable, but is less dangerous because of the porous character of the sandy soil. The pump well is unprotected from pollution either by seepage through its imperfect wooden walls or directly through the plank floor of the dock which forms its cover.

ENTERITIS IN PORT HURON.

Enteritis or diarrhea in children under 2 years of age is far too prevalent in Port Huron. Considering the size of the city, the social and economic conditions, the absence of slums, the access to flush closets, the general use of the public water supply, and absence of shallow wells, there should not be a rate for enteritis of children above 50, provided the public water supply was free from contamination. Compared with other cities of the same class, which have safe water supplies, Port Huron shows in a very unfavorable light in the matter of enteritis under 2 years of age.

TABLE 43.—*Cities from 12,000 to 20,000 population, lower peninsula of Michigan, deaths per 100,000 average for six years, 1905–1910.*

Cities.	Enteritis.	Typhoid fever.
Alpena	162.6	46.7
Port Huron	78.6	42.0
Traverse City	53.5	42.0
Manistee	48.0	20.8
Pontiac	44.0	24.5
Ann Arbor	18.6	22.1

Alpena, Port Huron, and Traverse City have contaminated water supplies.

Manistee, Pontiac, and Ann Arbor have water supplies generally considered to be safe. In the tables the cities with high enteritis rates have also very high typhoid fever rates.

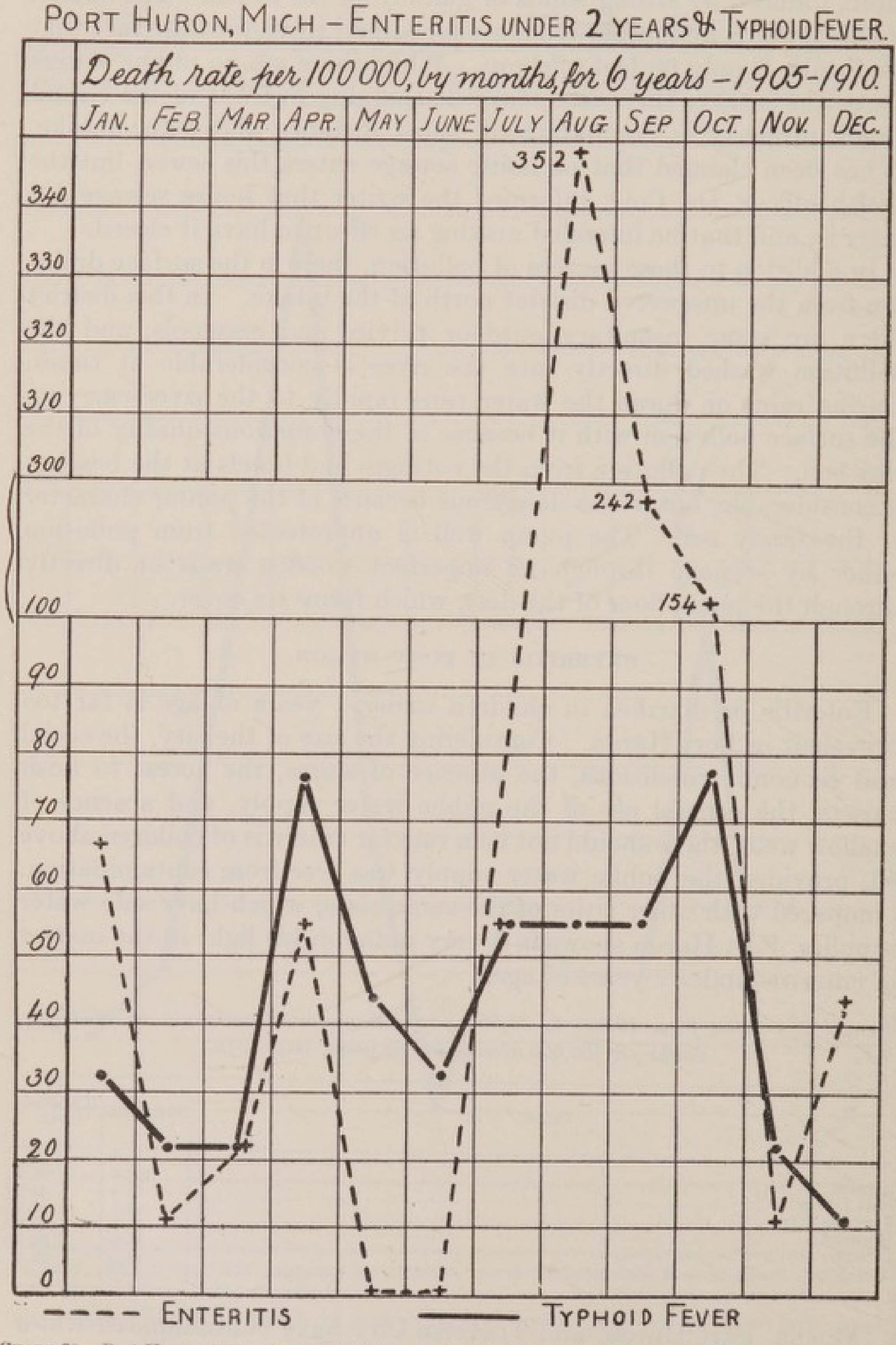


CHART 78.—Port Huron, Mich., showing the relation between the curves for typhoid fever and enteritis.

Chart No. 78 shows the seasonal prevalence of enteritis in Port Huron. This disease normally should have very little prevalence in winter or spring. In cities with polluted water supplies not only is the enteritis rate high for the year, but the rate is found to be excessive in the winter and spring months. The rise in the enteritis rate for January and April for the six years, 1905–1910, coincident with the rise of typhoid suggests common factors in transmission.

For the protection of its citizens and the thousands who visit there, Port Huron must install a safe water supply. It is not understood why the intake was not extended to the main channel to avoid shore pollution, and why a pump well of cement or other water-tight material has not been made and provided with a proper cover. These are obvious necessities which must have been apparent for years. To extend the present intake 500 feet, to construct a new pump well and mixing tanks, and to treat the water by the hypochlorite method, will be cheaper than filtration, but at times there will be turbidity. One thing is certain; it is the plain duty of the Port Huron authorities to provide safe water. The hypochlorite method could be applied at once, while deciding whether filtration or further treatment is necessary or desirable.

As to Port Huron's sewage, even if not necessary in the city's own interests, crude sewage should not be discharged into the Black or St. Clair Rivers, because of its effect upon the public water supplies of cities situated on the river below Port Huron.

The effect of Port Huron's sewage on the St. Clair River water will be more fully discussed later in considering the city of St. Clair.

ST. CLAIR.

St. Clair is situated upon the St. Clair River at the mouth of the Pine River, and has a population of 2,633. The public water supply is taken from the St. Clair River.

Typhoid fever was epidemic in March, 1908. Samples of water from the river near the intake pipe, from the settling basin, and from three faucets in different parts of the city showed fecal contamination upon analysis at the State laboratory. St. Clair County has had an average typhoid death rate for 18 years (1891–1908) of 30.9, and in 1908 the rural rate alone in St. Clair County was 51.2. Only 10 miles above St. Clair's waterworks intake the Port Huron sewage enters the river. It is not strange that this polluted water supply would be responsible for outbreaks of typhoid fever in St. Clair.

TYPHOID FEVER AND "WINTER CHOLERA" IN ST. CLAIR.

In a report upon the water supply, Dr. J. W. Inches, at that time health officer of St. Clair, said:

The records of the city of St. Clair show that in the first 10 months of 1908 there were 5 deaths from typhoid fever, which means, taking the population at 2,850, a

death rate per 100,000 population of 210. There were also about 60 cases of typhoid. The records of this city for the 10 years previous to this year are of no value whatever, for the reason that a portion of the deaths that have occurred from typhoid have been recorded under other names. With a well-meant intention of protecting the name of St. Clair as a summer resort, every effort has been made by some to minimize and even conceal the prevalence of typhoid fever.

But even the loss which St. Clair suffers from typhoid fever is secondary to that which is caused almost continually, and especially during the winter months, from the terrible scourges of intestinal troubles, or so-called "winter cholera."

It does not need any statistics to recall to our people their condition last winter, when nearly every person was afflicted, more or less, when hundreds were sick, and actually thousands miserable. When scores of people were thrown into such a serious condition that they were months recovering, and in some instances will never recover good health.

Even with the inclination to keep typhoid fever out of the records, the disease became so prevalent at times that a certain proportion of the deaths were recorded as typhoid. The record for 10 years by months from data furnished by Dr. Inches from the certificates of death is as follows:

Months.	Aggregate of typhoid deaths for 10 years.	Months.	Aggregate of typhoid deaths for 10 years.
January	2	July	0
February	1	August	0
March	2	September	0
April	9	October	0
May	4	November	1
June	1	December	1

Owing to the failure to report typhoid fever, the records previous to 1908 are not of much value, and the above table does not show the real prevalence; it merely shows the preponderance of April cases. The official records of the State of Michigan show the following deaths from typhoid in the year 1909:

Months.	Number.	Months.	Number.
January	1	July	0
February	0	August	0
March	1	September	0
April	5	October	0
May	5	November	0
June	0	December	0

This prevalence of typhoid fever is conceded by all to be due to the water supply. Cases in St. Clair occur consistently in greatest number in the flood months, March, April, and May. Examinations of the St. Clair public water supply have shown colon bacilli in all 1 c. c. samples, even when taken at a favorable time of year.

SOURCES OF POLLUTION OF WATER SUPPLY.

The entire sewage of Port Huron is discharged into the St. Clair, River; the bulk of it indirectly through the Black River. In the summer months the current of the Black River is not sufficient to carry sewage out into the current of the St. Clair. In fact, from June to September the water in the Black River at Port Huron is almost stagnant and sedimentation and septic action are very active processes. The danger from sewage pollution of the Black River is minimized by the lack of current in summer. In the winter months, and especially in the so-called flood months, the volume of water and velocity of the current are enormously increased, and the sewage-polluted water of the Black River is carried far out into the main current of the St. Clair. At such times the swift current in the St. Clair running from 4 to 7 miles per hour, quickly carries the pollution to the waterworks intake of St. Clair and Marine City, situated a few miles below.

The conditions of flood in the Black River simply make possible the carrying of sewage-polluted water quickly to the main current. This condition of flood eliminates to a large extent the time factor in the destruction of pathogenic organisms, prevents sedimentation, and retards dilution. The carrying of sewage-polluted material quickly to the main channel can be effected also by the dumping of dredged material. The accumulation of sewage, sludge, and muck in the sluggish Black River becomes at times an obstacle to navigation and dredging becomes necessary. The dredged material is dumped in 30 feet of water, which means usually that it is dumped in mid-channel. It has been claimed, and with good reason, that this dumping has been responsible for typhoid-fever outbreaks in the cities of St. Clair and Marine City and even in Detroit. An outbreak was said to have been due to this cause in 1892.

The dumping of sewage sludge and other dredgings from a grossly polluted stream into the main channel of a river used as a source of public water supply is a very dangerous procedure and unquestionably a very great menace to the public health. It must be remembered that what is occasionally done by Government dredges at long intervals is accomplished every year by the Black River in flood. The dredgings of such a river should be dumped behind retaining walls and in water where opportunity for sedimentation exists. This would not entirely protect St. Clair and Marine City, however, so long as Port Huron's sewage is discharged untreated into the Black or St. Clair Rivers.

In view of the fact that to effect a proper disposal of Port Huron's sewage will require years of effort the cities of St. Clair and Marine

City should give their citizens and visitors immediate protection by treating their public water supplies before distribution. The hypochlorite method is effective and cheap. It can be quickly installed while the argument as to more complete treatment of the water and disposal of Port Huron sewage is being carried on.

Port Huron's sewage pollution of the Black River is about to be made a more consistent menace. The unspeakably foul water of the river gives off such a stench that the citizens demand relief. A canal is nearly completed from Lake Huron to the nearest bend in the Black River. The canal is 5,840 feet long and leaves the lake just north of the city limits. This will have the effect of constantly flushing the Black River. It will obviate the nuisance so far as odor is concerned, but the increased stream flow will carry the polluted water farther out toward the main current in the St. Clair in the summer months. The lack of current in the Black, in summer, has been a protection to the water supplies of cities situated below. This measure of protection will be removed by the flushing process about to be inaugurated.

MARINE CITY.

Marine City is situated on the St. Clair River at the mouth of Belle River, and has a population of 3,770. There are few wells, as the public waterworks is patronized by nearly everyone. The public supply is taken from the St. Clair River. Over 3,000 people have access to sewers which discharge into the St. Clair and Belle Rivers. The history of Marine City resembles that of St. Clair. The waterworks intake is only 18 miles below Port Huron's sewers and less than 8 miles below those of St. Clair. The water is furnished without treatment or filtration of any kind, and typhoid fever has been prevalent.

LAKE ST. CLAIR, ALGONAC.

Algonac has a population of 1,200 and derives its public water supply from Lake St. Clair. There are also numerous shallow wells. Three-fourths of the population depend upon privies and but one-fourth have access to sewers, which discharge into the St. Clair River below the waterworks. The water is used unfiltered.

NEW BALTIMORE.

New Baltimore is a village of about 1,000 inhabitants, situated upon Lake St. Clair. The public water supply is pumped from Lake St. Clair to a standpipe. About 900 people use the public water supply, which is delivered unfiltered. There are no sewers.

CLINTON RIVER BASIN.

Clinton River drains a great part of Macomb County and about one-third of Oakland, in which county it has its source. The largest communities on the watershed are Pontiac and Mount Clemens.

ROMEO.

Romeo has a population of 1,787, and about 500 of these have access to sewers discharging into Clinton River. About 80 per cent use the public water supply derived from wells 26 feet deep, situated in a ravine about a mile south of the village; about 20 per cent of the population use private shallow wells, which are subject to contamination.

ROCHESTER.

Four-fifths of the population of Rochester have access to sewers, which discharge into Paint Creek and Clinton River. The total population is about 1,500. The public water supply is from artesian wells and is patronized by 95 per cent of the population.

PONTIAC.

The population of Pontiac is 14,532. The dangerous effect of its sewage upon the Clinton watershed is minimized by distance and by the low prevalence of typhoid fever in Pontiac. Pontiac's public water supply is derived from wells 175 feet deep. Owing to the character of the upper layers, the water may be considered a safe supply. Typhoid fever has prevailed in Pontiac as follows:

Deaths per 100,000 population: Average, 16 years (1889–1905), 11.7; 1906, 35; 1907, 25.6; 1908, 8.3; 1909, 16.

MOUNT CLEMENS.

The population of Mount Clemens is 7,707. It is situated near the mouth of the Clinton River. The public water supply is derived from 22 wells of a depth of from 25 to 41 feet. While the depth of the wells is not great, there are two layers each of blue clay and "hardpan" above the water-bearing gravel stratum. It would have been safer to locate these wells above the town.

The first waterworks were established in 1889, and Clinton River water was used. The typhoid fever rates were very high, and a badly constructed filter bed was put in, which was shown to have made matters worse.

The deep wells at Mount Clemens go down several hundred feet. They furnish brines which are responsible for the popularity of Mount Clemens as a health resort. The water is used in sanitariums and bathhouses, and several thousand transients come to Mount Clemens for the baths every year. The entire sewage of Mount Clemens discharges into the Clinton River. Typhoid fever

rates in Mount Clemens have been continuously high for years, as shown by the following statement:

Deaths per 100,000 population: Average for 16 years (1889–1905), 33.2; 1906, 40.7; 1907, 40; 1908, 39.3.

The significance of excessive rates of typhoid fever in Mount Clemens from an interstate standpoint is apparent when the number of transients visiting the city is considered. Further, there are several miles of sewers, serving 7,000 people, which discharge by 10 outlets into the Clinton River, only a few miles from the main channel of Lake St. Clair.

THE DETROIT RIVER.

The Detroit River is a stream of great volume and is naturally one of the finest streams of potable water in the world. United States engineers estimate the flow at Fort Wayne as 209,000 cubic feet per second. Opposite Detroit the river has an average depth of 37 feet and a width of 2,200 feet.

The western end of Lake Erie is really a delta of the Detroit and Maumee Rivers, and that portion north of the mouth of the Raisin may be considered as part of the Detroit River drainage area.

DETROIT.

In 1910 the city of Detroit had a population of 465,766. It is situated on the Detroit River, within a few miles of Lake St. Clair. Practically the entire lake traffic passes through the Straits at Detroit. Over 3,000 vessels, with a net tonnage of 2½ millions, arrive at Detroit yearly. The enormous amount of freight handled at other lake ports is largely due to two commodities—coal and iron. Detroit's freight is made up of miscellaneous shipments and its importance as a receiving and a distributing center for passengers in lake traffic can scarcely be overestimated. Thousands of tourists visit the city each year because of its situation and other attractions.

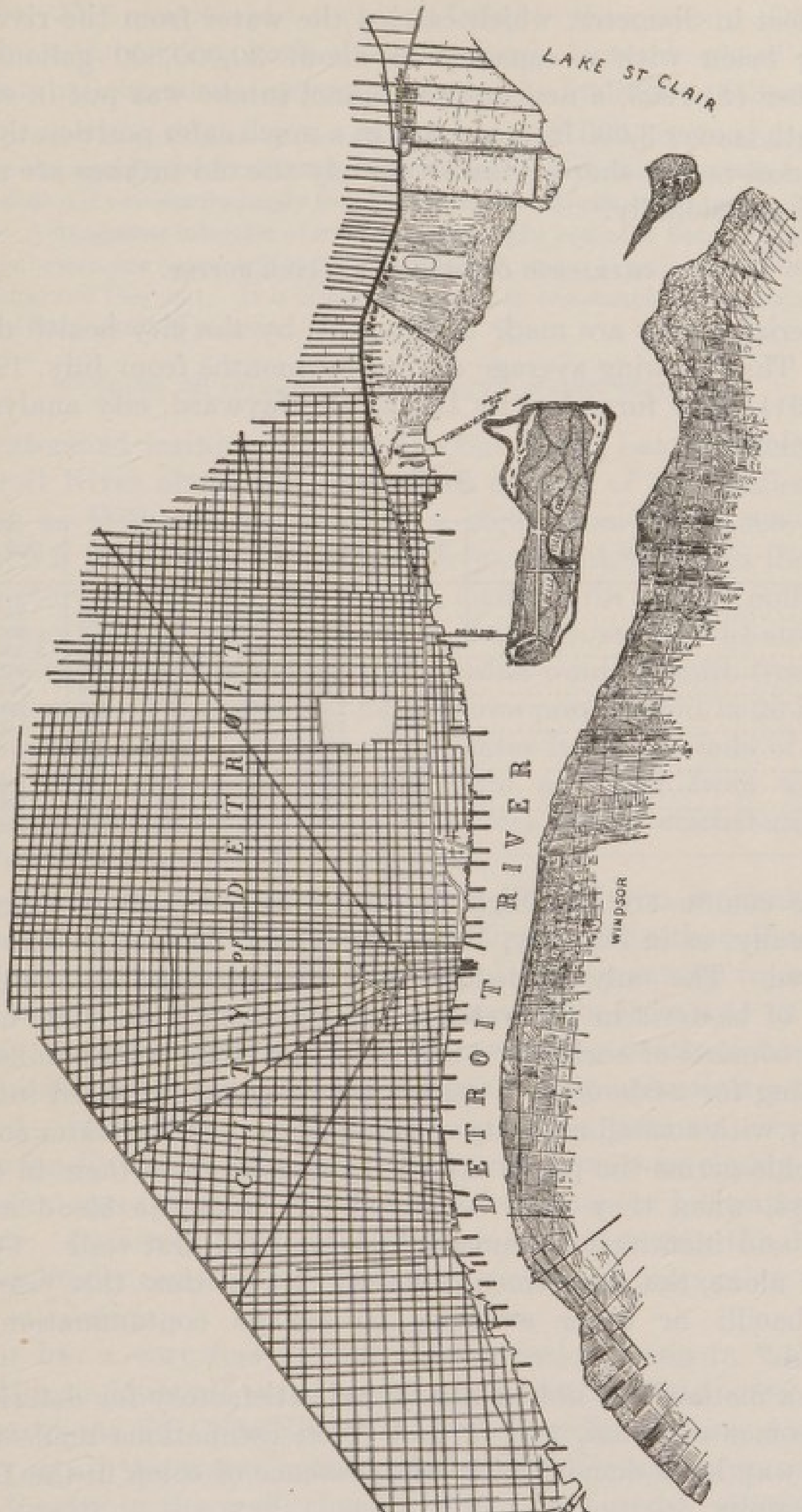
SEWER SYSTEM.

Detroit's sewer outfalls extend from the River Rouge to Park View Avenue, along almost the entire water front of the city. The sewage is discharged from these outfalls without treatment into the Detroit River. The nearest sewer to the waterworks is situated below the intake.

WATER SUPPLY.

Detroit's water supply is taken from the American channel of the Detroit River at a point near the northeastern extremity of Belle Isle.

Formerly there were three intake pipes, one of these 1,000 feet long and 5 feet in diameter, the other two 1,500 feet in length each



MAP 38.—Detroit, Mich., showing existing sewer outlets, proposed new sewer for diverting sewage from Conners Creek, and the waterworks tunnel and intake.

and 6 feet in diameter, which carried the water from the river to a settling basin with a capacity of about 30,000,000 gallons. On December 18, 1905, a new 10-foot tunnel intake was put in service. Its length is over 3,000 feet, and it is in a much safer position than the old intakes nearer shore. Unfortunately the old intakes are said to be used occasionally.

CHARACTER OF DETROIT'S WATER SUPPLY.

Bacterial counts are made at intervals by the city health department. The following average counts by months from July, 1905, to May, 1911, were furnished by Dr. E. H. Hayward, city analyst and bacteriologist.

TABLE 44.

Months.	1905	1906	1907	1908	1909	1910	1911
January	....	310	1,809	197	308	310	168
February	....	262	190	206	272	236	301
March	....	248	164	260	326	3,200	316
April	....	220	327	728	380	268	320
May	....	220	228	168	288	284	218
June	....	270	287	168	118	278	....
July	490	128	210	154	232	148	....
August	362	130	209	286	210	170	....
September	189	154	207	174	184	....	....
October	208	118	196	132	194	210	....
November	164	198	251	126	102	210	....
December	368	226	180	164	101	304	....

These counts are not high for an unfiltered surface water, but occasionally, as in January, 1907, and March, 1910, high counts are registered. The only procedure used to determine the dangerous quality of bacteria in the water is animal inoculation. The method in brief consists of enriching a sample of the water with bouillon and incubating for 24 hours. A guinea pig is then inoculated intraperitoneally with a small quantity of this culture. If the water contains pathogenic germs the pig is expected to succumb to them in two to five days, when they may be plated out from the blood in pure culture and identified by morphologic and cultural tests. On this method alone, the department reports: "At no time this year have colon bacilli or other evidence of sewage contamination been observed."

Such a method can not be considered satisfactory for determining the presence of colon, and in fact colon estimations made in the regular way have demonstrated the presence of colon in the Detroit water supply.

A special commissioner sent by the Journal of the American Medical Association on September 21 and 22, 1910, examined specimens of the Detroit water supply from a tap in the business district. On September 21 colon was present in 1 c. c. in 1 sample out of 3. On

September 22, 3 samples of 1 c. c. each failed to show colon. One c. c. sample from the settling basin showed colon in 1 sample out of 4.

The Journal commissioner comments on the findings as follows:

These bacterial examinations do not afford any marked evidence of contamination at the time the samples were collected. On the other hand, their generally negative character does not necessarily imply that the water is at all times and under all conditions safe. A dangerous infection of such a water supply as that of Detroit might exist for a day, or even a few hours, and remain undetected, unless examination of the water was searching and frequent. It is noted above that in one sample of tap water colon bacilli were demonstrably present.

SOURCES OF POLLUTION OF DETROIT'S WATER SUPPLY.

The watershed draining into the St. Clair River, Lake St. Clair, and the Detroit River above the intakes has an area of 5,800 miles and according to Williams had in 1897 a population of 300,000. The population is considerably greater at present, and, owing to the nonporous nature of the soil, the run-off, loaded with surface pollution, finds its way quickly over the surface of the ground to the streams. Williams estimated that 1½ inches of rainfall would furnish from this watershed as much water as ordinarily flows past Detroit in 20 hours. The nonporous nature of the soil is greater in the periods of thaw following frost and snow. Besides this pollution from surface washings of the watershed there is a very direct contribution of sewage from the city of Port Huron.

As noted above, the entire sewage of Port Huron is discharged untreated into the Black and St. Clair Rivers. The time of transit necessary for polluted material to reach Detroit's intake from Port Huron's sewers has been carefully estimated to be from 6 to 12 days. Obviously this is too short a time to insure the death of bacteria. What agencies act to minimize this danger? Two agencies are chiefly concerned—dilution and sedimentation. The amount of water available for dilution is enormous. However, it must be clearly borne in mind that mere dilution does not disinfect water or kill pathogenic organisms. It merely lessens the chances of contracting the disease and undoubtedly reduces the number of victims in proportion to the amount of dilution.

Detroit has a very fine natural sedimentation basin in Lake St. Clair. This undoubtedly exercises a very great beneficial effect upon the water of the St. Clair River. However, sedimentation does not act fully on all the water entering Lake St. Clair, and some of it is carried directly in the main channel where the current retards sedimentation and may carry the polluted material to Detroit's intake. There are, however, nearer sources of pollution. None of Detroit's sewers discharge above the waterworks, but Connors Creek receives the sewage of Fairview (a suburb annexed to Detroit in 1907) and

the drainage of a considerable area. Connors Creek empties into the Detroit River above the waterworks intake.

In order to reach the present inlet the polluted water from Connors Creek would have to cross a stream of water of great volume and considerable velocity. When the volume of water from Connors Creek is small the trend of this polluted current would be alongshore and not toward the intake. This would pollute intakes nearer shore, which, according to the Journal's commissioner, are occasionally used. A freshet in Connors Creek would project its polluted water very much farther out in the Detroit River, and pollution of the intake, which is only 2,500 feet distant and 1,000 feet downstream, might occur.

Plans are completed for a sewer in Parkview and Jefferson Avenue, which will intercept the sewage now going into Connors Creek, and carry it to the river below the waterworks. When this sewer is complete the pollution of Connors Creek will no longer be a menace to the waterworks intake.

There is another possible source of pollution, viz, from passing vessels. In general, on the Great Lakes, such pollution is considered small, but when one considers the concentration of traffic at Windmill Point, a few miles above the intake, and the fact that practically all lake vessels pass this point, danger from this source must be conceded.

TYPHOID FEVER IN DETROIT.

The records of typhoid fever cases in Detroit are very unsatisfactory. Like a great many other large cities the number of cases reported is obviously too small compared with the deaths. The only reliable basis for estimating the prevalence of typhoid fever is the record of typhoid deaths. These multiplied by 10 or 12 give a fair estimate of the number of cases.

Chart No. 79 gives the typhoid fever deaths per 100,000 population by years from 1890 to 1910. The four last quinquennial periods give the following average rates:

Five-year period.	Average typhoid deaths per 100,000.	Five-year period.	Average typhoid deaths per 100,000.
1891–1895	44.5	1901–1905	20.5
1896–1900	19.9	1906–1910	22.68

The very high rate in the five-year period, 1891–1895, is due especially to the excessive prevalence of typhoid fever in 1891, 1892, and 1893. In these three years the rate was always above 30, and in 1892, 209 typhoid fever deaths occurred in the city of Detroit, a rate

in excess of 93 per 100,000. In the period from 1896 to 1900, the rate was much lower (19.9 per 100,000), and the same may be said for the next quinquennial period, 1901–1905. During the last five-year period, 1906–1910, a marked change is noticeable and the average for the period is 22.68. This upward tendency of typhoid fever in Detroit is in striking contrast to the reductions in typhoid rates in Philadelphia, Pittsburgh, Cincinnati, Columbus, and other cities coincident with the furnishing of filtered water to the citizens of those

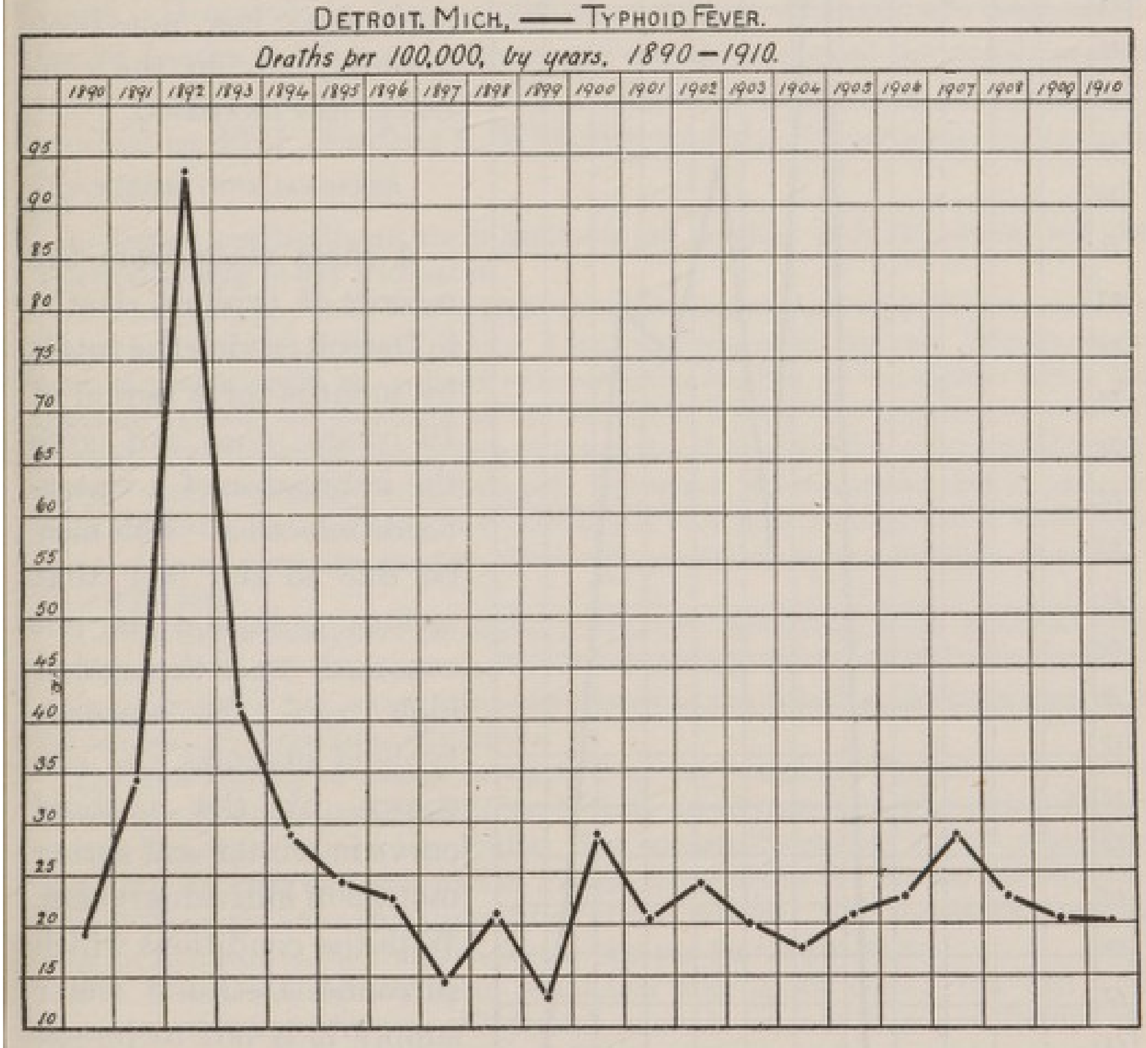


CHART 79.—Detroit, Mich., showing the death rate for typhoid fever by years since 1890.

cities. It is difficult to understand why typhoid fever rates should be higher instead of lower in Detroit when the good work of the Detroit Health Department is taken into consideration.

Detroit's Board of Health has waged a vigorous campaign against the insanitary privy. Much good work has been done in the sanitary control of milk. The efforts of the board have resulted in improvement in housing of the poor. The campaign against the fly has been chiefly directed against its breeding places, and a great deal has been accomplished in abating nuisances from stable manure and

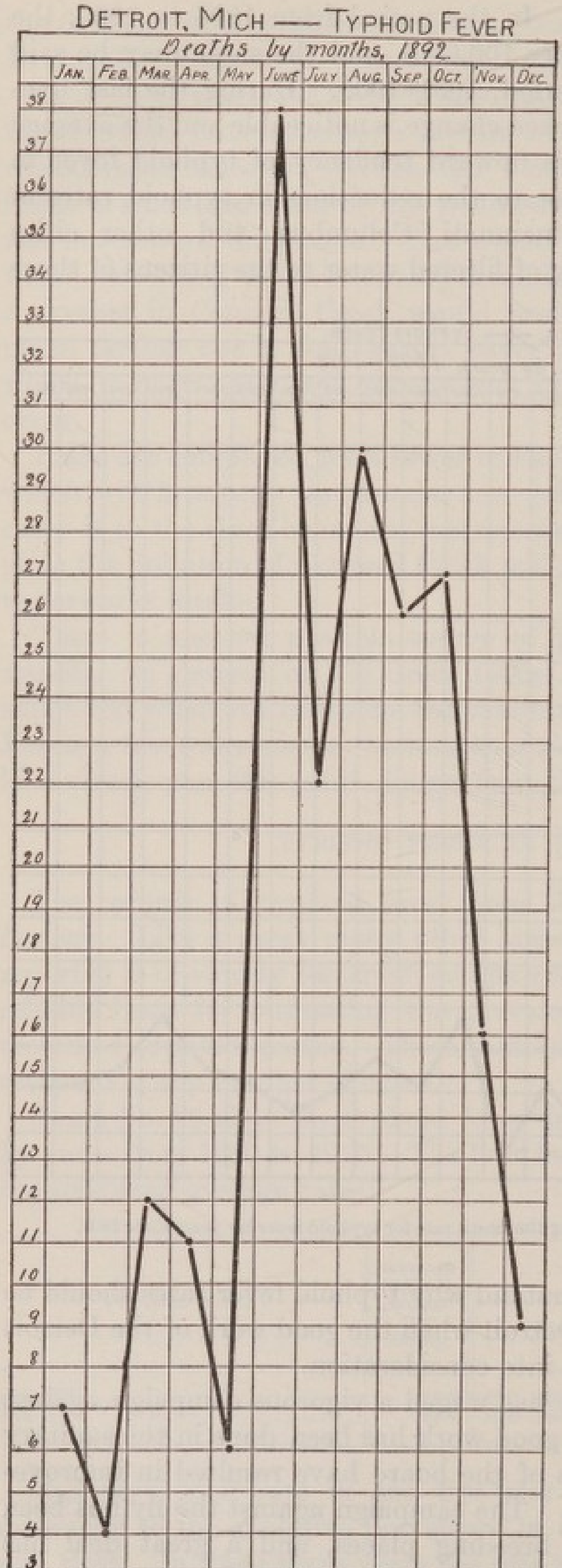


CHART 80.—Seasonal prevalence of typhoid fever in Detroit during 1892; the massive explosive outbreak in June is well shown.

neglected garbage. In spite of the fact that sanitary conditions have been improved and that the board has made progress in every line of prophylaxis against typhoid fever except improvement of the water supply, the typhoid fever rate has not been lowered, but, on the contrary, has increased.

SEASONAL PREVALENCE.

A chart made from the records of typhoid deaths in Detroit, giving the totals by months for a period of 10 years, does not give the impression of a water-borne infection. This may be due to the fact that serious pollution is not constant, and the rather high rate for autumn typhoid obscures the rise shown by the typhoid curve in winter and spring months of individual years. With the conditions which surround Detroit's water supply it is not to be expected that massive outbreaks would occur frequently. The distance from Port Huron, the enormous volume of water available for dilution, the action of Lake St. Clair as a natural sedimentation basin, the position of the intake in relation to local sources of pollution, all militate against

disaster on a large scale. If we except 1892, there has been no severe epidemic to swell the figures for the months from January to June, but, considering the sanitary condition of Detroit, there have been consistently too many deaths of typhoid fever in the first half of the year, and especially in March and May. If we take individual years this fact is still more striking.

Seasonal prevalence in the year 1892 is shown by Chart No. 80. In that year there was a rather high rate in March with a drop in April and May to about the usual rate for those months in other years. However, in June an epidemic occurred which was responsible for 38 deaths in 25 days in June and which increased the total typhoid fever deaths for the year to 209. This epidemic was very carefully studied by Prof. Gardner S. Williams, and the following is taken from his report:

In Detroit practically all the inhabitants are supplied with city water, less than 1 per cent being to-day without it.

As I have already said, it is evident that if an outbreak of typhoid fever were produced by imperfect drainage, which, I may say, was never the case, or milk, or raw food, the cases would be confined to a particular locality, as the district where poor drainage existed, the dwellings of the patrons of a particular huckster, or the route of a particular milkman, while only if the outbreak were produced by a public water supply would the cases be distributed. Moreover, we remember that in case of a milk epidemic the morbidity and mortality is very great among infants, while under other circumstances the greatest effects of the disease appear between the ages of 15 and 30 years.

A study of the location of the deaths in this city shows them to be, in almost every outbreak, so widely distributed as to remove entirely the possibility in most cases of milk or anything but water being the agency of the infection, and the ages of the decedents lead to the same conclusion.

The water supply of Detroit is drawn from the American Channel of the Detroit River, at a point about one-half of the distance across from the north bank and nearly on the line of the eastern city limits. The watershed draining into St. Clair River and Lake St. Clair and that part of Detroit River above the intakes has an area of over 5,800 square miles and a population of over 300,000. The population per square mile for that part in the United States is 59.3 and for Canada 48.3.

This includes cities ranging in population from 30,000 down. One and a half inches of rainfall on this area will furnish as much water as flows past Detroit in 20 hours.

The soil is of such a nature that water falling upon it is in general very slowly absorbed, so that heavy rains invariably tend to wash the accumulations of previous periods into the streams and so may cause dangerous contamination, if a communicable disease has recently been prevalent on any part of the watershed. This is especially the case in the times of breaking up after periods of frost and snow.

Remembering that the period of incubation of the disease is from 6 to 30 days, the average being about 12 days, and that in the event of death it occurs from 21 to 30 days from the beginning of the fever, the first deaths from a given typhoid infection may be expected to occur 4 weeks from the date of taking it, and the last would probably occur about 7 or possibly 8 weeks after it, the average occurrence of the deaths being about 5 weeks after the infection was taken. Therefore, in studying an outbreak of typhoid, the infection would be looked for about 5 or 6 weeks before

the deaths began to occur in noticeable numbers. To study the question of the amount and the causes of typhoid fever in Detroit, the date of each death occurring in the city from that disease since 1888 was obtained from the records of the local board of health. These were found to be arranged by months, as shown in the following table:

TABLE 45.—*Typhoid fever deaths in Detroit.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Rate per 10,000 living.
1889	5	4	3	1	6	3	5	7	8	9	11	0	62	3.13
1890	3	1	3	1	0	3	4	8	7	3	3	3	39	1.89
1891	2	2	0	2	[1] 6	3	1	4	19	15	16	3	73	3.35
1892	7	4	12	11	6	38	22	30	26	27	16	9	209	9.19
1893	4	3	8	10	6	3	7	12	14	14	11	5	97	3.95
1894	6	3	7	6	4	3	6	6	8	7	7	4	67	2.64
1895	3	1	1	4	4	4	0	8	9	10	10	2	56	2.13
1896	4	4	5	7	3	2	2	6	11	4	2	4	54	1.96
1897	1	0	0	1	0	1	3	10	6	3	4	2	31	1.10

[1] 4 reported typho-malarial fever.

NOTE.—This table included deaths reported from typho-malarial fever.

The most striking feature of this table is the record of 1892, but studying it carefully we see a sudden rise in mortality in September, 1891, and that it continues above the average until the close of the following year. We might anticipate finding a cause for this excess that began to operate about the 1st of August, 1891, and that continued through 1892 and possibly was operating intermittently in 1893, when the mortality is high in every month except possibly June.

To discover if possible this cause, these deaths were platted under their respective dates upon a chart which was also shown the rainfall and snow on the ground at time of thaws, and the dates of freezing and thawing weather. From this chart it was readily seen that a heavy rainfall was uniformly followed in about 50 days by a group of typhoid deaths, and that the January and spring thaws were similarly connected with typhoid, but meteorological conditions failed to account for the remarkable typhoid record of June, 1892, and the months following.

A table was next compiled of the reported cases and deaths from typhoid fever on both the Canadian and American watersheds, but beyond showing a small excess in 1892 for most of the towns along the river and a remarkable amount in Port Huron in the fall, it failed to afford much of a clue to the cause that was sought.

A further study of the localities of the deaths in 1891, 1892, and 1893 was then made, which showed conclusively by the location of those in June, 1892, near the large water mains of the city that there was a close connection between them and the water supply. Of the first 12 deaths in that month, 9 were females and may therefore be presumed to have taken the infection at their homes, and all but 1 lived within 1,000 feet of a large water main, and all were supplied with city water. The youngest was 8 years old and the oldest was 34. Only two others were under 22 years, one being 14 and one 18 years old. No two of these cases were in the same locality, or appear to have had any connection with each other.

These facts all seemed to point to but one conclusion: The water was at fault, but how did the water become so remarkably contaminated at the particular period? There had been a series of very heavy rains in April and May, but similarly heavy rains in other years, while evidently producing some typhoid, had been accompanied by nothing to compare with the record of June, 1892, when there were 38 deaths in 25 days, as many as 5 occurring in a single 24 hours.

At last attention was turned again toward Port Huron, which then was the only city on the American watershed having a system of sewerage, and hence the most likely one to contaminate the water, if it were not for its distance. From the best available data a computation was made to determine the time required for water to flow from Port Huron to Detroit and it was found that not more than 12 nor less than 6 days would be probably required. As the life of the typhoid germ in water has been found to be 20 days, and as the distribution system of our waterworks only holds about one-third of a day's supply, it at once became apparent that the disease might travel from Port Huron to Detroit through the water and be distributed with it to the consumers.

The sewers of Port Huron all empty into Black River, a sluggish stream which flows through the center of the city, dividing it nearly in halves. The discharge from this stream into St. Clair River caused the formation of a shoal at its mouth, which, becoming a menace to nagivation, was partially removed by dredging in 1889 by the United States Government. In 1891 the work was continued and during the same year a contract was let for dredging a channel up Black River. The latter work began in 1891, but only extended a few hundred feet upstream. In 1892 work commenced again on April 16, at a point just below the outfall of the two largest sewers. For the next 30 days the dredges were working up and down the river in the accumulated sewage deposits, which in some places are reported to have been nearly 10 feet deep. The material excavated was loaded upon scows and dumped in St. Clair River, about a mile below the city. When this information was obtained the cause of the typhoid in Detroit was easily explained. Allowing 10 days for the travel of the water, 12 days for the incubation of the disease, and 26 days to produce death, makes a total of 48 days. From April 16, when the first scow load of sewage deposit was dumped in St. Clair River, until June 5, when 4 deaths were recorded from typhoid fever in Detroit, there having been but 1 in 24 days preceding, is just 50 days.

By the 9th of July the first force of the outbreak was spent. From that time on secondary infection and the normal seasonal increase obscures relations with other conditions. The dredging in the heavily contaminated portion of the river was finished by May 16, and after that the work had less effect, although it continued to pollute our water supply until it was finally completed on Decenber 7.

Looking back now at the records of 1889 and 1891, we find the excess of deaths in those years to be coincident with the work on the bar at the mouth of Black River and in that stream. And similarly since the years of little dredging in the waters above us have been years of low typhoid in Detroit.

During the year 1893 there was an abnormal prevalence in March, April, and May.

More than 25 per cent of the total typhoid deaths for the year occurred in these three months. The Chart No. 82 shows the seasonal prevalence in 1894. This year shows an unusually high rate in March and April, and 43 per cent of the total typhoid deaths occurred in the first half of the year.

In the year 1900 there was an excessive prevalence of typhoid fever. The rate for the year increased to 28.4. In spite of an unusually high rate in September the total typhoid fever deaths from January to June constituted nearly 45 per cent of the total typhoid deaths for the year.

The year 1904 is another example of excessive prevalence in the spring months. Chart No. 83 shows the rise culminating in May,

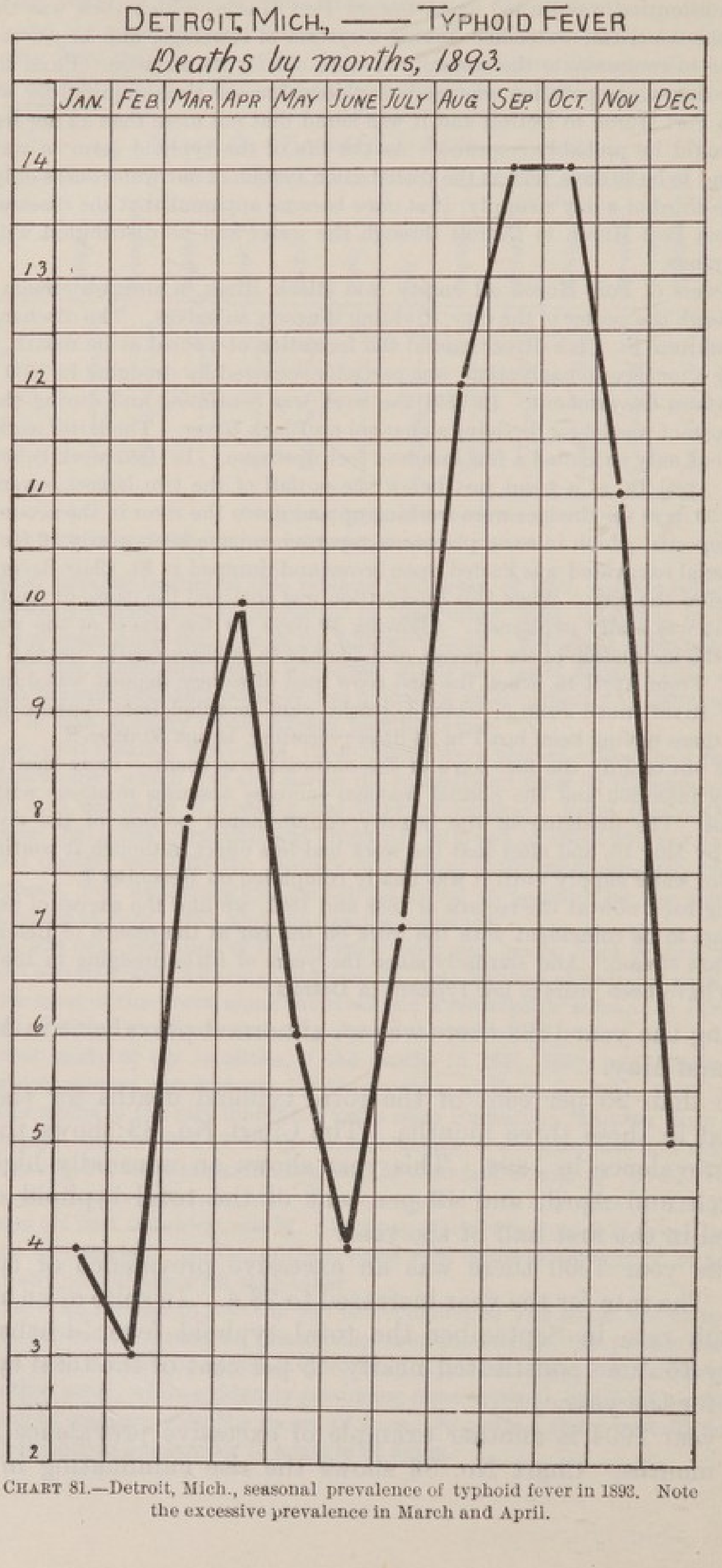


CHART 81.—Detroit, Mich., seasonal prevalence of typhoid fever in 1893. Note the excessive prevalence in March and April.

which almost equals the high point for the year in August and which is considerably higher than September or October. This August rise can not be considered normal, as August is manifestly too early a month to have the greatest number of typhoid deaths. This doubtful honor usually belongs to September or October.

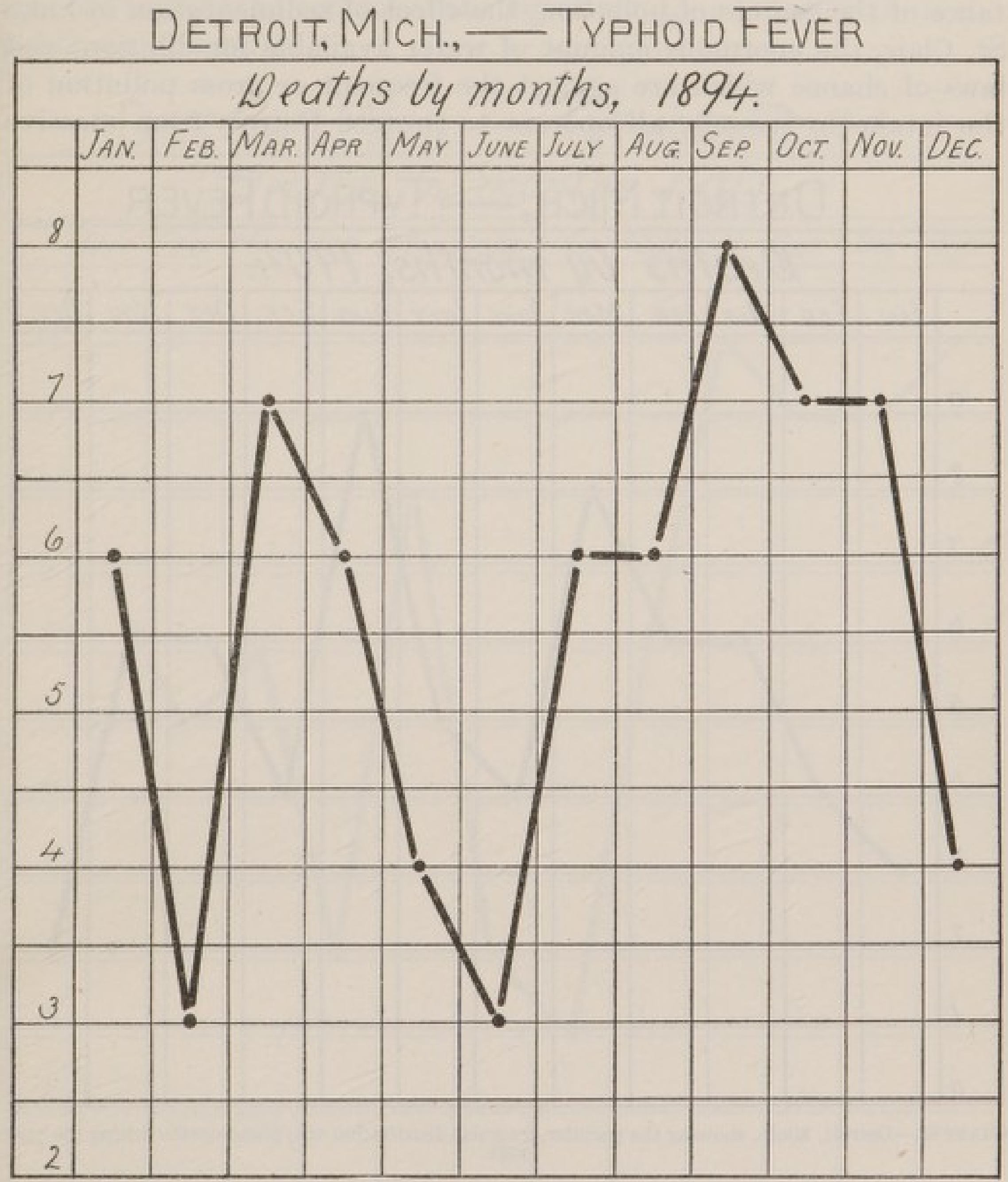


CHART 82.—Detroit, Mich., showing excessive prevalence in March and April, 1894.

In 1907 the autumnal prevalence was marked, but the sharp rise in May is very noticeable. There was also a high rate in January, February, and March, and the first half of the year contributed more than 41 per cent of the total typhoid deaths.

The nonporous character of a great part of this very populous watershed, the gross pollution of the St. Clair River by the sewage of Port Huron, the possible pollution from near sources, especially

Connors Creek, and the passing of thousands of vessels within a short distance of the intake all indicate the possibility of pollution. Such possibility makes necessary the protection of Detroit's citizens and of the thousands of visitors who come to the city by proper treatment of the public water supply of Detroit. It is conceded that the distance of the sources of pollution, the effect of sedimentation in Lake St. Clair, the enormous amount of water available for dilution, and laws of chance which are against the frequent or gross pollution of the intake by vessels, all operate to protect Detroit from massive

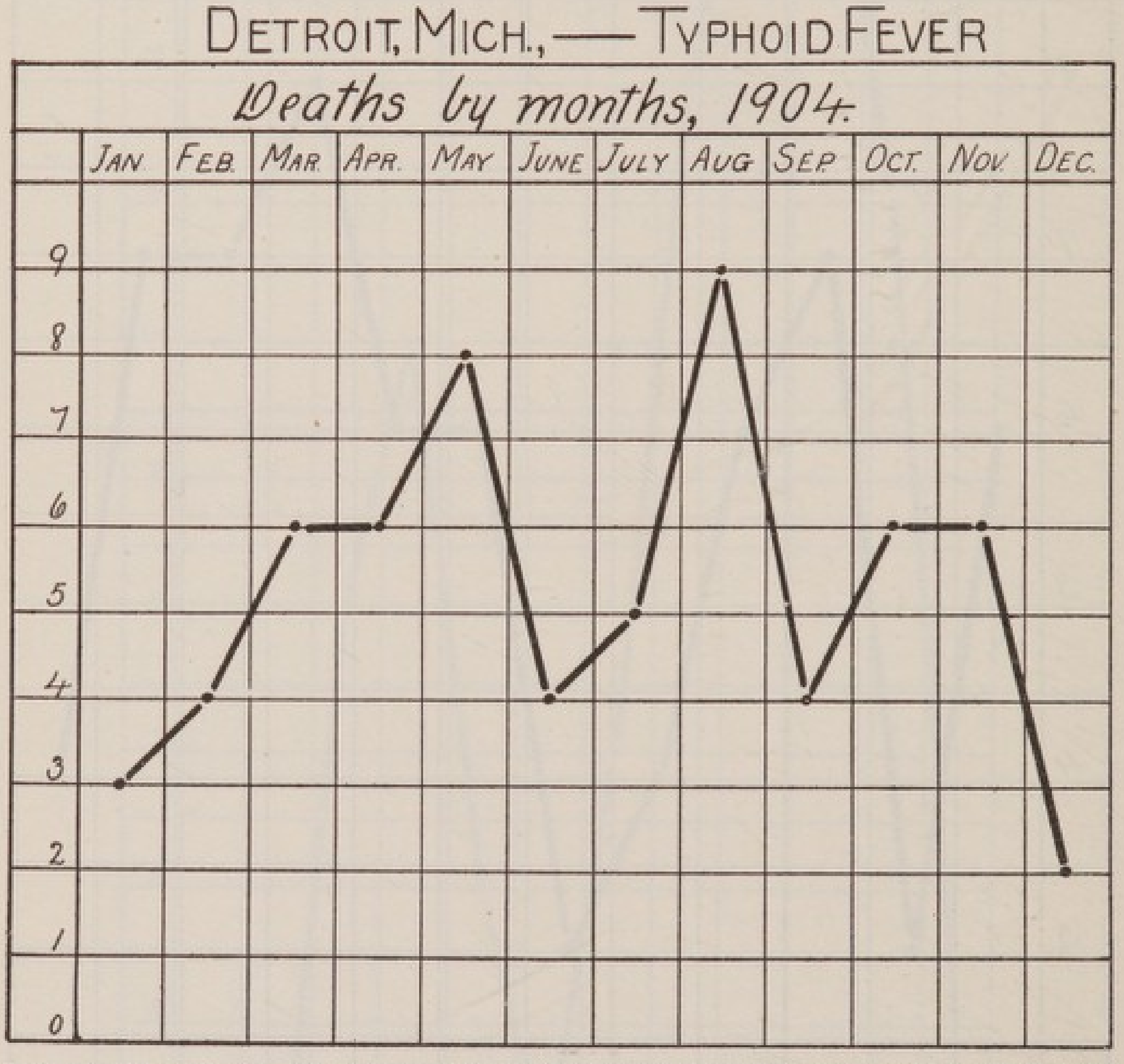


CHART 83.—Detroit, Mich., showing the peculiar, irregular distribution of typhoid deaths during the year 1904.

explosive outbreaks, which can easily be traced to water. But are these agencies or conditions sufficient protection for all years and for 365 days in each year?

Epidemics in Detroit have been water-borne in the past, and at least one has been so clearly traced that the most eminent sanitarians in the country have accepted the findings. In spite of the efficient work of the health department in milk inspection, housing, elimination of insanitary privies, in work against the breeding places of the fly, and in other measures of undoubted value in the prophylaxis

of typhoid fever, the rate has not decreased; on the contrary, the tendency of the last five-year period is upward, indicating some factor over which the health department has no control and against which the department work has no effect.

There is only one factor in the transmission of typhoid which is entirely beyond the control of the department, and that factor is the public water supply.

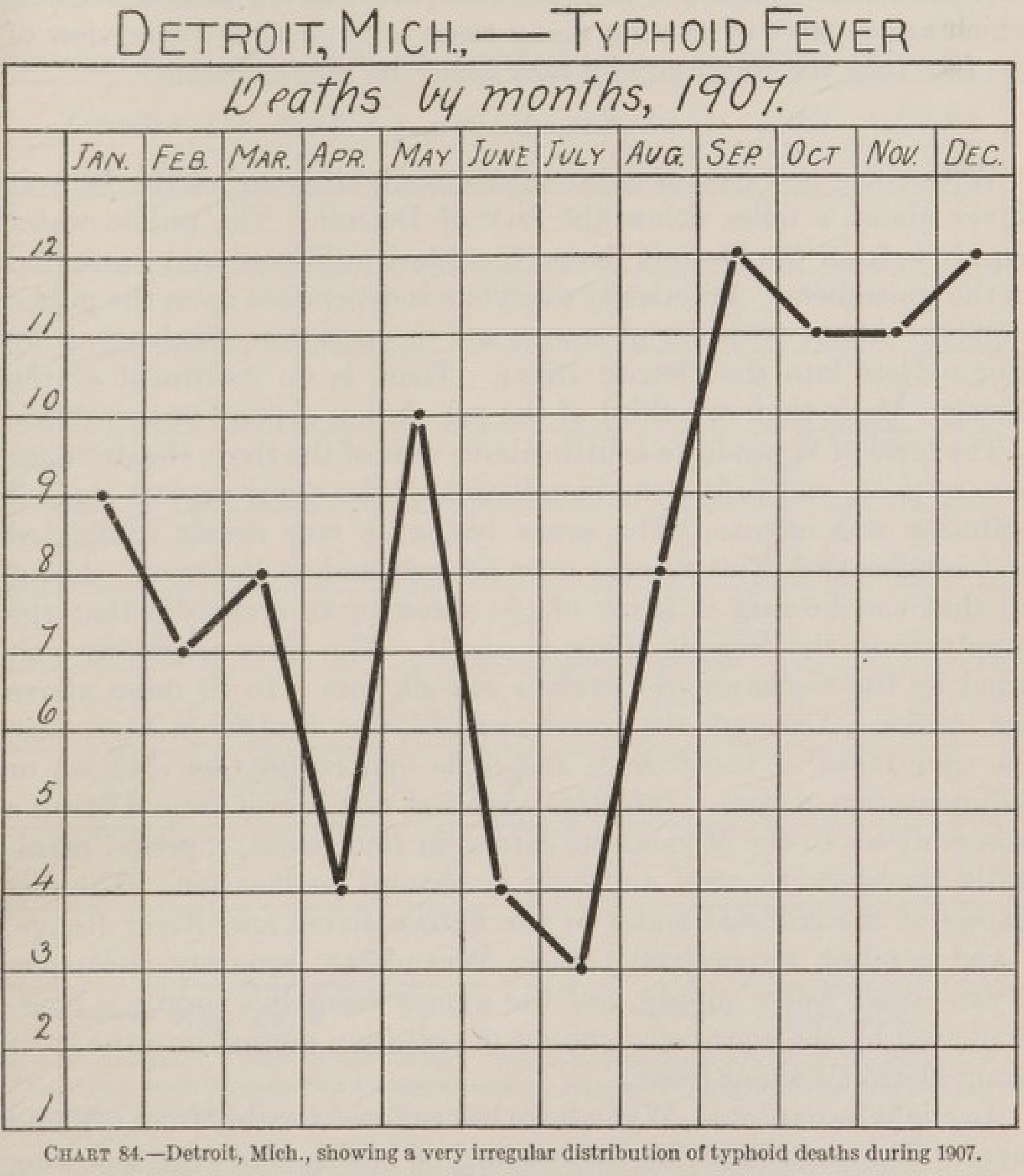


CHART 84.—Detroit, Mich., showing a very irregular distribution of typhoid deaths during 1907.

In assuming that a public water supply is entirely guiltless in the transmission of typhoid fever, we must first be sure that such supply is safe from pollution or treated in such a way that possible pollution is rendered innocuous. In Detroit's case the possibility of pollution is always present, and no measures are taken to render the water safe. It might be argued that the case against the present water supply is not proven, except by circumstantial evidence and infer-

ence, and such is the fact. However, it must be borne in mind that with the enormous dilution, distance, and other factors a massive outbreak easily traceable to water is unlikely to occur. In spite of these factors, however, many cases could be caused by the dilute infection of the water, whose origin would be difficult to trace definitely to the water. Even conceding that a massive explosive outbreak, such as the Erie outbreak of January–February, 1911, could not occur at Detroit, is it justifiable to rest satisfied with conditions which are capable of causing many cases of typhoid fever in view of the fact that the water supply may easily be rendered safe?

WYANDOTTE.

Wyandotte is a city of 8,287 inhabitants, situated on the Detroit River about 8 miles below the city of Detroit. The public water supply is from the Detroit River, furnished unfiltered and untreated to the consumers. Practically everyone is dependent upon the public supply. About 25 miles of sewers are in operation, discharging by four outlets into the Detroit River. There is no treatment of the sewage. Less than one-third of the population depend upon privies.

The level of Wyandotte is little above that of the river, the drainage is very poor, and before the installation of the sewer system the soil pollution was intense. The sewer system is now nearly completed and conditions in this respect may be expected to improve. About all that can be said in favor of the waterworks system is that the supply from the Detroit River is ample. The river is grossly polluted by the discharge of Detroit's sewers from 6 to 10 miles above the intake. Although the water available for dilution is enormous, the time factor is insufficient, and little opportunity for dilution or sedimentation occurs. Infective material can travel from Detroit's sewers direct to the Wyandotte intake in four hours, a period manifestly too short to avail anything in natural purification. The discharge of the polluted water of the Ecorse River and River Rouge, 1 and 6 miles, respectively, above Wyandotte, seriously endangers Wyandotte's water supply, but the danger from this source is overshadowed by the enormous amount of pollution poured into the river along Detroit's water front.

As might be expected, Wyandotte has suffered terribly from typhoid fever. The records of the State board of health show the following rates:

Death per 100,000 typhoid fever: Average (1889–1905), 85.8; 1906, 72.1; 1907, 107.0; 1908, 123.5; 1909, 87.5; 1910, 75.0.

Chart No. 85 shows the seasonal prevalence of typhoid fever in Wyandotte, compared with Cadillac, Mich. The total typhoid deaths for 10 years are shown by months. These cities are of the same size and Cadillac has had a high typhoid rate. Cadillac's water supply,

although from a near-by lake and wells, has not been grossly contaminated and is probably safe. Cadillac's typhoid curve is low in winter and spring and high from August to November.

Wyandotte has a polluted water supply for the entire year, and its typhoid curve is high from February to September, still higher in October and November, and reaching its highest point in December. Its high typhoid prevalence from February to September is still higher in October, November, and December, i. e., about one month

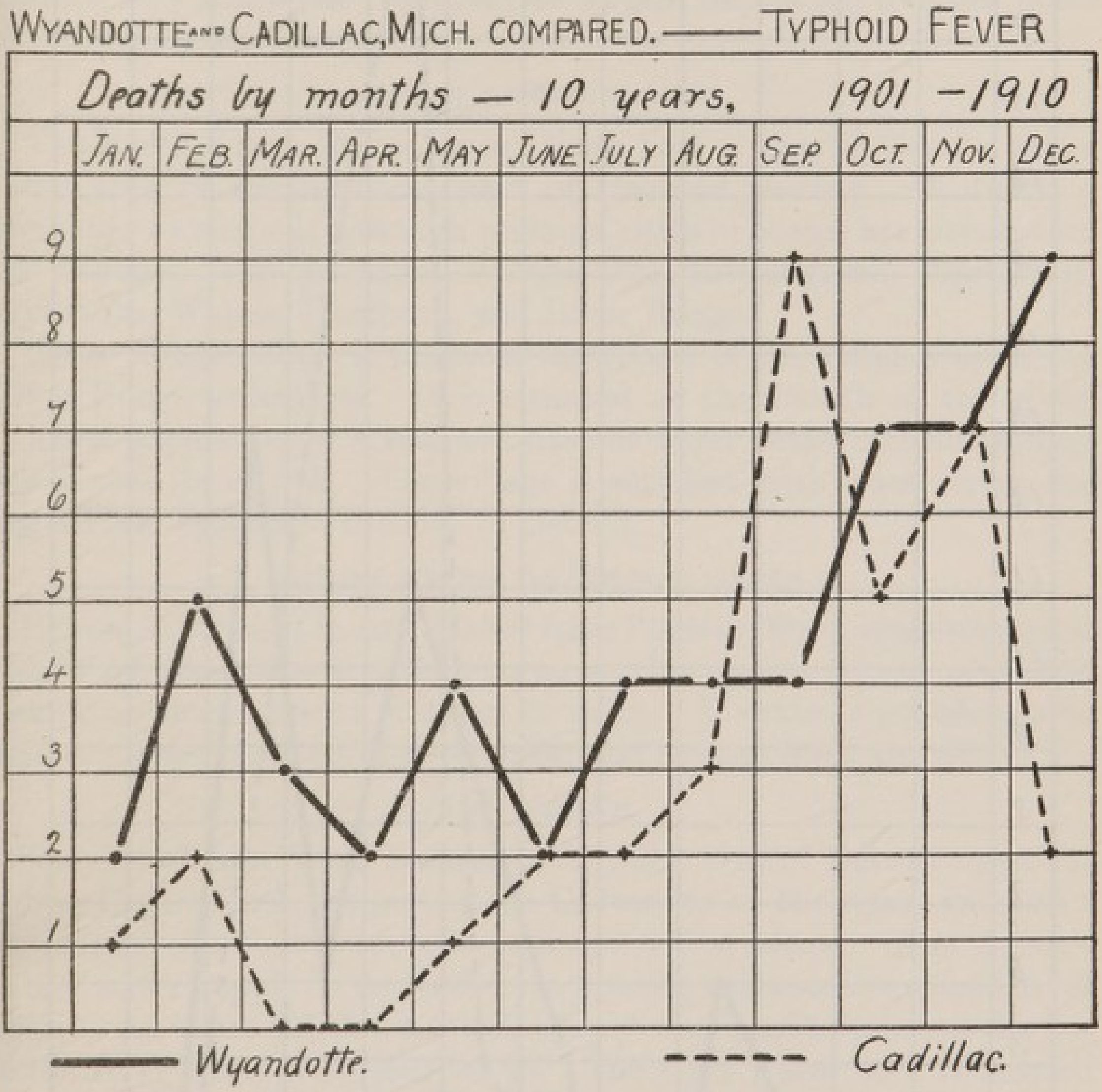


CHART 85.—Comparing Wyandotte and Cadillac. There is nothing unusual in Cadillac's typhoid curve. Wyandotte's March curve shows a peculiar seasonal prevalence. The progressive rise from September to December is unusual.

later than the months of greatest prevalence in Detroit (September, October, and November). This seems a logical sequence in view of the fact that Wyandotte's citizens drink diluted Detroit sewage.

A study of enteritis under 2 years of age in Wyandotte is also interesting. In the 10 years 1901–1910 there were 67 deaths from enteritis in this little city, or about 8 more than the combined deaths from this cause in Benton Harbor and Holland. Holland has 10,490 population, Benton Harbor 9,185, and Wyandotte 8,287.

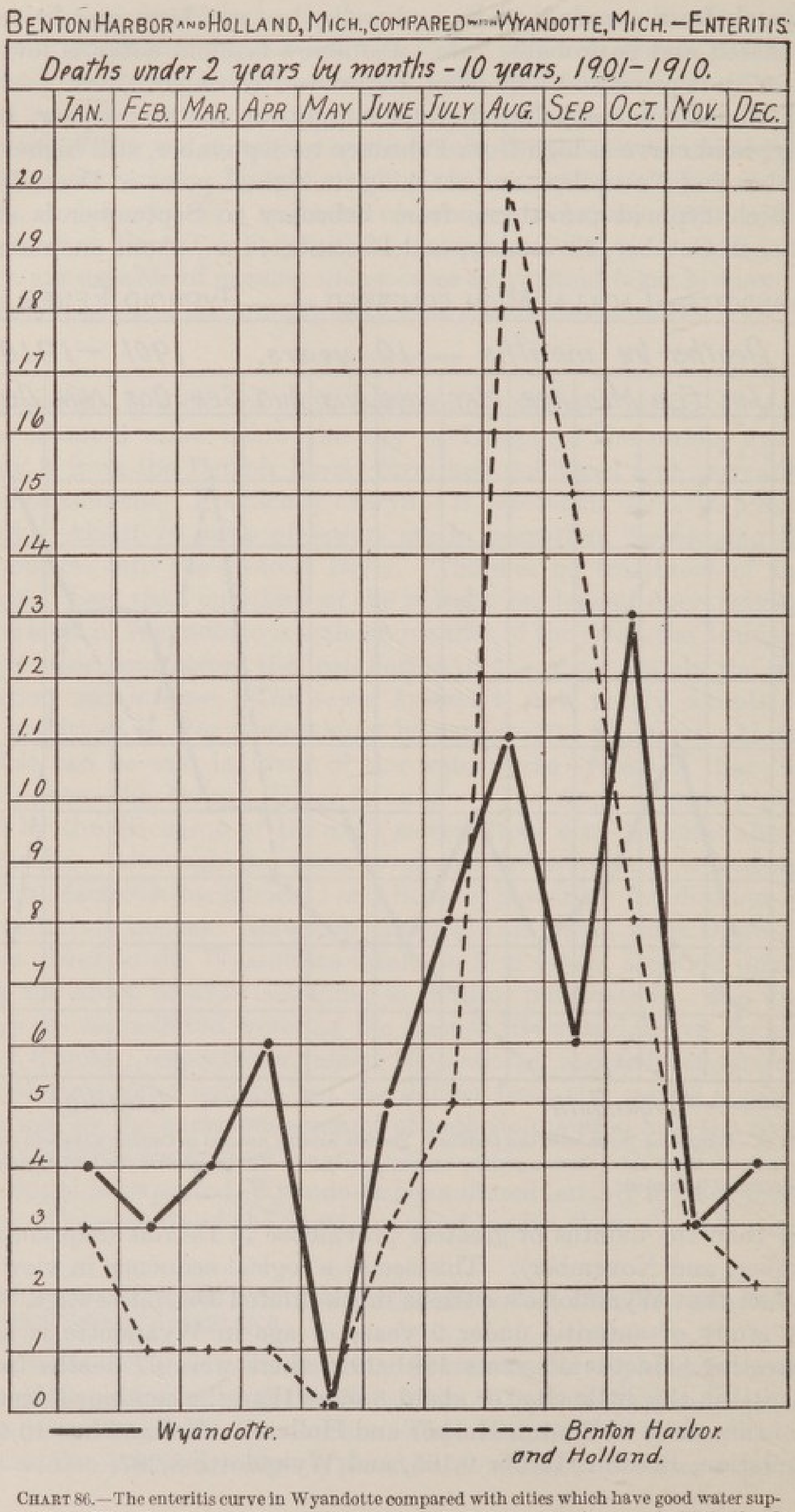


CHART 86.—The enteritis curve in Wyandotte compared with cities which have good water supplies. Wyandotte's curve shows a peak in April, which is absent in the curve for Holland and Benton Harbor.

Chart No. 86 shows the total enteritis deaths for 10 years (1901–1910) by months, comparing Holland and Benton Harbor combined with Wyandotte. Holland and Benton Harbor have public water supplies from wells which are considered safe. The contrast on the chart is striking. Note the sharp rise of the Wyandotte curve in March and April is notable, as is also the very pronounced rise in October. The curve for Benton Harbor and Holland is like a normal enteritis curve for a small city with a good water supply; low until June, a very sharp rise from July to August, and a fall to a low point in November and December.

RIVER ROUGE BASIN.

The River Rouge drains the northern half of Wayne County and a small area in the southern part of Oakland County. It drains a populous watershed, although no large cities or towns are situated on the Rouge. The principal villages are Birmingham, Northville, Plymouth, Wayne, Dearborn, and River Rouge.

River Rouge village is the most important of the villages upon the River Rouge watershed. It is situated at the mouth of the river. It has a population of 4,163, and has one sewer outlet into the Rouge River near its mouth. The village is supplied with water from the waterworks system of the city of Detroit.

HURON RIVER DRAINAGE BASIN.

Huron River rises in small lakes near Pontiac, flows southwestward into Washtenaw County, then turns southeastward and empties into Lake Erie after a course of about 80 miles. It drains a populous area with a considerable rural population and several large towns.

ANN ARBOR.

The city of Ann Arbor is situated 35 miles west of Detroit upon the Huron River. It is the seat of the University of Michigan, and has a population of about 20,000, including 5,000 students. Ann Arbor's public water supply is derived from flowing wells and ozonized river water. At times the flowing well supply was insufficient and the use of the river water was resorted to. The river water used is treated by the ozone process.

Ann Arbor has had a low rate for typhoid fever; the average for 20 years ended 1909 was only 15.4 deaths per 100,000 population. About 75 per cent of the population is tributary to the sewer system. There are about 30 miles of sewers. The sewage is discharged into the Huron River without treatment.

YPSILANTI.

The only other community of importance sewering into the Huron River is the city of Ypsilanti, with a population of 6,230. Ypsilanti has a public water supply from flowing wells. The wells are about

60 to 80 feet deep and pass through clay, but are unwisely located, as the natural drainage of the city is past the wells toward the Huron River. The supply seems to have escaped contamination, and typhoid death rates have been low in Ypsilanti:

Death rate per 100,000, typhoid fever: Average 16 years (1889–1905), 10.3; 1906, 13.0; 1907, 0; 1908, 0; 1909, 16; 1910, 16.

THE RAISIN RIVER BASIN.

The Raisin River basin includes a small portion of the south-eastern part of Jackson County, nearly the entire county of Lenawee, the southern one-third of Washtenaw County, and the northern one-half of Monroe County. The most important municipalities in this area are Manchester, Clinton, Dundee, Tecumseh, Adrian, and Monroe.

Most of the villages on the Raisin are unsewered and contribute very little direct pollution to the river.

Clinton village has three private sewers with three outlets into River Raisin. The population tributary to these sewers is less than 100.

Tecumseh has a population of 2,332. It has 110 sewer connections with one main sewer outlet into the River Raisin.

ADRIAN.

The population of Adrian in 1910 was 10,763. Adrian's public water supply is taken from Wolf Creek, a surface supply subject to contamination, delivered, unfiltered and untreated, to consumers.

About 50 per cent of the residents depend upon wells. Adrian has had a high typhoid fever rate for many years, as shown below:

Deaths per 100,000, typhoid fever: Average 1889–1905 (16 years), 31.1; 1906, 44.7; 1907, 34.9; 1908, 17.1; 1909, 34.2; 1910, 17.1.

Adrian has about 25 miles of sewers, to which over 5,000 persons have access. These sewers discharge by 12 outlets into the River Raisin. There is no sewage treatment of any kind.

MONROE.

Monroe has a population of 6,893; 90 per cent of the population have access to sewers which discharge into the Raisin River. There is one sewer which discharges into an open ditch and another discharges into a bayou. These latter cause considerable local nuisance and complaint. The condition of the river at low water in the vicinity of the sewer outfalls is said to be foul.

Monroe's water supply is taken from Lake Erie at a point which is supposed to be too far north for contamination from the River Raisin. It is also supposed to be west of the polluted current of the Detroit River. The danger of depending upon lake currents is well

known. It is too much to expect that the polluted water of the Detroit River, carrying the sewage of Detroit and other cities, always maintains the same channel in the lake. The course in the lake of the polluted current will depend upon weather conditions and, given certain winds, polluted water from th Detroit River might easily reach the Monroe intake. The same is true of polluted water from the Huron River and the Raisin River itself in time of flood. The course of polluted water from these rivers depends entirely upon the lake currents, which are quite as likely to be from one direction as another.

As a matter of fact examinations of the Monroe public water supply made in 1909 by the State board of health showed gross contamination in 100 per cent of the samples examined.

Typhoid fever rates in Monroe have been low in spite of the water supply. The low typhoid rate for Monroe is difficult of explanation. The two most potent factors in minimizing the danger from the sewage polluted water of the Detroit River are the sedimentation afforded by the great shallow delta in the western end of Lake Erie and the great body of water available for dilution.

The low rate of prevalence as shown by typhoid fever deaths in Monroe may be due to the factors indicated acting upon the grossly polluted water of the Detroit River. The few typhoid deaths have a remarkably even distribution throughout the year.

Total typhoid deaths, 10 years, 1901–1910: January, 1; February, 1; March, 1; April, 1; May, 0; June, 0; July, 0; August, 1; September, 1; October, 1; November, 1 December, 0.

This even distribution suggests some factor like water, but it is impossible to draw conclusions from such small numbers.

CONCLUSIONS.

(1) There is need of a thorough investigation of the conditions in Alpena which are responsible for the high typhoid fever rate and the appalling infant mortality. From a study of the data it is almost certain that polluted drinking water is largely responsible for the high typhoid rate. The seasonal prevalence of the enteritis of children also points to water as a factor. The milk supply should be very carefully investigated. The defective water mains should be replaced. The insanitary privies and shallow wells should be eliminated in districts supplied with water and sewer mains. In districts not so supplied the sanitary privy should replace the type now so common. The public water supply should be extended and treated with hypochlorite or a filter plant installed. These measures should effect a material reduction in the typhoid fever rate, especially in the winter and spring months. Enteritis of children, regardless of its real identity, whether it be bacillary dysentery, typhoid, or other disease,

should be reduced to a reasonable rate by the same measures. It will probably be necessary to improve the milk ordinances and enforce them more rigorously

(2) The excessive prevalence of typhoid fever in Flint is probably due to insanitary conditions produced or accentuated by its very rapid growth. It has a polluted public water supply which is supposed to be used only for lawn sprinkling, in case of fire, and for factory uses. The significance of typhoid fever in Flint so far as this investigation is concerned lies in the fact that the city's sewage goes untreated into a branch of the Saginaw River. The State board of health doubtless will investigate the milk supply, water supply, and the insanitary conditions in Flint in view of the rate of 105 deaths per 100,000 population in 1910. Whatever may be the underlying causes of the high typhoid fever rate, they seem also to affect the enteritis rate of children. The natural inference is that correction of these defects will reduce the rate for both typhoid fever and enteritis under 2 years of age. Flint is an example of a city which furnishes a polluted public water supply, trusting the people not to drink it. This is a dangerous policy and has resulted disastrously in other places.

(3) The public water supply of Saginaw is grossly polluted and this fact is common knowledge. The city government has provided many deep wells, hoping that the people will not drink the polluted city water which is intended for fire, lawn sprinkling and manufacturing purposes.

The typhoid history of Saginaw suggests that the deep wells prevented many cases of typhoid fever, but that in spite of the supposedly common knowledge of the dangerous character of the public water supply this easily accessible but grossly polluted water was used to some extent for domestic purposes and was responsible for many cases of typhoid fever, especially in winter and spring months. The first sanitary necessity in Saginaw is a filtration plant for the public water supply. This supply should be extended to all parts of the city to make possible the elimination of the insanitary yard privy and the shallow well. Where sewer connections are not feasible a sanitary privy should be substituted for the insanitary one and its sanitary condition maintained by frequent inspection.

The sewage of Saginaw should be intercepted and carried to a disposal station at some point near the northern limits of the city. The purification should be carried far enough to secure a good raw water at the Saginaw intakes when reverse currents in the Saginaw River are running. The purification should be carried also to such a point that the raw water at the Bay City intakes would not be affected materially by the Saginaw sewage. The effect of Saginaw's sewage on the raw water of Saginaw Bay in the vicinity of the Bay

City intakes may be gauged with fair accuracy by the quantitative colon estimations and bacterial counts made daily for considerable periods.

Bay City is in a similar position to Saginaw in regard to water supply. The water should be filtered to render it safe, but the raw water should be improved in order to avoid too great a strain on the filters.

To improve the raw water of Saginaw Bay the untreated sewage of Saginaw and Bay City must be kept out of the Saginaw River. The Bay City sewage should be collected by interceptors and brought to a disposal station. The degree of purification or chlorination of the effluent necessary would have to be decided by the condition of the raw water examined daily at the intakes. In Saginaw and Bay City the public water supplies should be rendered safe at once. For this purpose, because of the turbidity, the hypochlorite method would not be satisfactory except perhaps as a temporary expedient. Filtration by the so-called "rapid sand" type would probably give the best results. The question of sewage disposal in these cities is important, but is secondary to the improvement of the water supply.

The public should be protected by making the water safe at once, while the sewage disposal question could be given full consideration later. After the installation of a safe public water supply the campaign against insanitary privies and shallow wells should be pushed vigorously in both Bay City and Saginaw.

(4) The typhoid history of Port Huron indicates that the public water supply is responsible for many cases of the disease, especially following heavy rains, thaws, and floods. The intake is only a few feet offshore and receives shore pollution whenever rains or thaws bring the surface washings to the river. Extension of the intake pipe to a point at least 500 feet from shore would avoid most of the shore pollution. The pump well should be made water-tight and properly covered. The water supply should be filtered or treated with the hypochlorite method in order to be safe 365 days in the year. The sewage of Port Huron as discharged into the Black and St. Clair Rivers, outside of the fact that it makes an intolerable nuisance in summer in the Black River, is a menace to the water supplies of cities situated on the St. Clair River below Port Huron. The sewage of Port Huron should be collected at a central disposal station and purified to the extent that its discharge into the St. Clair would not be detrimental to the water supplies of other communities.

(5) St. Clair and Marine City should protect their citizens at once by the installation of a plant for treating the water with "hypochlorite." Marine City could be protected for the present from St. Clair sewage by treating its drinking water with "hypochlorite." The sewage of Marine City is not a menace at present. In view of the

fact that these small cities are not growing fast enough to cause apprehension making the drinking water safe would fulfill present sanitary indications.

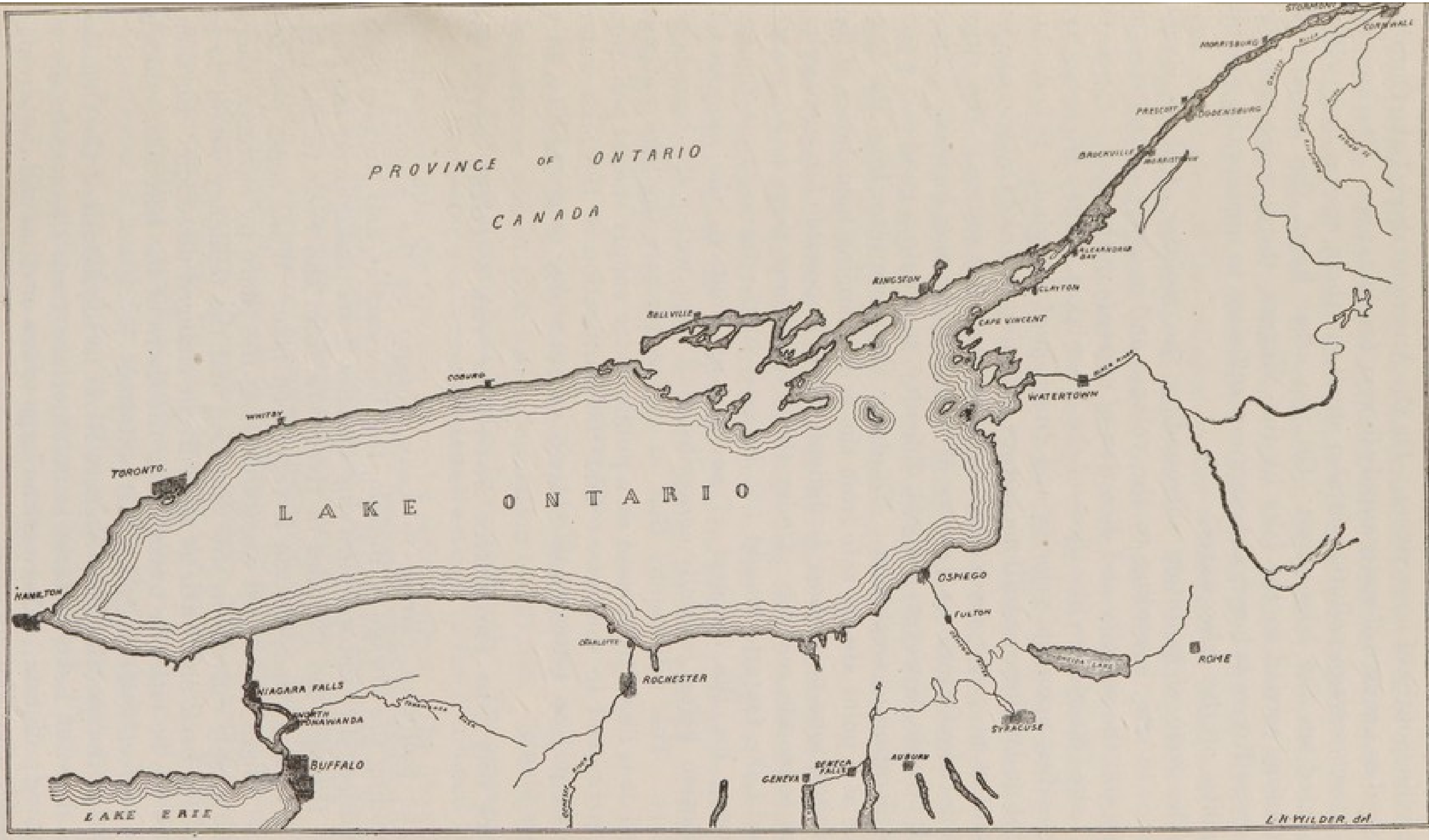
(6) The water supply of Detroit should be rendered safe by filtration or treatment.

The best possible location has been selected for obtaining a good raw water, but it is subjected to pollution at times and can never be considered as really safe every day in the year. The fact that the pollution is necessarily dilute, and typhoid deaths are few and scattered and difficult to trace to water, is no excuse for postponing an obvious necessity. Colon estimations by standard methods should be made in Detroit daily instead of the occasional animal inoculations as a test of pollution. A primary sanitary necessity in Detroit is safe water for every day in the year.

The disposal of sewage in Detroit is of secondary importance, and from a selfish local standpoint is not a problem. There is ample dilution to avoid nuisance and economically the method of disposal is ideal. Unfortunately the Detroit River is so grossly polluted thereby that the city of Wyandotte has suffered terribly from typhoid fever. Undoubtedly Wyandotte and Monroe also should filter their water supplies and protect themselves, but they should not be required to treat a raw water which puts an unreasonable strain and responsibility on their filter plants. It is probable that "rapid" sand filter plants with "hypochlorite" as an adjuvant would afford ample protection to Wyandotte and Monroe without change in Detroit's method of sewage dispsoal. In the future partial purification of Detroit's sewage may become necessary.

V. LAKE ONTARIO AND THE ST. LAWRENCE RIVER.

Although Lake Ontario is the smallest of the Great Lakes in superficial area, it contains a much greater volume of water than Lake Erie, because of its greater depth. The maximum depth of Lake Ontario is 738 feet. The area of the water surface is 7,243 square miles. Allowing an average depth of 250 feet, the storage capacity of the lake would be 50,480,812,800,000 cubic feet. The discharge from the lake by the St. Lawrence River is about 250,000 cubic feet per second, or 21,600,000,000 cubic feet per day. At this rate of discharge, Lake Ontario would require 2,337 days or over six years to empty itself if all inflow were stopped. This is a conservative computation and it may be reckoned that given proportions of water contributed to the lake at the western end will have the benefit of over six years' storage before making their exit into the St. Lawrence River. This means that the water in Lake Ontario is capable of purifying an enormous amount of organic matter and that with the existing pollution the water should be pure outside of the zones of



MAP 39.—Lake Ontario and a portion of the St. Lawrence River.

polluted water which surround the water front of cities and towns and the mouths of large rivers. On the American shore Lake Ontario is used as a source of water supply in very few instances. The amount of direct sewage pollution is also small, as there are no large cities situated on the lake shore. On the other hand, the amount of pollution carried to the lake by the Niagara, the Genesee, and the Oswego Rivers is large, although not sufficient to menace the general quality of the lake water.

The zone of pollution surrounding the mouths of these rivers varies in size, according to the volume and velocity of the stream flow and the velocity and direction of currents in the lake. Currents in Lake Ontario are like those of the other lakes. They are irregular, depending upon the velocity and direction of the wind. It is doubtful if under these conditions sewage pollution in Lake Ontario can be manifest at any considerable distance from the source. The cities using Lake Ontario as a source of water supply may increase. They will be able, however, without difficulty, to obtain a good raw water for filtration or treatment. To obtain the pure water from the deep lake at a point always safe from the ever changing boundaries of the polluted zone near shore is difficult if not impossible for engineering and economic reasons. Under these conditions there is no reason why Lake Ontario should not be used in the future, to a limited extent, for the disposal of sewage by dilution, the amount of pollution being carefully controlled and kept within the bounds of safety. This will require that at no point where the lake water is used or is likely to be used as a public water supply should pollution be permitted to the extent that the purification of the lake water would put an unreasonable strain or an undue responsibility on a filter plant.

LAKE ONTARIO FROM THE MOUTH OF THE NIAGARA RIVER TO CHARLOTTE.

The pollution carried to Lake Ontario by the Niagara River, including the sewage of Buffalo, the Tonawandas, and Niagara Falls, is subjected to natural purifying agencies in its passage over the Falls and through the 13 miles of river flow from the Falls to the lake. It is then discharged into a very deep lake. While some polluted water might be carried eastward along the shore by currents, there is no steady current in this direction and the tendency would be to oscillate back and forth as the current changed direction. Further, there are no cities or towns along the shore of the lake near enough to be affected seriously by this pollution.

From the mouth of the Niagara River to the mouth of the Genesee the shore of Lake Ontario is unimportant from the standpoint of existing pollution. There are no large towns or cities and the streams entering the lake are small.

THE GENESEE RIVER DRAINAGE AREA.

The Genesee River, with its tributaries, drains an area of about 2,500 square miles. From the standpoint of pollution of interstate waters and the spread of disease thereby, it will not be necessary to consider the entire watershed. Of paramount importance from this standpoint is that portion of the rivers from above Rochester to its mouth, including the city of Rochester. Outside of the city of Rochester the population of the villages on the watershed is small and their sewage pollution of only local importance. The rural population is not large, being only about 40 persons to the square mile.

As a source of pollution of Lake Ontario, the Genesee is of importance chiefly because of the sewage of the city of Rochester. Of course the aggregate pollution from the agricultural country, the villages and hamlets, is considerable and, exclusive of Rochester's sewage, quite sufficient to render the water of the lake in the vicinity of the river's mouth unfit for drinking without treatment, but the discharge of a large quantity of fresh sewage within a few miles of the lake, by the city of Rochester, is a much greater menace to the purity of the lake water.

The Genesee is noted for the great variation in its stream flow. In dry weather the flow may be only 200 cubic feet per second, while in flood it reaches 40,000 cubic feet per second. This great variation of flow has made the stream an unsatisfactory sewage carrier for Rochester, and necessitated some change in the system of sewage disposal employed by that city.

ROCHESTER.

Rochester is a city of considerable commercial and industrial importance and in 1900 had a population of 227,000. It is situated on the Genesee River about 7 miles from its mouth. The sewage system of Rochester was formerly almost entirely of the combined type, discharging into the Genesee River by eight outlets. The growth of the city and the low dry weather flow have combined to produce conditions in the Genesee which demanded a change in the sewage disposal to obviate the nuisance caused in summer. As a result Mr. Emil Kuichling, consulting engineer, prepared plans for intercepting sewers to divert the sewage of Rochester from the river to a point in Lake Ontario several thousand feet offshore. Mr. Kuichling's plans were approved by Mr. Rudolph Hering, and by Mr. Geo. H. Benzenberg, consulting engineers, and were finally submitted to the State department of health for approval by the city engineer. The plans as submitted provided for 7½ miles of intercepting and main trunk sewers to carry the sewage to detritus tanks about 3 miles north of the city. There were to be six detritus tanks, and in the outlet channel from the tanks was to be placed a revolving screening appara-

tus with one-twelfth inch mesh. After a short detention and screening, the sewage was to be carried by the outfall sewer 7,000 feet out in the lake. The outfall sewer was to terminate in a protecting crib and the discharge would be about 45 feet below the surface of the lake.

The plans were simple, even revolutionary, yet promised to be effective. The official sanction of the State health authorities of the use of the lake for sewage disposal was very properly withheld pending a careful consideration of the matter. The principles involved are of such importance that the review of the plans by Mr. Theodore Horton, chief engineer, New York State Board of Health, is given in part.

To summarize briefly my opinions and conclusions concerning these plans, following a careful examination and study of them, I would state:

(1) That the proposed system of intercepting and outfall sewers will remove from the Genesee River practically all of the sewage now discharged into the river by the city of Rochester at all times, except during heavy rainfalls, when the sewage will be discharged through overflows in a highly diluted state.

(2) That the diversion of this sewage will remove practically all offense and nuisance along the river in and below the city and along the shores of Lake Ontario near the outlet of the river.

(3) That during heavy rainfalls, when overflowing of sewage will occur, the dilution of the sewage will be so great as to prevent any appreciable nuisance in and along the river below the points of overflow.

(4) That whereas the method of sewage disposal proposed, viz, by a preliminary treatment in settling and screening tanks and final treatment by dilution, oxidation, and digestion in Lake Ontario is in principle a suitable and appropriate one for the city of Rochester, the plans are insufficient and inadequate as to capacity and important details and should be so modified and corrected as to provide:

(*a*) Settling tanks of twice the capacity shown by the plans.

(*b*) Skimming boards or other means for removing objectionable grease and oils.

(*c*) Branch connections near the end of the outfall sewer in the lake to permit the flow to be divided and discharged at two or more outlets in the lake whenever such provision may become necessary.

(*d*) Suitable means at the end of the outfall sewer which will permit of its being extended further out into the lake, if, or whenever, such provision may become necessary.

(5) That the proposed method of preliminary treatment, if modifications in the plans are made in accordance with the above recommendations, will eliminate from the sewage all of the grosser, and a large percentage of the finer, suspended matters which, on account of their relative insolubility and difficulty of segregation, and their offensive and dangerous nature, are easily transported by winds and induced surface currents, to considerable distances.

(6) That if the changes above recommended are made in the plans the finer suspended solids remaining in the partially clarified effluent, after passing through the settling and screening tanks, and after their discharge into Lake Ontario, 7,000 feet from shore, in over 50 feet of water, will be subject to combined action of sedimentation, dilution, and dispersion to such an extent that no traces of sewage will be discernible to the senses along the shores of the lake or at any considerable distance from the outlet.

(7) That at times, under unfavorable conditions of wind and wave action, pollution from the effluent of the proposed settling and screening plant discharged into the lake 7,000 feet from shore will even with modifications in plans above recommended, be carried to the intakes of the water supplies of the Rochester and Ontario Water Co., and of the village of Charlotte. This pollution will, on the whole, be much less in amount than occurs under existing conditions with the sewage of Rochester discharged into the river, and in turn into the lake near these intakes, and it will occur in such small amounts, at such infrequent intervals and be so diluted and attenuated, that with properly installed water purification plants, the health of the communities using those supplies will be amply protected against any danger of infection.

(8) That the possibility of any traces of sewage from the proposed outfall ever reaching the intake of the Oswego water supply, some 50 miles distant, is too remote for practical consideration. Even if traces were ever carried to this intake under unfavorable conditions they would be in such minute amounts and so attenuated as to have no appreciable effect on the public health of the citizens of Oswego, and entirely negligible as compared with the pollution of this water supply by the polluted waters of Oswego River which now enters the lake only a short distance from said intake.

(9) That if it be found in the future, after these works have been put in operation and after practical opportunity has been afforded to observe and study the effects of the discharge of effluent from the proposed plan into the water of the lake, that the health or comfort of the people who reside along the shores of Lake Ontario, or who may use the water for drinking, bathing, or other purposes, is in anyway deleteriously affected, it will be easily possible, and within reasonable cost, to increase the degree of purification by providing increased or additional sedimentation, supplementary treatment in biological filters, or the application of disinfectants, or all.

In view of the foregoing conclusions, and of the expressed policy of this department of preventing the discharge of raw or insufficiently treated sewage into the waters of this State, I beg to recommend that these plans be disapproved in their present form, and that they be returned for corrections and modifications in accordance with the suggestions and recommendations outlined above.

In accordance with Mr. Horton's review and recommendations the commissioner of health of the State of New York approved the plans provisionally on July 26, 1910. The very advanced position taken is amply safeguarded by the proviso which reserves the right to exact further purification of the sewage should this become necessary. It would be unwise to prevent the use of the cheapest known means of sewage disposal, namely dilution, when this method may be employed without detriment to other communities. Control over the pollution must necessarily be maintained to keep it within reasonable bounds in the event of greatly increased population and the possibility of an increased use of Lake Ontario water for public water supplies.

WATER SUPPLY.

Rochester's water supply is from Hemlock Lake, an unfiltered surface supply. However, the watershed is under control and has large storage capacity. It is, of course, exposed to accidental pollution, but must be classed as a good water supply.

TYPHOID FEVER.

The typhoid fever rate in Rochester has been consistently low for years. Since 1900 it has never been above 18 deaths per 100,000, and in 1909 was less than 10.

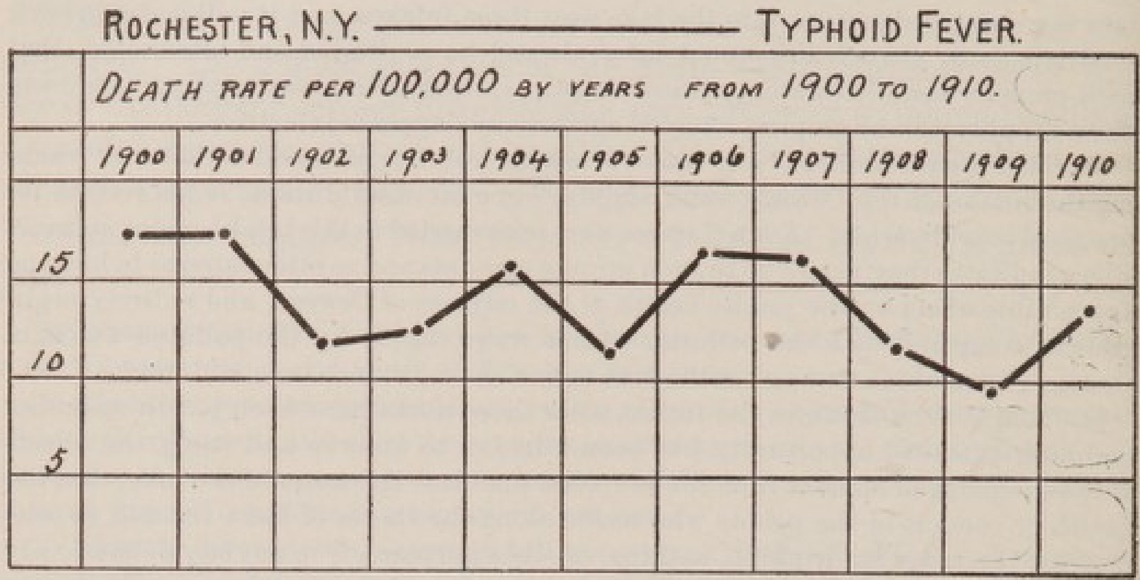


CHART 87.—Showing the comparatively low typhoid fever rates for many years in Rochester, N. Y.

The character of the water supply has undoubtedly been a factor in maintaining this low rate. In addition, the control of milk has been very effective in Rochester.

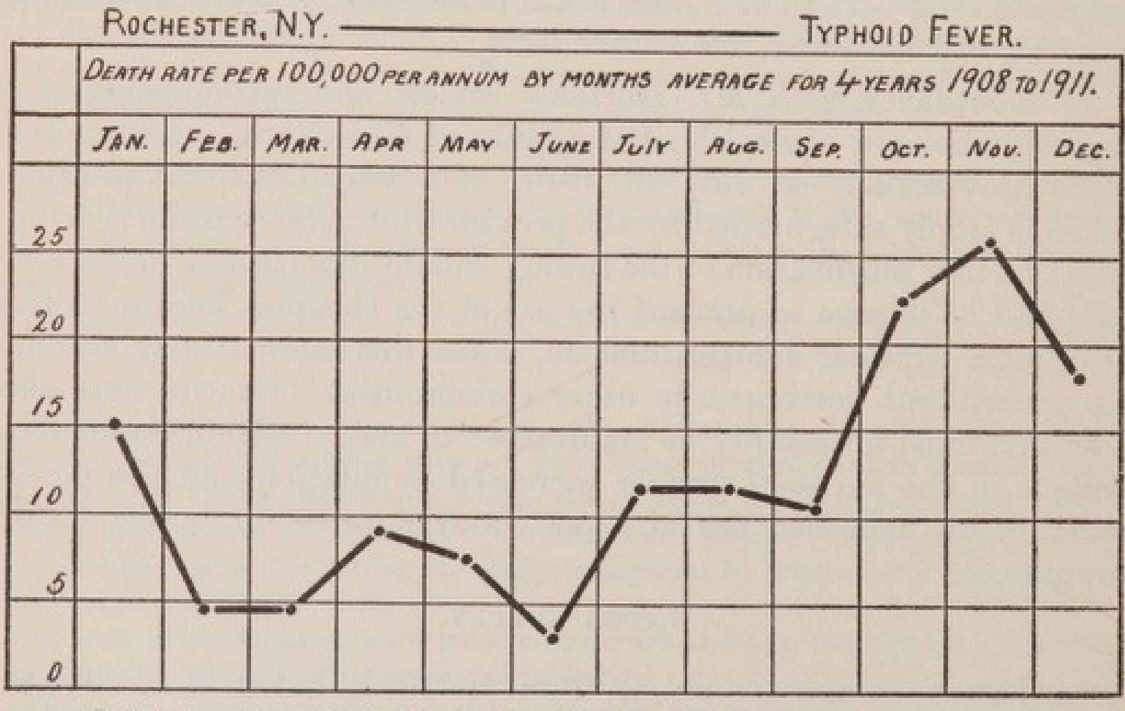


CHART 88.—Showing the distribution of typhoid deaths in Rochester, N. Y., by months.

Chart No. 88 shows the seasonal prevalence of typhoid fever in Rochester. The curve is low for February, March, and June, but begins to rise in July and reaches its highest point in November.

The Rochester water supply, though classed as a good supply, is not absolutely safe, and pollution might occur, although it would be necessarily of brief duration. Any surface supply from an inhabited watershed may receive small amounts of pollution at times. The effect of such pollution would depend upon the point in the water system at which it was received, and how much storage it was subjected to before delivery to the consumers. Not only the factor of dilution comes in here, but also the time factor. In most cases such small amounts of pollution as are contributed upon a carefully patrolled watershed are nullified by the storage and are negligible. It must be conceded, however, that constant vigilance is necessary to prevent or control such contamination. It is certain that pollution of the water supply in Rochester plays little if any part in increasing the low typhoid fever rate of that city. Yet in view of the work done in the control of milk, it is difficult to explain the relatively high rates which prevailed for example in January, 1908; in April, 1909; in January, 1910; in May, 1910; and in May, 1911. Taking the average of the four years from 1908 to 1911, the rates in January and April were higher than one would expect with a safe water supply and good control of milk.

THE OSWEGO RIVER DRAINAGE AREA.

The Oswego River drainage area is the largest in the State of New York. It consists of over 5,000 square miles of territory and includes the so-called "finger lakes" and many other natural reservoirs. The watershed is very thickly populated, and the sewage pollution contributed at various points is very large, but the stream flow and large storage in lakes minimizes the dangers of this pollution on the waters of Lake Ontario.

The rural population on the watershed is about 50 to the square mile. Adding the urban population, the persons per square mile are increased to 100. This is not a sufficient density of population to cause very bad conditions in the Oswego River with its large and relatively uniform stream flow. In addition, the sewage from some of the largest cities, Syracuse, Rome, Ithaca, and Geneva, must pass through large lakes before reaching the main river. Under these circumstances, from the standpoint of sewage pollution of international or interstate waters, it is unnecessary to consider in detail the watershed of the Oswego River above the junction of the Seneca and Oneida Rivers. There are many interesting problems in the area above this point, but they are purely local and have no particular bearing upon the water of Lake Ontario. About 12 miles from Lake Ontario the city of Fulton discharges its sewage into the Oswego River. There is no other considerable source of pollution until the mouth of the river is reached at Oswego.

Exclusive of the sewage of Oswego, the river draining this populous watershed would pollute the lake water for a variable distance about the river's mouth. This pollution, however, has far less significance than that contributed by the city of Oswego.

OSWEGO.

Oswego is situated on both banks of the Oswego River at its mouth. In 1910 it had a population of 23,612. The sewage of Oswego is discharged into the river or into small tributary streams.

Oswego's water supply has been taken from the Oswego River, and this polluted water supply has been responsible for very high typhoid fever rates. A new supply will soon be in use, taken from the lake at a point 8,800 feet from shore. Oswego's typhoid fever rate has averaged about 50 deaths per 100,000 in the past 10 years. From 1906 to 1908 inclusive, the average was 64 deaths per 100,000. In 1909, the rate was lower (26.6) but in 1910 was 43.4.

Chart No. 89 shows the seasonal prevalence in Oswego. The typhoid curve is characteristic and exactly what might be expected in a city using unfiltered water from a polluted river.

THE BLACK RIVER DRAINAGE BASIN.

From Oswego to the mouth of the Black River the sewage pollution of Lake Ontario is negligible. There are no cities or towns of importance. The Black River drains less than 2,000 miles of sparsely settled country and the sewage pollution carried to Lake Ontario by this stream is inconsiderable, except that of the city of Watertown. There are interesting problems of sewage disposal and disposal of manufacturing wastes, but these are of a purely local character and have no interstate significance.

The sewage of West Carthage and other small communities seriously affects the quality of the water at Watertown. The effect of Watertown's sewage pollution of the river is the only one necessary to be considered in connection with pollution of Lake Ontario.

WATERTOWN, N. Y.

The city of Watertown is situated on the Black River about 8 miles from Lake Ontario. It had a population of 27,090 in 1910. Its sewers discharge into the Black River.

The water supply is from the Black River and is filtered by a mechanical filter. The rates for typhoid fever have been altogether too high in Watertown. Chart No. 90 shows the typhoid fever death rate per 100,000 in Watertown from 1900 to 1910. A mechanical filter plant was installed in 1904 and was followed by a remarkable drop in the typhoid fever prevalence.

The rate has not remained as low as was expected, being above 40 in 1906–7, and 1908, and in 1910 it reached 88. These high

rates are probably due to poor filter efficiency coupled with a very bad raw water. The seasonal prevalence (see Chart No. 91) indicates plainly that the high rates are due to winter and spring typhoid and suggest that the filter efficiency should be improved and probably also the quality of the raw water furnished to the filters.

Prof. Ogden, who recently made an investigation, is of the opinion that the polluted wells which are in use in Watertown, are responsible

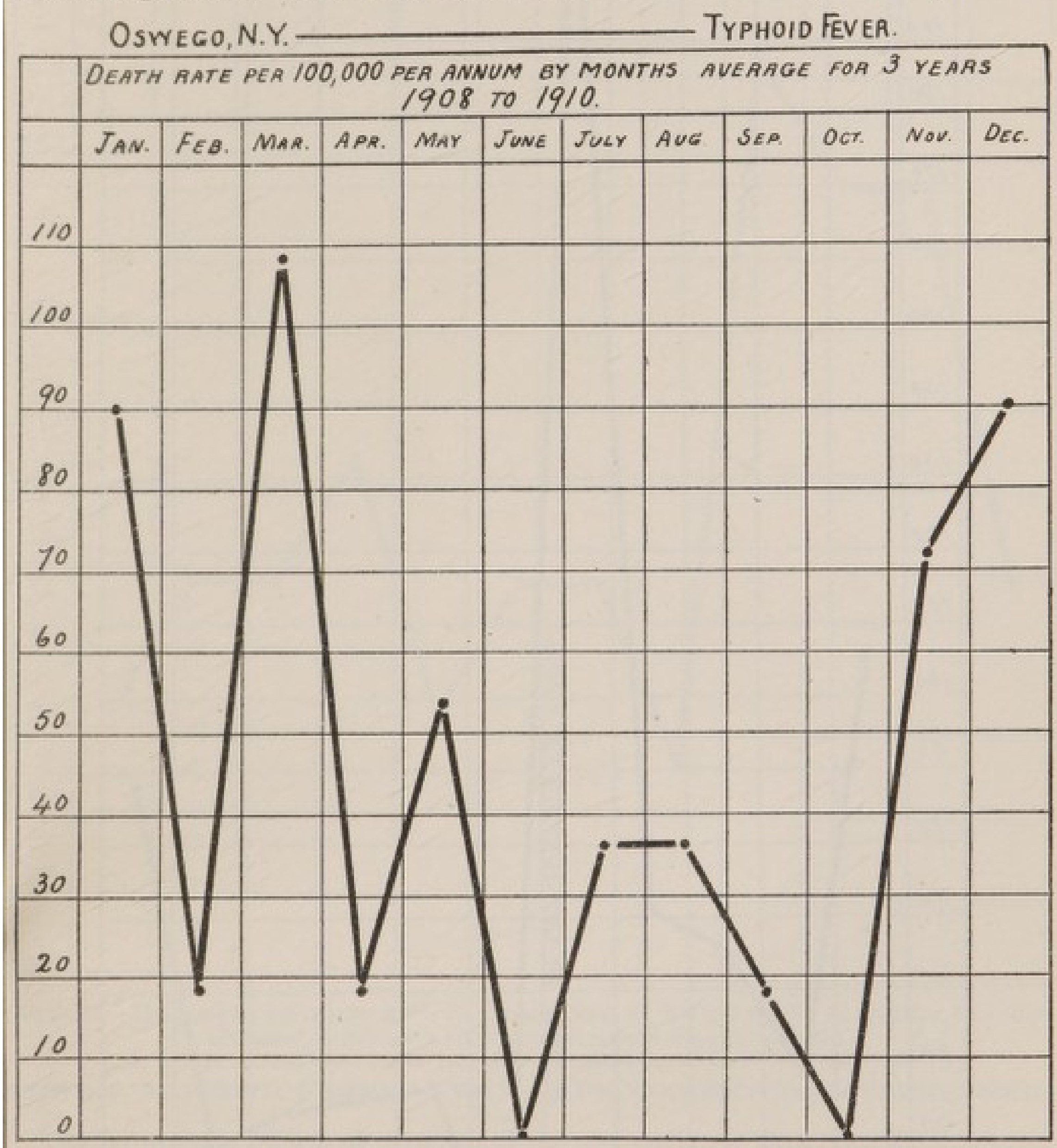


CHART 89.—Showing seasonal prevalence of typhoid fever in Oswego, N. Y., 1908, 1909, 1910. The character of Oswego's water supply is sufficient explanation for its undue prevalence in winter and spring.

for the very high typhoid rates in that city. The experience of Watertown is probably similar to other cities and suggests that in addition to the installation of a proper filter plant, certain things are essential, as follows: (1) Expert supervision; (2) a reasonably good raw water; (3) the substitution of this good safe water for contaminated wells supplies wherever these are in use. A properly con-

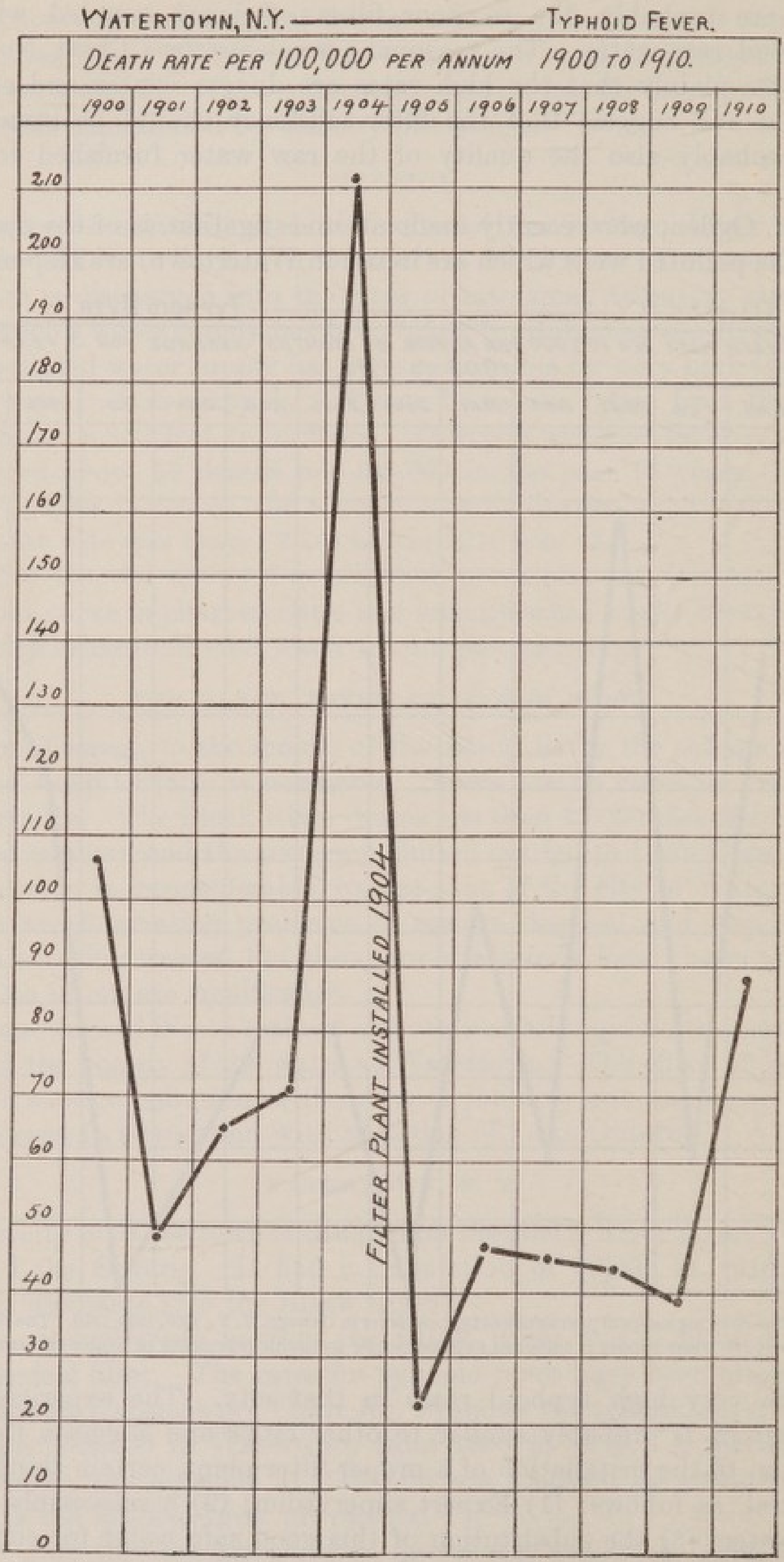


CHART 90.—Watertown, N.Y. The installation of a filter plant in 1904 is coincident with a marked reduction in typhoid fever.

structed and intelligently operated filter plant, with a safe water as a result, often gives disappointing results in typhoid reduction, when a large part of the population persist in using contaminated wells.

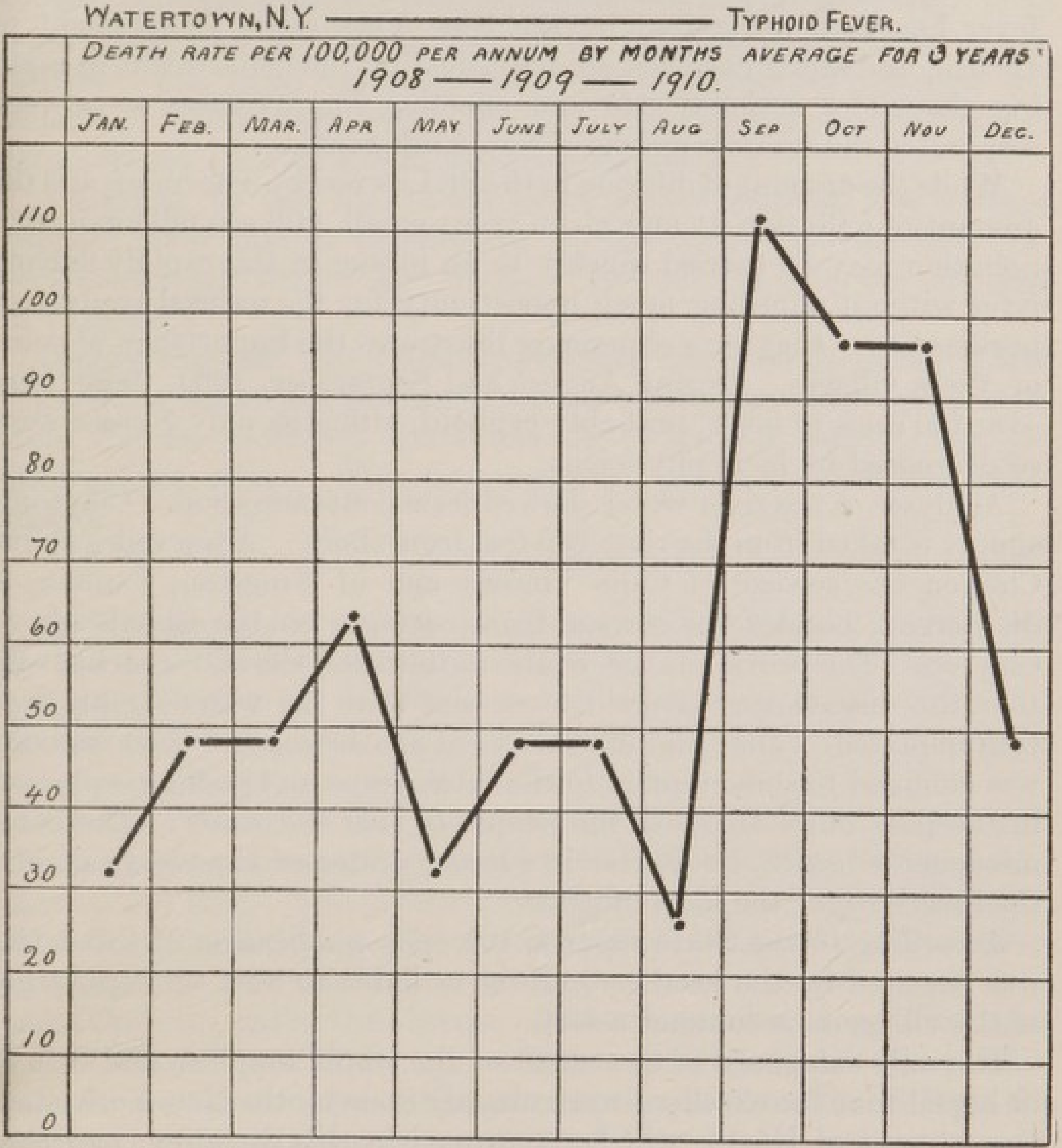


CHART 91.—The seasonal prevalence curve for typhoid fever in Watertown, N. Y., suggests poor filter efficiency, or that some other polluted sources of supply are used.

THE ST. LAWRENCE RIVER FROM CAPE VINCENT TO OGDENSBURG.

There are no cities or towns of importance on the American shore of the river between these two points. The amount of sewage pollution contributed is small and insignificant compared to the stream flow of the St. Lawrence. Were it not for the fact that this is a summer resort section, the amount of pollution and the prevalence of typhoid fever would be a purely local affair.

The three villages of Cape Vincent, Clayton, and Alexandria Bay, as well as the numerous summer resorts on this shore and upon the

numerous islands in the river, are receiving points for thousands of summer visitors, and the question of their water supplies and the local prevalence of typhoid fever assumes an interstate significance. The importance of summer resorts as distributing points for typhoid fever has been recognized by the New York State Department of Health, and much has been accomplished by the department in making the water supplies safe and effecting improvement in sewage disposal in the summer resorts of New York State.

While the amount of dilution in the St. Lawrence is enormous and the amount of pollution at any given point small, still a small amount of pollution may be carried quickly to an intake in this rapidly flowing river without affording much opportunity for the natural agencies of purification. Clayton's experience illustrates the importance of some of these villages. During August and September, 1909, there were over 100 cases of fever, probably typhoid, although only 7 cases were so diagnosed by local physicians.

Analyses of the river water showed fecal contamination. Clayton's supply is taken from the river 600 feet from shore. A few miles above Clayton the sewage of Cape Vincent and of Kingston, Canada, is discharged, besides the sewage from cottages on the islands above Clayton. The work of the State authorities showed conclusively that the disease was typhoid fever and that the water supply was contaminated. The local officials were apathetic, and their activity was confined to some repairs to the intake pipe and posting a placard in the post office advising the people to boil the water. The commissioner of health, Dr. Porter, in a letter, protested vigorously against the inactivity of the local officials.

According to the State reports, the open publication of this letter was resented by the local authorities as liable to hurt the reputation of the village as a summer resort.

The only safeguard is treatment of the water supplies, and it is to be hoped that the excellent work already done by the New York State Department of Health will be continued in this direction, and that in this work they will receive the proper support.

THE OSWEGATCHIE RIVER DRAINAGE BASIN.

The Oswegatchie drains about 1,600 square miles of sparsely settled country. The sewage contributed to the river above Ogdensburg is negligible, except that of the village of Gouverneur, and this is discharged 56 miles from the St. Lawrence River. Local questions arise here, as on other watersheds, which the excellent machinery of the State health department is handling. The most serious sewage pollution from an international standpoint is that contributed by the city of Ogdensburg.

OGDENSBURG.

Ogdensburg is situated on the St. Lawrence River at the mouth of the Oswegatchie. In 1910 it had a population of 16,000. The sewers discharge into the Oswegatchie and St. Lawrence Rivers. The water supply is taken from the Oswegatchie River above the sewer outlets. The river water has as possible sources of pollution the village of Gouveneur, about 50 miles above, and several smaller communities situated much nearer Ogdensburg.

According to the New York State health reports, the average typhoid fever rate in Ogdensburg for the 10 years 1900–1909 was 48.5 deaths per 100,000 population. In 1909 the rate was 26.8 and in 1910, 37.5.

During the past two years Ogdensburg has been installing a new filtration plant of the slow sand type to purify the water to be taken from the St. Lawrence River instead of the old supply from the Oswegatchie River. This new filtration plant is practically completed.

CONCLUSIONS.

(1) The danger of sewage pollution of Lake Ontario is minimized by the depth of the lake and it enormous capacity for storage. The pollution carried by the Niagara, the Genesee, and other rivers is rendered much less serious by this fact and also by the paucity of large cities using the lake as a source of public water supply.

(2) That portion of the shore of Lake Ontario from the mouth of the Niagara to the mouth of the Genesee contributes no serious pollution to the lake. The Genesee carries a large quantity of pollution to the lake, including (at present) the sewage of the city of Rochester. In view of the fact that Rochester does not take its water supply from Lake Ontario, and in the absence of other large cities depending upon Lake Ontario water, there can be little valid objection to the permission to use the lake for ultimate reception of the effluent from the proposed sewage disposal plant at Rochester.

The requirements exacted by the State department of health are reasonable and the suggested methods are of the simplest character. Nevertheless, they seem to supply the needs of the present situation. Reserving the right to require further purification if and when necsary provides the necessary safeguard against inevitable or unforeseen circumstances. Even if Rochester itself should find it necessary to use the lake as a source of water supply, filtration or treatment would always be necessary, in any event, and under these circumstances a good raw water is insured.

Rochester's typhoid fever rate is low, and has been consistently low for years. In view of the reports of the Rochester City Health Department of work done in the control of milk, the rate should be

even lower, especially in the months from December to May, with a water supply safe at all times.

(3) The pollution of the lake by the discharge of the Oswego River has only local effect. The water supply of Oswego has been very recently improved by substituting Lake Ontario for the polluted Oswego River as a source of public water supply. It remains to be seen whether the change will effect a reduction in Oswego's high typhoid fever rate. The distance from shore (8,800 feet) may insure a safe water most of the time, but eventually, according to the experience of other lake cities, some treatment or filtration will be found necessary to insure safe water every day in the year.

(4) The pollution of Lake Ontario by the discharge of the Black River, including the sewage and wastes of Watertown, is considerable. The color derived from the Black River is said to be noticeable near shore for a long distance, even for some distance after the lake water passes into the St. Lawrence. It is reasonable to suppose that pollution extends at least so far as the color. The villages exposed to such theoretical pollution should filter or treat their water supplies for their own protection even if the Black River did not exist. The whole question of pollution of the Black River is local, and is being ably handled by the New York State Department of Health.

(5) The prevalence of typhoid fever in the villages of Cape Vincent, Clayton, or Alexandria Bay, and in any of the many summer resorts in the Thousand Islands region, has an interstate significance. Its importance is recognized by the State department of health, however, and that body is making an earnest effort to better conditions. Much has been done, especially in the better disposal of excreta, but unfortunately the health department of the State of New York lacks the authority for proper control of public water supplies, and the earnest exhortations of the commissioner of health for better supplies are not always heeded with alacrity.

Safe water supplies in these resorts are a necessity for the protection, not only of the citizens of the State of New York, but for the protection of the public health in other States.

(6) The pollution of the St. Lawrence River by the Oswegatchie River is negligible, except that furnished by the city of Ogdensburg. It is doubtful if this has anything more than a local effect, in view of the enormous volume of water in the St. Lawrence River, and the absence of cities or towns of importance for a considerable distance below Ogdensburg. Ogdensburg very properly is protecting its citizens by the installation of a slow sand-filter plant to purify the water taken from a new intake in the St. Lawrence River.

GENERAL SUMMARY.

CONDITIONS.

There is an undue prevalence of typhoid fever in many cities and towns in the drainage basin of the Great Lakes.

This excessive prevalence of typhoid fever, especially in the winter and spring months, is due in greatest measure to sewage pollution of interstate and international waters used as a source of public water supplies.

Given the sewage pollution of the source of supply, the excessive prevalence is made possible by the use of such water unfiltered and untreated or by the faulty operation or poor efficiency of filter plants. Most of the cities with excessive prevalence of typhoid fever use unfiltered surface water as a public supply, although disasters have occurred where inefficient filtration was being depended upon to make a polluted water safe. Some of these unfiltered lake supplies are alleged to be safe, but proper bacteriologic examination is not made daily. In one large lake city a sample is sent occasionally to a State laboratory; in another, a bacterial count is made daily, but no *B. coli* estimation is made, the only test employed to detect pollution being the obsolete and very indefinite method of animal inoculation.

Some filter plants have serious structural defects. Others are structurally satisfactory, but improperly or carelessly operated. Some well constructed modern plants are struggling with a bad raw water in which the bacterial content is so high that even with fair efficiency of the plant the filtered water can not be classed as safe. In some instances there is no adequate bacteriologic control, and samples of the water are examined only once or twice a month.

In many of these cities excessive rates prevail for the group of diseases classified as enteritis or diarrhea. In most of these places a distinct winter and spring prevalence is demonstrable, coupled with a coincidently high typhoid fever rate. This enteritis to some extent seems to be water borne, and the disease sometimes called "winter cholera" is presumably entirely water borne. Some of the so-called enteritis and winter cholera may be typhoid fever or bacillary dysentery. An exhaustive investigation of the diarrhea and enteritis of children is necessary to determine accurately the real incidence of the various entities which are grouped under this heading.

The undue prevalence of typhoid fever is an interstate menace and is responsible for the spread of the disease from one State to another, when such undue prevalence is manifest in: (1) Cities of commercial or industrial importance; (2) Tourist resorts which attract visitors by their natural or artificial advantages; (3) Summer resorts.

The drainage basin of the Great Lakes contains many cities and communities in each of the three classes. Not only is typhoid infection distributed by these polluted water supplies to the thousands of visitors from other States, but railroad trains and vessels take their food and drink supplies from these infected centers and distribute such supplies en route to their interstate passengers.

REMEDIES.

The prime requisite is safe water supplies. Filtered or treated supplies must be substituted for the present polluted or dangerous public supplies where adequate protection of such supplies against pollution is not feasible. No single method of water purification or sterilization can be expected to be applicable in all instances. The degree of purification necessary, the character of the raw water, and the financial condition of the community must be considered, and the remedy should be selected which will result in a safe water supply at the least cost.

In regard to raw lake water alleged to be safe, bacteriologic examinations, including bacterial counts and quantitative estimation of *B. coli*, should be made daily. No accurate deductions as to the quality of a raw water can be drawn from a few scattered examinations. To have value, bacteriologic examinations must be made daily for at least a year under all kinds of weather conditions. If such comprehensive daily examinations are made, it will be found that there are few, if any, municipalities in the Great Lakes Basin which have a safe water supply from the lakes 365 days in the year without filtration or treatment.

In those cities which possess filter plants expert supervision is necessary, with daily bacteriologic examination of the raw and filtered or treated water. In some cases extra units are necessary to relieve the strain on an overworked plant. In slow sand plants extra units are necessary to permit proper cleaning and ripening of the "schmutzdecke."

They are also necessary when mechanical filter plants are in use, to provide for necessary repairs or the renewal of parts of the working units. There should be the closest supervision of municipal filter plants exercised by the State and city boards of health to maintain efficiency and insure proper protection of the public health.

In the prevention of the spread of water-borne contagious disease in the basin of the Great Lakes as the problem now stands sewage treatment is secondary in importance to filtration or treatment of the public water supplies. It will always be an aid and will sometimes be a necessity in furnishing a raw water which can be rendered safe without undue expense. In general it is cheaper to purify

water than to purify sewage, but sewage purification should be carried far enough to insure a good raw water for the filters.

It would be unreasonable to expect a large city to expend millions for sewage purification for the protection of the water supply of some near-by village or small city, provided the water supply of the smaller community could be rendered safe or another supply substituted at a much smaller cost.

No general rules can be formulated for the disposal of sewage in the Lakes cities. Each city must be studied separately, the remedy depending upon local conditions. In general the methods necessary will be simple because of the enormous volume of water available for dilution, which eliminates the factor of nuisance. From the standpoint of menace to health the degree of purification required will depend upon the amount of the sewage and the proximity of waterworks intakes.

Dilution as a means of sewage disposal should be permitted for economic reasons wherever possible without detriment to the public health up to the point where the sewage contributed does not put an undue strain or an unreasonable responsibility upon filter plants by making the bacterial count and the colon content of the raw water too high for safety.

Actual pollution of waterworks intakes by sewage from ships is difficult to demonstrate, but its possibility is apparent at once. In most instances the elimination of such pollution from the problem would not result in a safe water, as there is usually other more consistent pollution near by. Marking out of zones about the intakes, such zones not to be crossed by vessels, or during the crossing that all toilets be closed, has been suggested. This has serious objections, viz, failure to close the toilets for some reason and the impossibility of maintaining a zone where the channel is narrow, as for instance at the Lime Kiln crossing above Detroit. The most satisfactory solution of the problem seems to be the installation of retention tanks on vessels for human excreta.

Sewage pollution of intakes by the deposition of dredgings containing sewage sludge has probably taken place, and its results in one instance at least seem to have been disastrous. However, in all instances where complaint has been made against dumping such dredgings there was an obvious necessity for filtration or treatment of the public water supply as a protection of the public health, for reasons independent of the dredging, and further, if such necessary water purification had been effected, it would have afforded ample protection against the alleged ill effect of the dredgings.

Aside from these facts, it must be apparent to everyone that the dumping of dredgings from a sewage-polluted river into the current

of a stream used as a source of public water supply is a very dangerous and unwise procedure. Such dredgings should be dumped in still water, either behind breakwaters or retaining walls or in mid-lake many miles from shore and from the nearest waterworks intakes.

In order to secure efficient and uniform results from the application of these remedies, it is necessary to have two distinct official standards: (1) Standards of raw water; (2) standards of filtered or treated water.

In the opinion of the writer the best way to fix the boundaries of permissible pollution of interstate or international waterways is to fix standards of raw water at the intakes. A second standard for the filtered or treated water is necessary in order to insure safe water for interstate travelers. These standards should be based upon the bacterial count and the quantitative estimation of B. coli and should be the minimum requirements to prevent the spread of disease, such as typhoid fever or Asiatic cholera in interstate traffic, the various States retaining the right to impose additional requirements, consistent with State laws where such laws exist.

LIST OF HYGIENIC LABORATORY BULLETINS OF THE PUBLIC HEALTH AND MARINE-HOSPITAL SERVICE.

The Hygienic Laboratory was established in New York, at the Marine Hospital on Staten Island, August, 1887. It was transferred to Washington, with quarters in the Butler Building, June 11, 1891, and a new laboratory building, located in Washington, was authorized by act of Congress, March 3, 1901.

The following *bulletins* [Buls. Nos. 1–7, 1900 to 1902, Hyg. Lab., U. S. Mar.-Hosp. Serv., Wash.] have been issued:

*No. 1.—Preliminary note on the viability of the *Bacillus pestis*. By M. J. Rosenau.

No. 2.—Formalin disinfection of baggage without apparatus. By M. J. Rosenau.

*No. 3.—Sulphur dioxid as a germicidal agent. By H. D. Geddings.

*No. 4.—Viability of the *Bacillus pestis*. By M. J. Rosenau.

No. 5.—An investigation of a pathogenic microbe (*B. typhi murium* Danyz) applied to the destruction of rats. By M. J. Rosenau.

*No. 6.—Disinfection against mosquitoes with formaldehyde and sulphur dioxid. By M. J. Rosenau.

*No. 7.—Laboratory technique: Ring test for indol, by S. B. Grubbs and Edward Francis; Collodium sacs, by S. B. Grubbs and Edward Francis; Microphotography with simple apparatus, by H. B. Parker.

By act of Congress approved July 1, 1902, the name of the "United States Marine-Hospital Service" was changed to the "Public Health and Marine-Hospital Service of the United States," and three new divisions were added to the Hygienic Laboratory.

Since the change of name of the service the bulletins of the Hygienic Laboratory have been continued in the same numerical order, as follows:

*No. 8.—Laboratory course in pathology and bacteriology. By. M. J. Rosenau. (Revised edition, March, 1904.)

*No. 9.—Presence of tetanus in commercial gelatin. By. John F. Anderson.

*No. 10.—Report upon the prevalence and geographic distribution of hookworm disease (uncinariasis or anchylostomiasis) in the United States. By Ch. Wardell Stiles.

*No. 11.—An experimental investigation of *Trypanosoma lewisi*. By Edward Francis.

*No. 12.—The bacteriological impurities of vaccine virus; an experimental study. By M. J. Rosenau.

*No. 13.—A statistical study of the intestinal parasites of 500 white male patients at the United States Government Hospital for the Insane; by Philip E. Garrison, Brayton H. Ransom, and Earle C. Stevenson. A parasitic roundworm (*Agamomermis culicis* n. g., n. sp.) in American mosquitoes (*Culex sollicitans*); by Ch. Wardell Stiles. The type species of the cestode genus *Hymenolepis;* by Ch. Wardell Stiles.

*No. 14.—Spotted fever (stick fever) of the Rocky Mountains; a new disease. By John F. Anderson.

*No. 15.—Inefficiency of ferrous sulphate as an antiseptic and germicide. By Allan J. McLaughlin.

*No. 16.—The antiseptic and germicidal properties of glycerin. By M. J. Rosenau.

*No. 17.—Illustrated key to the trematode parasites of man. By Ch. Wardell Stiles.

*No. 18.—An account of the tapeworms of the genus *Hymenolepis* parasitic in man, including reports of several new cases of the dwarf tapeworm (*H. nana*) in the United States. By Brayton H. Ransom.

*No. 19.—A method for inoculating animals with precise amounts. By. M. J. Rosenau.

*No. 20.—A zoological investigation into the cause, transmission, and source of Rocky Mountain "spotted fever." By. Ch. Wardell Stiles.

*No. 21.—The immunity unit for standardizing diphtheria antitoxin (based on Ehrlich's normal serum). Official standard prepared under the act approved July 1, 1902. By M. J. Rosenau.

*No. 22.—Chloride of zinc as a dedorant, antiseptic, and germicide. By T. B. McClintic.

*No. 23.—Changes in the Pharmacopœia of the United States of America. Eighth Decennial Revision. By Reid Hunt and Murray Galt Motter.

No. 24.—The International Code of Zoological Nomenclature as applied to medicine. By Ch. Wardell Stiles.

*No. 25.—Illustrated key to the cestode parasites of man. By Ch. Wardell Stiles.

*No. 26.—On the stability of the oxidases and their conduct toward various reagents. The conduct of phenolphthalein in the animal organism. A test for saccharin, and a simple method of distinguishing between cumarin and vanillin. The toxicity of ozone and other oxidizing agents to lipase. The influence of chemical constitution to the lipolytic hydrolysis of ethereal salts. By J. H. Kastle.

*No. 27.—The limitations of formaldehyde gas as a disinfectant with special reference to car sanitation. By Thomas B. McClintic.

*No. 28.—A statistical study of the prevalence of intestinal worms in man. By Ch. Wardell Stiles and Philip E. Garrison.

*No. 29.—A study of the cause of sudden death following the injection of horse serum. By M. J. Rosenau and John F. Anderson.

*No. 30.—I. Maternal transmission of immunity to diphtheria toxin. II. Maternal transmission of immunity to diphtheria toxin and hypersusceptibility to horse serum in the same animal. By John F. Anderson.

*No. 31.—Variations in the peroxidase activity of the blood in health and disease. By Joseph H. Kastle and Harold L. Amoss.

*No. 32.—A stomach lesion in guinea pigs caused by diphtheria toxin and its bearing upon experimental gastric ulcer. By. M. J. Rosenau and John F. Anderson.

*No. 33.—Studies in experimental alcoholism. By Reid Hunt.

*No. 34.—I. *Agamofilaria georgiana* n. sp., an apparently new roundworm parasite from the ankle of a negress. II. The zoological characters of the roundworm genus *Filaria* Mueller, 1787. III. Three new American cases of infection of man with horsehair worms (species *Paragordius varius*), with summary of all cases reported to date. By Ch. Wardell Stiles.

*No. 35.—Report on the origin and prevalence of typhoid fever in the District of Columbia. By M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle. (Including articles contributed by Ch. Wardell Stiles, Joseph Goldberger, and A. M. Stimson.)

*No. 36.—Further studies upon hypersusceptibility and immunity. By M. J. Rosenau and John F. Anderson.

*No. 37.—Index-catalogue of medical and veterinary zoology. Subjects: Trematoda and trematode diseases. By Ch. Wardell Stiles and Albert Hassall.

No. 38.—The influence of antitoxin upon post-diphtheritic paralysis. By M. J. Rosenau and John F. Anderson.

*No. 39.—The antiseptic and germicidal properties of solutions of formaldehyde and their action upon toxins. By John F. Anderson.

*No. 40.—1. The occurrence of a proliferating cestode larva (*Sparganum proliferum*) in man in Florida, by Ch. Wardell Stiles. 2. A reexamination of the type specimen of *Filaria restiformis* Leidy, 1880=*Agamomermis restiformis*, by Ch. Wardell Stiles. 3. Observations on two new parasitic trematode worms: *Homalogaster philippinensis* n. sp., *Agamodistomum nanus* n. sp., by Ch. Wardell Stiles and Joseph Goldberger.

4. A reexamination of the original specimen of *Tænia saginata abietina* (Weinland, 1858), by Ch. Wardell Stiles and Joseph Goldberger.

*No. 41.—Milk and its relation to the public health. By various authors.

*No. 42.—The thermal death points of pathogenic micro-organisms in milk. By M. J. Rosenau.

*No. 43.—The standardization of tetanus antitoxin (an American unit established under authority of the act of July 1, 1902). By M. J. Rosenau and John F. Anderson.

No. 44.—Report No. 2 on the origin and prevalence of typhoid fever in the District of Columbia, 1907. By M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle.

*No. 45.—Further studies upon anaphylaxis. By M. J. Rosenau and John F. Anderson.

*No. 46.—*Hepatozoon perniciosum* (n. g., n. sp.); a hæmogregarine pathogenic for white rats; with a description of the sexual cycle in the intermadiate host, a mite (*Lelaps echidninus*). By W. W. Miller.

*No. 47.—Studies on Thyroid: I. The relation of iodine to the physiological activity of thyroid preparations. By Reid Hunt and Atherton Seidell.

*No. 48.—The physiological standardization of digitalis. By Charles Wallis Edmunds and Worth Hale.

No. 49.—Digest of comments on the United States Pharmacopœia. Eighth decennial revision, for the period ending December 31, 1905. By Murray Galt Motter and Martin I. Wilbert.

No. 50.—Further studies upon the phenomenon of anaphylaxis. By M. J. Rosenau and John F. Anderson.

No. 51.—Chemical tests for blood. By Joseph H. Kastle.

No. 52.—Report No. 3 on the origin and prevalence of typhoid fever in the District of Columbia (1908). By M. J. Rosenau, Leslie L. Lumsden, and Joseph H. Kastle.

No. 53.—The influence of certain drugs upon the toxicity of acetanilide and antipyrine. By Worth Hale.

No. 54.—The fixing power of alkaloids on volatile acids and its application to the estimation of alkaloids with the aid of phenolphthalein or by the Volhard method. By Elias Elvove.

No. 55.—Quantitative pharmacological studies: Adrenalin and adrenalinlike bodies. By W. H. Schultz.

No. 56.—Milk and its relation to the public health. (Revised edition of Bulletin No. 41.) By various authors.

*No. 57.—I. The presence of tubercle bacilli in the circulating blood in clinical and experimental tuberculosis. By John F. Anderson. II. The viability of the tubercle bacillus. By M. J. Rosenau.

No. 58.—Digest of comments on the Pharmacopœia of the United States of America (eighth decennial revision) and the National Formulary for the period ending December 31, 1906. By Murray Galt Motter and Martin I. Wilbert.

No. 59.—The oxidases and other oxygen catalysts concerned in biological oxidations. By Joseph Hoeing Kastle.

No. 60.—A study of the anatomy of Watsonius (n. g.) Watsoni of man, and of 19 allied species of mammalian trematode worms of the superfamily Paramphistomoidea. By Ch. Wardell Stiles and Joseph Goldberger.

No. 61.—Quantitative pharmacological studies: Relative physiological activity of some commercial solutions of epinephrin. By W. H. Schultz.

No. 62.—The taxonomic value of the microscopic structure of the stigmal plates in the tick genus Dermacentor. By Ch. Wardell Stiles.

*No. 63.—Digest of comments on the Pharmacopœia of the United States of America (eighth decennial revision) and the National Formulary (third edition) for the calendar year ending December 31, 1907. By Murray Galt Motter and Martin I. Wilbert.

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*No. 67.—The solubilities of the pharmacopœial organic acids and their salts. By Atherton Seidell.

No. 68.—The bleaching of flour and the effect of nitrites on certain medicinal substances. By Worth Hale.

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No. 71.—I. Some known and three new endoparasitic trematodes from American fresh-water fish. By Joseph Goldberger. II. On some new parasitic trematode worms of the genus *Telorchis*. By Joseph Goldberger. III. A new species of *Athesmia* from a monkey. By Joseph Goldberger and Charles G. Crane.

*No. 72.—I. Report on an outbreak of typhoid fever at Omaha, Nebr. (1909–1910). By L. L. Lumsden. II. The water supply of Williamson, W. Va., and its relation to an epidemic of typhoid fever. By W. H. Frost.

No. 73.—The effect of a number of derivatives of choline and analogous compounds on the blood pressure. By Reid Hunt and R. de M. Taveau.

*No. 74.—Digitalis standardization and the variability of crude and of medicinal preparations. By Worth Hale.

No. 75.—Digest of comments on the pharmacopœia of the United States of America (eighth decennial revision) and the national formulary (third edition) for the calendar year ending December 31, 1908. By Murray Galt Motter and Martin I. Wilbert.

*No. 76.—The physiological standardization of ergot. By Charles Wallis Edmunds and Worth Hale.

No. 77.—Sewage pollution of interstate and international waters with special reference to the spread of typhoid fever. By Allan J. McLaughlin.

No. 78.—Report No. 4 on the origin and prevalence of typhoid fever in the District of Columbia (1909). By L. L. Lumsden and John F. Anderson. (Including articles contributed by Thomas B. McClintic and Wade H. Frost.)

*No. 79.—Digest of comments on the pharmacopœia of the United States of America (eighth decennial revision) and the national formulary (third edition) for the calendar year ending December 31, 1909. By Murray Galt Motter and Martin I. Wilbert.

*No. 80.—Physiological studies in anaphylaxis. Reaction of smooth muscle from various organs of different animals to proteins. (Including reaction of muscle from nonsensitized, sentitized, tolerant, and immunized guinea pigs.) By William H. Schultz.

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No. 82.—I. Method of standardizing disinfectants with and without organic matter. By John F. Anderson and Thomas B. McClintic. II. The determination of the phenol coefficient of some commercial disinfectants. By Thomas B. McClintic.

No. 83.—Sewage pollution of interstate and international waters with special reference to the spread of typhoid fever. II. Lake Superior and St. Mary's river. III. Lake Michigan and the Straits of Mackinac. IV. Lake Huron, St. Clair river, Lake St. Clair, and the Detroit river. V. Lake Ontario and St. Lawrence river. By Allan J. McLaughlin.

In citing these bulletins, beginning with No. 8, bibliographers and authors are requested to adopt the following abbreviations: Bull. No. ——, Hyg. Lab., U. S. Pub. Health & Mar.-Hosp. Serv., Wash., pp. ——.

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