REPORT

UPON THE

CHICAGO DRAINAGE CANAL

BY THE

INTERNATIONAL WATERWAYS COMMISSION.

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INTERNATIONAL WATERWAYS COMMISSION,
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The Honorable SECRETARY OF WAR OF THE UNITED STATES,
The Honorable MINISTER OF PUBLIC WORKS OF CANADA:

The International Waterways Commission has the honor to submit the following report upon the Chicago Drainage Canal:

1. The headwaters of the Illinois River, an important tributary of the Mississippi, approach within 10 miles of Lake Michigan near its southerly end, where stands Chicago. The river, called here the Des Plaines, is separated from the lake by a low and narrow divide running nearly north and south. In the divide are two depressions, about 8 miles apart, in which the height is only about 10 feet above the surface of the lake. The area eastward of the divide is drained by two streams, the Chicago and the Calumet rivers, which empty into Lake Michigan.

The city of Chicago was originally built on the Chicago River and, although it is now spreading into the Calumet region, it was for many years drained exclusively by the Chicago River, and its principal parts are now so drained. This river constitutes the main sewer of Chicago. The lake furnishes the city's water supply. To prevent the pollution of the water supply by sewage has always been the most important municipal problem with which Chicago has had to deal. Its solution has from a very early day been found in diverting a part of the river's flow into the valley of the Des Plaines through the most northerly of the two depressions mentioned above. The Illinois and Michigan Canal, which was opened to navigation in 1848, was at once utilized for this purpose, and all subsequent improvements consisted in efforts to force more sewage through that canal until, in 1889, it was decided to build a new and greatly enlarged channel which should completely divert the Chicago River from Lake Michigan and draw from that lake a body of pure water large enough to make the sewage inoffensive to the communities by whose doors it must pass.

2. Before embarking upon this work the city in 1886 appointed a commission of three engineers "to consider and report on any and all things which relate to the matter of water supply and drainage of the city of Chicago." In January, 1887, the commission submitted a report to the mayor and city council of Chicago (copy appended marked A), which it styled a preliminary report. It intended to submit an additional or final report in which the data upon which its conclusions were based should be given in greater detail, but such additional report was never submitted. After remarking that "almost every conceivable way of dealing with these questions had been suggested and in some form applied during the past thirty years," the commission stated that "among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy

of consideration, namely, a discharge into Lake Michigan, a disposal upon land, and a discharge into the main river." It considered the first method too expensive, involving as it does a wide separation between the outlets of the sewers and the intakes of the water supply. It pronounced the second inapplicable to the metropolitan district as a whole, under the topographical conditions existing, but thought that it might be employed for the extreme northern and southern parts, the latter including the Calumet region. It recommended the third method. It was uncertain as to the quantity of water required to dilute the sewage so as to make it inoffensive, but in order to prepare an estimate of cost it was compelled to assume some approximate size of channel, and it did assume a size large enough to discharge 600,000 cubic feet per minute, that being the estimated amount of water falling upon the area tributary to the canal during storms and not otherwise disposed of. It includes the drainage basins of the upper Des Plaines and of the Chicago rivers, but not that of the Calumet River. With a channel of less dimensions in times of storms and floods the Chicago River would not be fully diverted into the Des Plaines, but would back up into Lake Michigan. The result was a supply of 24,000 cubic feet per minute for each 100,000 people in a population of 2,500,000, the population which the commission thought it desirable to provide for, and the opinion was expressed that this would equal the maximum requirements.

3. Following this report the Illinois legislature passed an act approved May 29, 1889, "to create a sanitary district and to remove obstructions in the Des Plaines and Illinois rivers," of which the twenty-third and twenty-fourth paragraphs read as follows, viz:

Paragraph 23. If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Des Plaines or Illinois rivers, such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than 14 feet, and a current not exceeding 3 miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than 18 feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than 160 feet at the bottom capable of producing a depth of not less than 18 feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000, such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than 3 miles per hour, and if at any time the General Government shall improve the Des Plaines or Illinois rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall, within one year thereafter, enlarge the entire channel leading into said Des Plaines or Illinois rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute, with a current of not more than 3 miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water of not less than 18 feet throughout said channel, and shall have a width of not less than 160 feet at the bottom. In case a channel is constructed in the Des Plaines River, as contemplated in this section, it shall be carried down the slope between Lockport and Joliet to the pool, commonly known as the upper basin, of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act may correct, modify, and

remove obstructions in the Des Plaines and Illinois rivers wherever it shall be necessary so to do to prevent overflow or damage along said river, and shall remove the dams at Henry and Copperas Creek, in the Illinois River, before any water shall be turned into the said channel. And the canal commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers by any drainage district or districts, to maintain a depth of not less than 6 feet from any dam owned by the State to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said canal commissioners to cause such dam or dams to be removed. This act shall not be construed to authorize the injury or destruction of existing water-power rights.

Paragraph 24. When such channel shall be completed, and the water turned therein, to the amount of 300,000 cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the General Government shall improve the Des Plaines and Illinois rivers for navigation, to connect with this channel, said General Government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary or drainage purposes.

By this act a flow of not less than 20,000 cubic feet per minute is required for each 100,000 inhabitants and provision is made for a population of 3,000,000. The evidence before the legislative committee which framed the bill as to the quantity required was contradictory. The amount fixed for dilution of the sewage was a minimum. (See Appendix B.)

4. Under this act the sanitary district of Chicago was organized, embracing all of the city north of Eighty-seventh street and some 43 square miles of Cook County outside of the city limits. The total area of the district was 185 square miles, and did not include the Calumet region nor the north shore. The trustees held their first meeting January 18, 1890. The Chicago Drainage Canal was then constructed, water being turned into it for the first time in January, 1900. It was not then, and has not since, been completed to its full capacity as designed. In places where the excavation was in rock the full dimensions of the prism were taken out, but in earth a considerable volume was left to be removed by the easy method of dredging hereafter. When fully completed it was designed to have a capacity of 600,000 cubic feet per minute, or 10,000 cubic feet per second, flowing at a velocity of 1.25 miles per hour in earth and 1.9 miles per hour in rock.

5. The canal is 28.05 miles in length. For a distance of 7.8 miles from its junction with the Chicago River at Robey street its dimensions are 110 feet width at bottom, side slopes 1 on 2, depth of water 22 feet at low stage of Lake Michigan, with a grade of 1 in 40,000, the material being earth. This section is eventually to have a width of 200 feet at bottom.

6. For a farther distance of 5.3 miles, although the material is principally earth, the dimensions are 202 feet width at bottom, side slopes 1 on 2, minimum depth of water 22 feet, with a grade of 1 in 40,000. This section is completed.

7. For the remaining 15.95 miles the canal is excavated wholly or partially in rock. Where the natural rock does not come to the surface walls of masonry have been built upon the rock surface, thus artificially carrying it to a height 5 feet above datum. The dimensions here are 160 feet width at bottom, 162 feet width at top, minimum depth of water 22 feet, with a grade of 1 in 20,000. This section also is completed.

8. The controlling works are situated near the town of Lockport at the western end of the canal. They consist of a bear trap dam 160

feet wide, with a vertical play of 17 feet, and of seven sluice gates of the Stoney type, each 30 feet wide and having a vertical play of 20 feet. These works provide a very efficient means of controlling the flow of water through the canal.

9. The project of the sanitary district for the disposal of sewage by the canal when completed is briefly as follows: All sewers will discharge into the Chicago River, either directly or through intercepting sewers. From the mouth in Lake Michigan to the point where the North and South branches unite the river will flow 8,000 cubic feet per second, less such quantity as may be pumped into the upper portion of the North Branch, which under the original project was 200 cubic feet per second admitted through a conduit at Fullerton avenue. From this point the combined flow will be 8,000 cubic feet to the point where the South Fork enters the South Branch, where it will be increased to 10,000 cubic feet by water pumped from Lake Michigan at Thirty-ninth street and flowing through a large conduit in Thirty-ninth street to the South Fork. The volume which will finally enter the canal under this project will be 10,000 cubic feet per second.

10. The channel of the Chicago River is not large enough to transmit that volume from the lake to the canal except at velocities which are an obstruction to navigation. The amount which the Secretary of War has thus far permitted the sanitary district to pass through the river is 4,167 cubic feet per second. In order to obtain authority for a larger amount the trustees have undertaken to enlarge the channel of the river and have accomplished a large amount of work in that direction.

11. By act of the Illinois legislature in 1903 the sanitary district was enlarged by annexing thereto the north shore district, containing 78.6 square miles, and the Calumet district, containing 94.48 square miles. The total area of the sanitary district is therefore now 358.08 square miles. The same legislature authorized the development of the water power created by the diversion.

12. The plans for the north shore region involve two additional conduits from the lake to the North Branch of the Chicago River, one at Lawrence avenue, into which 583 cubic feet per second, and one at Wilmette, into which 1,000 cubic feet per second, are to be pumped. As this water is to form a part of the 10,000 cubic feet originally to be taken out through that river, it does not add to the amount of water to be taken from Lake Michigan.

13. The plans for the Calumet region involve a treatment of the Calumet River similar to that of the Chicago River. The river is to be diverted into the Des Plaines Valley. For this purpose a new channel is to be cut through the southerly depression in the divide, and to join the present drainage canal at Sag, about 11 miles from the controlling works at Lockport. From Sag to Lockport the drainage canal must carry the flow from the Calumet River in addition to that from the Chicago River. It was designed to accommodate the latter river alone, or 10,000 cubic feet per second, but improved methods of excavation, particularly channeling in rock, gave it a greater capacity than was computed; and the hydraulic formulæ with which its dimensions were figured, being adapted to smaller streams, gave results which proved to be too large. It is found that the portion completed in rock, which includes the reach from Sag to Lockport, will carry an amount stated by the chief engineer to be 14,000 cubic feet per second. The differ-

ence, 4,000 cubic feet per second, is the amount which it is proposed to divert from the Calumet River. For this purpose it is proposed to excavate a channel having in earth a bottom width of 72 feet, with side slopes 3 on 5, and in rock a bottom width of 90 feet with vertical sides, the depth in both cases to be 25 feet.

14. Work in the territory annexed in 1903 has been limited to surveys, and the preparation of plans, and the expenditures in that territory have been small. The amount expended upon the drainage canal and accessory works, including the above, to December 31, 1905, is $40,873,629.71; in addition to which $1,556,226.56 has been expended for the development of water power and $7,290,101.27 has been paid out for interest. For a financial statement more in detail, see Appendix C.

15. Although the primary object of the Chicago Drainage Canal was the discharge of Chicago sewage its function as a channel for navigation was kept in view from the beginning. All of the bridges over it are draw bridges with ample openings. A provision of this kind, as well as the care exercised to make the sewage inoffensive by liberal dilution, was necessary to conciliate the interests in the valley of the Des Plaines and Illinois rivers, which would otherwise be adversely affected. It can hardly be doubted that the canal will eventually form a part of an improved waterway between the Great Lakes and the Mississippi River, though its full depth will probably not be required for that purpose. Congress has not adopted any scheme for this improvement, but by its direction a survey was made, and plans with estimates for a waterway 14 feet deep were submitted, by a board of engineers in a report dated August 26, 1905. The board found that for a distance of about 100 miles from Chicago the improvement must be with locks and dams, and as the quantity of water required would be merely that needed for the service of locks and other incidentals, the extent of the improvement or depth which could be obtained in that part of the route was without limit so far as it depended upon the amount of water available. For the remaining distance, about 223 miles, the improvement would be an enlargement of the open channel and the degree to which it was practicable was entirely dependent upon the quantity of water flowing. The board assumed that the Chicago Drainage Canal would eventually be permitted to take 10,000 cubic feet per second from Lake Michigan, and it expressed the opinion that with that volume added to the natural low-water discharge of the Illinois River a depth of 14 feet in the open channel could be maintained; also that if a much greater depth was to be secured a much larger volume of water must be taken from Lake Michigan.

16. In the neighborhood of Lockport the natural level of the ground falls away rapidly and excellent facilities are found for the development of water power. Under the State legislation of 1903 the sanitary district is now engaged in utilizing this incidental advantage of the drainage canal. The plans provide for an extension of the canal 10,700 feet between concrete walls and earth and rock embankments to the site selected for the power house and for the excavation of a tail race 6,800 feet long, 160 feet wide, and 22 feet deep. If the maximum quantity of water which the sanitary district now claims to be necessary for sanitary purposes—14,000 feet per second—be utilized it will be possible to develop about 40,000 electrical horsepower under a head of 34 feet. With 10,000 cubic feet per second about 28,000

horsepower can be developed. A power house is being erected which will accommodate 8 turbines, each capable of generating 5,000 horsepower.

17. The sanitary district has acquired land on both sides of the canal throughout its length, the width of the strips varying from 200 to 800 feet. This land is offered to manufacturers at moderate prices, and it seems probable that they will in the course of time be attracted thereto, particularly after arrangements for furnishing them with cheap power from Lockport are completed.

18. The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress. The plans of the sanitary district, except those for the enlargement of the Chicago River, have not been submitted to any Federal authority for approval. It was only after the opening of the canal that application was made to the Secretary of War for permission to divert the quantity of water required by the State law. The Secretary granted permission for such quantity as would pass through Chicago River without detriment to navigation, a quantity considerably less than that required by the State law. After experimenting with various amounts it was fixed at 250,000 cubic feet per minute, or 4,167 cubic feet per second, and that is the amount now authorized. It is "subject to such modification as, in the opinion of the Secretary of War, the public interests may from time to time require." Copies of all the permits granted by the Secretary of War in this connection will be found in Appendix D.

19. In the expenditure of $40,000,000 for the drainage canal the people of Chicago, with its population of 2,000,000, incurred a burden equivalent to that due to an expenditure of $1,600,000,000 by the United States, with its population of 80,000,000—that is, enough to build eight or more Panama canals. It was a very serious effort and has commanded the admiration and sympathy of all observers. The diversion of 10,000 cubic feet per second from Lake Michigan affects other interests adversely, but these interests have withheld their opposition, seeming to believe that some such amount was necessary, and apparently willing to contribute their share to protect the lives and health of the people of a great city. The plans calling for that amount have been under public discussion for some years. Although withholding formal approval, the Federal authorities have taken no steps to prevent their execution. Congress has called for a plan and estimates for an improvement of the waterways connecting with it, the scope of which is fixed by that amount. There appears to be a tacit general agreement that Chicago needs or will need about 10,000 cubic feet of water per second for sanitary purposes and that the city should have it without further question.

20. It was not generally known until after the publication in March last of the report of the American section of this Commission upon Niagara Falls that an amount greater that 10,000 cubic feet per second would be asked for. In that report, subsequently concurred in by the Canadian section, it was recommended that the diversion of 10,000 cubic feet be allowed. The preservation of Niagara Falls alone was considered, and that in the light of the tacit agreement above described. It was supposed at the time that this was all that Chicago needed, but the recommendation gave offense to the officials of the sanitary district, and the further demand then came out in the form of appeals to the

committees of Congress and to the Secretary of State. It is necessary now to take up the question anew, and, after considering it in all its bearings, to reach some conclusion as to whether there should be a limit to the amount of water to be diverted at Chicago, and, if so, as to what that limit is.

21. That the abstraction of water from Lake Michigan has a tendency to lower the level of that lake and of all the waters to which it is tributary is self-evident; but the exact effect of abstracting a given amount can be ascertained only from prolonged observation of the natural outlets under the varying conditions to which they are subjected during a series of years. An elaborate investigation of this subject was made under the office of the United States Lake Survey in Detroit, the results of which were published in the annual reports of the Chief of Engineers for 1900, page 5401; for 1902, pages 2779 and 2825; and for 1904, page 4120. Further observations are needed to be made when the difference of level between Lake Erie and Lake Huron is greater or less than when the existing observations were made, but the results obtained from the latter are believed to be reliable within one-tenth of a foot. The amounts by which the mean level, as derived from observations of the last forty-six years, of the various waters will be lowered by a discharge of 10,000 and also by 14,000 cubic feet per second are given in the following table:

Location.	Water level lowered by diversion at Chicago of—	
	10,000 cubic feet per second.	14,000 cubic feet per second.
	Inch.	*Inch.*
Lakes Huron and Michigan	0.52	0.70
Lake St. Clair	.45	.64
Lake Erie	.45	.64
Lake Ontario	.35	.49
St. Lawrence River at Rapide Plat	.40	.56

From this table it appears that all the waters, including Lakes Michigan and Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, besides the important connecting channels, the Detroit and St. Clair rivers, will be lowered by amounts varying from 4¼ to 6¼ inches for 10,000 cubic feet and from 6 to 8½ inches for 14,000 cubic feet per second. The length of time required to produce this effect is about five years; about half of it will be produced at the end of eighteen months. The above figures give the effect at average level; they are much more considerable during low-water periods.

22. Variations in the level of the lakes' surface, due to winds and to change of barometric pressure, are frequent and irregular and at times violent. Variations of more than 6 inches are very common, often occurring hourly for many hours in succession, while variations of 2 or 3 feet within an hour are not uncommon. Besides these irregular variations there is a regular annual variation due to difference in rainfall, evaporation, and run-off, the water level being highest in midsummer and lowest in midwinter. The levels are affected also by the greater or less severity of the winter and the consequent greater or less decrease in the discharging capacity of the outlets by ice. In order to study the annual oscillations it is necessary to eliminate the

irregular oscillations, and that is accomplished by using the average levels for a month. Using the monthly mean levels it is found that the regular fluctuation in Lake Huron-Michigan usually does not exceed 2 feet in any one year, but in a long series of years there is a great difference in the height to which high water will rise. The highest high water (monthly mean) recorded for that lake was in June, 1886, and the lowest high water in June, 1896, the difference between the two being over 3½ feet. The first is what navigators of the Great Lakes call a high-water year and the second a low-water year.

23. It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they can not see it they will not know it and will not feel it. The argument is fallacious. It is true that they can not see it immediately, but they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works.

24. The most important lake traffic is now carried on in large freight carriers which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the lakes. With the depth now available they are usually loaded to a draft of about 19 feet, but careful watch is kept on the stage of the waterways and advantage is taken of any temporary increase of stage to load the vessels deeper. In the modern vessel each inch of increased draft adds about 100 tons to the carrying capacity. To lower the water surface 6 inches is to reduce the capacity of the vessel about 600 tons. If the freight rate on iron ore be taken at 55 cents per ton, exclusive of the cost of loading and unloading, and the number of trips during the season at 22, there appears a loss of over $7,000 for the season for each vessel. The number of vessels navigating the Great Lakes which draw 19 feet or more is 417, and their tonnage is 1,541,414 tons, which is about three-quarters of the total tonnage of the Great Lakes. It is a conservative estimate that the loss to the navigation interests resulting from a reduction of 6 inches in the depth of water is $2,500,000 per annum, which, capitalized at 4 per cent, amounts to a loss of $62,500,000. With a greater reduction of depth the resulting loss would be proportionately greater. The number of deep-draft vessels and the share of lake traffic which they carry is increasing each year, while the lake traffic itself is increasing with marvellous rapidity. The total number of tons of freight which passed through Detroit River in 1905 was about 58,000,000, valued at about $615,000,000. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit River in 1906 exceeded 65,000,000, valued at $690,000,000. The loss will be even greater in the future than it is now. It is quite certain that the loss will not pass unnoticed, and that the governments will be compelled to restore the depth either by additional excavations or by regulating works.

25. Careful estimates have been made of the cost of deepening the channels between the lakes 1 foot. To deepen the Detroit River is

estimated to cost $4,115,430. In Lake St. Clair the full depth of the lake is now utilized, and any lowering of its surface involves the excavation of an artificial channel entirely across the lake, a distance of 18 miles, of which it has been necessary heretofore to artificially deepen only one-third. To deepen the channel here and at certain shoal places in St. Clair River and at the foot of Lake Huron is estimated to cost $1,080,720. It results in replacing open lake navigation by canal navigation for a distance of 12 miles in Lake St. Clair, a decided disadvantage.

26. The data are not at hand for an accurate estimate of the cost of restoring the depths in the harbors of the Great Lakes, but an approximation may be reached from a consideration of the cost of improvements heretofore made. The depth to be gained being small, the cost will not vary largely, whether that gain be a few inches more or less. The United States has improved 35 harbors on Lakes Michigan, Huron, and Erie, and has expended thereon about $20,000,000, of which about one-quarter was for maintenance. The average increase of depth is 10 feet and the cost per foot of increase was therefore about $1,500,000, but as the cost of a small increase would be much greater per foot than an increase of 10 feet, and as several harbors on Lake Ontario are to be added, the cost per foot in this case would probably be not less than $2,000,000 for harbors in the United States. The Canadian Government has improved over 50 harbors on Georgian Bay, Lakes Huron, St. Clair, Erie, and Ontario. A large amount, say $3,000,000, must be added for increasing the depth of these harbors.

27. The depth in the Welland Canal and in the six canals employed to overcome rapids in the St. Lawrence River is now 14 feet, of which every inch is needed. At the head of the Cornwall Canal in the St. Lawrence River the abstraction of 14,000 cubic feet of water per second at Chicago will lower the surface about 6¾ inches at mean level and much more at low water. To restore the depth in these canals involves the reconstruction of all the end locks and deepening the approaches thereto, and is estimated to cost $2,500,000.

28. The total cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is therefore roughly $10,000,000, and of restoring it in the Welland and St. Lawrence canals is $2,500,000 additional, or $12,500,000 in all.

29. The shores of the Great Lakes are very far from being fully developed, and it is highly probable that many harbors not now in existence remain to be created, or if in existence remain to be improved. The lowering of the lakes' surface increases the difficulty and cost of such improvements. This consideration is of importance, although no money value can now be given it.

30. The expenditure of the sums mentioned above will restore the depths now existing, but it will not prevent very serious annoyance to the navigation interests during the execution of the work. The time required will be several years, and in the meantime the vast commerce of the Great Lakes will be hampered, not only by deficient depth, but also by the occupation of the channels, already crowded with commerce, by the excavating machines.

31. It is evident from the foregoing that large bodies of water can not be diverted by the Chicago Drainage Canal without very serious detriment to the navigation interests of the Great Lakes and of the St. Lawrence Valley. The greater the amount of water diverted the

greater the injury. Chicago being one of the principal lake ports, there will be very few communities which will feel this detriment more than she will.

32. In the presence of these interests the effect upon Niagara Falls may be simply mentioned with a reference to our former reports upon that subject. The volume of Niagara Falls will be reduced by the full amount diverted at Chicago.

33. The city of Chicago was organized as a city in 1837 with a population of about 4,000. Its population in 1840 was 4,479; in 1850, 28,269; in 1860, 112,172; in 1870, 298,977; in 1880, 503,185; in 1890, 1,099,850; and in 1900 it was 1,698,575. It is estimated now to be about 2,000,000. Should the rate of growth continue which prevailed between 1880 and 1900, the population will be 3,000,000 in the year 1922 and 4,000,000 in the year 1939. It is impossible to foretell its future growth, but there is no reason to doubt that it will in time greatly exceed the largest of these numbers. The city is the commercial center of an empire still in its infancy. It is entirely reasonable to expect a population of five or six millions or more. It will cover territory not now covered. Methods of sewage disposal appropriate to one portion of it may not be appropriate to other portions. If the diversion of 20,000 cubic feet per minute (or 333⅓ cubic feet per second) for each 100,000 of population, as required by the State law, is accepted as the standard, then from 17,000 to 20,000 cubic feet per second will be required, and the 14,000 cubic feet now contemplated will not be sufficient. Even more than 20,000 cubic feet will be required for a population greater than 6,000,000. The diversion of 20,000 cubic feet per second would lower Lakes Michigan and Huron about 13 inches and Lake Erie about 11 inches. Plans which lead to this result should be carefully scrutinized.

34. One of the reasons given in 1889 for adopting this method of disposing of Chicago sewage was that it offered the advantage of furnishing a navigable waterway from Chicago to the Mississippi River. The navigable depth or capacity of such a waterway has never been authoritatively fixed. Congress has considered a depth of 14 feet to the extent of ordering a survey and estimates of cost for that depth, but the Illinois legislature has declared its policy to be to secure the construction of a deeper channel, not limiting its proposed capacity in terms, but defining it to be "of the greatest practicable depth and usefulness for navigation." See joint resolutions adopted May 27, 1889, copy omitting preamble hereto appended, marked "E." A fair interpretation of this language gives a proposed depth of 20 feet, that being the depth required to accommodate the most important vessels now navigating the Great Lakes. It will require a volume of water greater than the 10,000 cubic feet per second originally contemplated.

35. The amount which it is proposed to divert from the Calumet River, 4,000 cubic feet per second, is fixed by accident rather than by design, being the excess which the Chicago Drainage Canal is found capable of carrying after providing for the 10,000 cubic feet from the Chicago River, for which it was originally constructed. It is certain that no greater amount than 4,000 cubic feet can be diverted from the Calumet without checking the flow from the Chicago River, and thus giving relief to a suburban portion of the city at the expense of the richest and most populous centers.

36. It is equally certain that the diversion of 4,000 cubic feet or less

will not at all times afford the desired relief to the Calumet. In the first place it provides for a population of only 1,200,000, a number which will in all probability be greatly exceeded at a day not remote. At present the population is estimated at about 200,000, but for the present necessities it is not a question of population, but of drainage area and rainfall. A flood discharge of the Calumet has been measured at Riverdale, about 10 miles from its mouth, of about 13,300 cubic feet per second from a drainage area of about 700 square miles, and even that amount may at times be exceeded. The total drainage area of the Calumet region, including the Sag Valley, is about 825 square miles, and assuming the discharge to increase in proportion to the area the flood discharge to be provided for is over 15,700 cubic feet per second. The diversion of only 4,000 cubic feet will not prevent a heavy discharge into Lake Michigan in time of flood. To overcome this difficulty it is proposed, if suitable legislation can be secured, to divert the upper Calumet into Lake Michigan through an artificial channel to be excavated in Indiana about 17½ miles east of the State line. Indiana has not authorized such diversion, but supposing it to be accomplished, there will still be times when the discharge from the drainage area remaining to be cared for by the canal, 238 square miles, will exceed 4,000 cubic feet per second. The excess must enter Lake Michigan through the mouth of the Calumet, and at such times the system will fail. Of course it makes no provision for the future occupation of the upper Calumet region and the pollution of the lake from that source. It thus appears that the diversion of the Calumet River as now proposed by the sanitary district will not be complete even for the present, and will not make adequate provision for the future.

37. The diversion of 4,000 cubic feet per second provides for a population of 1,200,000 by the standard fixed by the State law. The population of the Calumet region is now about 200,000, and until it reaches 1,200,000 only a part of the flow, will be needed for sanitary purposes during a large part of the year; but the channel must be there, available for the full flow, if this method of sewage disposal is to be useful to any population, however small. Likewise the channel from the Chicago River must be, as it is, large enough to provide for a population of 3,000,000, whether that number of people are ever to become tributary to the Chicago River or not. The channels having once been constructed, any reduction of flow below their fullest capacity is a dead loss to the water power dependent upon them. It has been said that it would be absurd to develop water power at the cost per horsepower which this water power costs if the drainage canal be included, and that is true. But being given the channels, it would not be absurd to use them to their fullest capacity. The Chicago Drainage Canal having been constructed with a capacity, as it turns out, of 14,000 cubic feet per second, full power development will call for the whole of that amount, and in fact power works are now under construction at Lockport to utilize it. Inasmuch as the sanitary requirements by the standard fixed in the State law are only 6,667 cubic feet per second for the present population of 2,000,000, it is evident that power development, incidental though it be, does lead to demands for water not required for sanitary purposes.

38. It remains to be seen whether any diversion, complete or otherwise, is necessary to preserve the health of Chicago. Upon this point the commission sought the advice of two eminent sanitary engineers—

Messrs. Rudolph Hering and George W. Fuller—whom it instructed as follows, viz: "To examine the sanitary situation at Chicago, so far as it is affected by sewage disposal, and to report whether it is or is not necessary to the health of the city to extend to outlying territory the system which was adopted in 1889 for the main city. * * * The commission desires an emphatic opinion from authoritative sources as to whether the system of diverting the water of Lake Michigan in large quantities into the Illinois Valley is the only way to preserve the lives and health of the people of Chicago. It does not desire an investigation of the effect upon the navigation interests of the Great Lakes. It has satisfied itself upon that point. Nor does it wish to reopen the case of the Chicago Drainage Canal as designed and built. It accepts that as a fixed fact, with its attendant diversion of 10,000 cubic feet per second through the Chicago River. The extension of the system to the Calumet River alone is in question, and the question is, Are there not other methods of sewage disposal which can be applied here at a cost not exceeding much, if at all, the cost of the method proposed, and which will be equally effective in preventing the pollution of the lake? It desires a report upon the various systems which may be found available for application here, with a statement of their relative efficiency. It also desires a statement of their relative cost, so far as that can be given without the preparation of detailed plans. The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive should be given." These gentlemen visited Chicago, and after a thorough examination of the situation submitted a report, of which a copy is hereto appended, marked "F." The entire report should be carefully studied. Its conclusions only are here quoted. They are as follows, viz:

The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive are that a dilution of 3½ cubic feet per second for each 1,000 persons connected with the sewers, as provided for in the enactment of the Illinois legislature in 1889, is as low a figure as it is now possible to state. We believe that with the elimination of objectionable trade wastes and the occasional dredging of the river this amount of dilution will be sufficient to prevent offensiveness.

The extension of the dilution method to the outlying territory is not the only way to preserve the lives and health of the people of Chicago. The application of this method, with flow of 10,000 and 14,000 cubic feet per second, respectively, for the area tributary to the present drainage canal, will serve populations not exceeding 3,000,000 and 4,200,000, respectively. For greater populations other methods of sewage disposal will be required.

For the Calumet area, as well as other districts, there are several methods for the disposal of sewage as effective as the present method of dilution in preventing the pollution of the lake waters.

All these methods involve intercepting sewers and pumping stations to collect and deliver the sewage at suitable sites. Septic tanks are used for partially clarifying the sewage, which may then be applied to any one of three methods of filters, viz, intermittent sand filters, contact filters, and sprinkling filters.

All of these filters if well built and well managed remove the suspended and organic matters so that the effluents are practically clear and nonputrescible. The removal of bacteria by these three types of filters averages at least 98, 80, and 90 per cent, respectively. Such effluents may be discharged into any of the water courses of the Calumet region.

The approximate total costs, liberally estimated, without the preparation of detailed plans, for a population of 1,200,000 are as follows:

A.—*Intermittent sand filters.*

Construction	$11,063,000
Annual cost of operation, $866,000, capitalized at 5 per cent	17,320,000
	28,383,000

B.—*Contact filters.*

Construction	$11,787,500
Annual cost of operation, $551,000, capitalized at 5 per cent	11,020,000
	22,807,500

C.—*Sprinkling filters.*

Construction	9,257,500
Annual cost of operation, $419,000, capitalized at 5 per cent	8,380,000
	17,637,500

The present population on the Calumet area of the sanitary district being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expended at the outset.

Of the available methods of disposing of the sewage of the Calumet area other than by dilution, the sprinkling filter method, being the cheapest both in cost of construction and of operation and accomplishing an adequate degree of purification, is clearly the most advantageous one.

These engineers stand in the front rank of their profession as sanitary experts. One of them, Mr. Hering, was chairman of the commission of 1887, whose report to the mayor and city council of Chicago was the foundation of the subsequent legislation and led to the construction of the drainage canal. The conclusions reached are those of friends of Chicago, and not of her enemies or rivals.

39. A method of sewage disposal for the Calumet region is proposed which for a population of 1,200,000 is estimated to cost $17,637,500. For the present population of about 200,000 only a part of the expense need be incurred, and the works can be developed as the population increases. It can when the necessity arises be applied with a population much exceeding 1,200,000. The cost of diverting the Calumet River into the Chicago Drainage Canal is estimated at $12,000,000. The greater efficiency at present and in the future of the method now proposed would justify a considerable increase of cost, but in view of the fact that the entire expense of the diversion must be incurred at the outset, while by the new method the expenditures will be regulated by the growth of population, the difference in cost may be considered unimportant.

SUMMARY.

40. The following is a summary of the more important facts recited in this report:

(*a*) Chicago obtains its water supply from Lake Michigan, and to avoid polluting it must either dispose of its sewage otherwise than in the lake or place its intakes for water at a great distance from the city.

(*b*) The topography of the country favors the discharge of the sewage into the Des Plaines River, a tributary of the Mississippi, through two depressions in the divide which separates that river from Lake Michigan.

(*c*) The slope on the lake side of the divide is drained by two streams, the Chicago River and the Calumet River, into which the sewers of the city empty. By a cut through the northerly depression the flow of the Chicago River has been reversed and diverted into the Des Plaines River instead of into Lake Michigan, and by a cut

through the southerly depression the same process can be applied to the Calumet River.

(*d*) To make this reversal effective the channels must be large enough to take all the water which falls upon the respective drainage areas during the most violent rain storms. This amount is estimated at 10,000 cubic feet per second for the Chicago River and 15,700 cubic feet per second for the Calumet River.

(*e*) The city of Chicago was originally built upon the Chicago River, and that stream now drains the richest and most populous part of the city. It is now spreading over the Calumet region.

(*f*) In 1889 the plan of diverting the Chicago River into the valley of the Des Plaines was definitively adopted, and the Chicago Drainage Canal was undertaken. It was designed to carry 10,000 cubic feet per second. Though not entirely completed, it has been in use since January, 1900. The amount expended upon the canal and accessory work is about $41,000,000.

(*g*) The Illinois law which authorized the canal required a flow of 333 cubic feet per second for each 100,000 of population in order to render the sewage inoffensive. This amount of dilution is probably not excessive. It is reasonable to expect a population in a future not remote of five or six millions or more, involving the diversion by this standard of some 20,000 cubic feet per second. The Chicago River with its 10,000 cubic feet provides for a population of 3,000,000. The present population of the city is about 2,000,000.

(*h*) It is now proposed to apply to the Calumet River a treatment similar to that applied to the Chicago River, viz, to reverse its flow; so that instead of discharging into Lake Michigan it shall discharge into the Des Plaines, but for a part of the new route it must follow the drainage canal already excavated for the Chicago River.

(*i*) Although the Chicago Drainage Canal was designed to carry 10,000 cubic feet per second, it is found to have, in its completed rock portion, an actual capacity of 14,000 cubic feet. This additional capacity fixes the amount which it is proposed to divert from the Calumet at 4,000 cubic feet per second. Any greater amount from the Calumet will overtax the drainage canal at the expense of the richest part of Chicago and for the benefit of a suburban part.

(*k*) The diversion of only 4,000 cubic feet will not be effective at all times, since a much greater amount must be diverted from the Calumet during heavy rain storms if the lake is to be protected. Moreover, it provides for a population not exceeding 1,200,000, which number will probably be exceeded at a date not far distant.

(*l*) The large channels necessary to provide for the contingencies of rain storms are capable of discharging a volume of water largely in excess of sanitary requirements during the greater part of the year, but the development of water power creates the demand that they be employed to their full capacity throughout the year.

(*m*) The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress, but there appears to be a tacit general agreement that no objection will be made to the diversion of 10,000 cubic feet per second, as originally planned.

(*n*) The diversion of 10,000 cubic feet per second will lower the levels of Lake Michigan-Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, besides the important connect-

ing channels, the Detroit and St. Clair rivers, by amounts varying from 4¼ to 6¼ inches for the different waters, and the diversion of 14,000 cubic feet will lower them from 6 to 8½ inches. The diversion of 20,000 cubic feet will lower Lake Michigan-Huron about 13 inches and Lake Erie about 11 inches.

(*o*) The lake traffic which passed through the Detroit River in 1905 was about 58,000,000 tons, valued at about $615,000,000. It is increasing annually with marvellous rapidity. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit River in 1906 exceeded 65,000,000, valued at $690,000,000. The lowering of the water surface has a very injurious effect upon this traffic, and upon that of the Welland and St. Lawrence canals. Chicago being one of the principal lake ports, there will be very few communities which will feel the injury more than she will.

(*p*) The cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is estimated at $10,000,000, and of restoring it in the Welland and St. Lawrence canals at $2,500,000. This expenditure would not prevent very serious annoyance to the navigation interests during the execution of the remedial works, which would occupy several years. In Lake St. Clair navigation of the open lake would be replaced by that of an artificial channel or canal with submerged banks.

(*q*) The extension to the Calumet region of the method of sewage disposal already applied to the Chicago River is not necessary to preserve the health of Chicago, there being other and better methods available for the Calumet region. The final cost of these methods is somewhat greater than that of the one proposed, but the works can be developed as the population increases, and only a part of their cost need be incurred at present, while their greater efficiency justifies the increase of final cost.

(*r*) The diversion of 10,000 cubic feet of water per second at Chicago will render practicable a waterway to the Mississippi River 14 feet deep. Any greater depth must be obtained by the abstraction of more water from Lake Michigan and at the expense of the navigation interests of the Great Lakes and of the St. Lawrence Valley.

(*s*) The effect upon Niagara Falls of diverting water at Chicago is of secondary importance when considering the health of a great city and the navigation interests of the Great Lakes and of the St. Lawrence Valley, but it is proper to note that the volume of the falls will be diminished by the full amount diverted at Chicago.

RECOMMENDATIONS.

41. The waters of Lake Michigan in the United States, the waters of Georgian Bay in Canada, and the waters of Lake Superior partly in the United States and partly in Canada all form sources of supply of the Great Lakes system, finding their way by the St. Lawrence to the sea. All are interdependent and there can be no diversion from any of them without injury to the whole system. By Article XXVI of the treaty of 1871 it is provided that "navigation of the river St. Lawrence, ascending and descending from the forty-fifth parallel of north latitude, where it ceases to form the boundary between the two countries, from, to, and into the sea, shall forever remain free and open for the purposes of commerce to

the citizens of the United States, subject to any laws and regulations of Great Britain, or of the Dominion of Canada, not inconsistent with such privileges of free navigation." It is desirable that in any treaty arrangement the waters of Lake Michigan, Georgian Bay, and all other waters forming part of the Great Lakes system should be declared to be "forever free and open for the purposes of commerce" to the citizens of the United States and the subjects of His Britannic Majesty, subject to any laws and regulations of either country not inconsistent with such privilege of free navigation.

42. The preservation of the levels of the Great Lakes is imperative. The interest of navigation in these waters is paramount, subject only to the right of use for domestic purposes, in which term is included necessary sanitary purposes. In our report of November 15, 1906, upon the application of the Minnesota Canal and Power Company to divert certain waters in Minnesota we recommended, among other things—

that any treaty which may be entered into should define the uses to which international waters may be put by either country without the necessity of adjustment in each instance, and would respectfully suggest that such uses should be declared to be (*a*) uses for necessary domestic and sanitary purposes; (*b*) service of locks for navigation purposes; (*c*) the right to navigate.

It is our opinion that so far as international action is concerned a treaty provision of that kind is all that is required in this case. We accordingly renew our recommendation of November 15, 1906, just quoted.

43. A careful consideration of all the circumstances leads us to the conclusion that the diversion of 10,000 cubic feet per second through the Chicago River will, with proper treatment of the sewage from areas now sparsely occupied, provide for all the population which will ever be tributary to that river, and that the amount named will therefore suffice for the sanitary purposes of the city for all time. Incidentally it will provide for the largest navigable waterway from Lake Michigan to the Mississippi River which has been considered by Congress.

We therefore recommend that the Government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal.

All of which is respectfully submitted.

O. H. Ernst,
Brigadier-General, U. S. Army, retired,
Chairman American Section.
George Clinton,
E. E. Haskell,
Members American Section.
Geo. C. Gibbons,
Chairman Canadian Section.
W. F. King,
Louis Coste,
Members Canadian Section.

Attest:

W. Edward Wilson,
Secretary American Section.
Thomas Côté,
Secretary Canadian Section.

APPENDICES.

APPENDIX A.

CHICAGO, *January, 1887.*

To the honorable mayor and city council of the city of Chicago:

GENTLEMEN: On January 27, 1886, your honorable body passed a resolution authorizing the creation of a drainage and water-supply commission. After being amended, February 23, it read as follows:

"Whereas pure water and scientific drainage are necessities of this community, and the people demand a system of water supply and drainage adequate to meet the requirements not only of the present, but of years to come, nor will any temporary expedient or makeshift satisfy them; and

"Whereas a thorough and permanent system of supplying pure water to our citizens and caring for the drainage of the municipality can not be paid for out of current taxation, therefore it is desired that a plan shall be devised and perfected before the next meeting of the legislature to the end that necessary legislation may be had.

"For the purpose of carrying into effect the objects sought, there is recommended the appointment by the mayor of a commission to consist of one expert engineer, whose reputation is so high that his opinion and report will command the respect of the community, and with him one or two consulting engineers of like experience in engineering and sanitary matters. The duty of this drainage and water-supply commission, made up as above set forth, should be to consider all plans relating to drainage and water supply which may be brought to its attention; to make such examinations and investigations and surveys as may be deemed necessary; to collect all information bearing on this problem; to consider all recent developments in the matter of sewage disposal, and their application to our present and future needs; to consider and meet necessity of increasing our water supply and of protecting the same from contamination; to remedy our present inadequate methods of drainage and sewage disposal; to consider the relations of any system proposed to adjacent districts, and whether there may not be a union between the city and its suburbs to solve the great problem; to determine the great question as to the interest which the State and the United States may have in the disposal of sewage by way of the Illinois River, and to devise plans to meet any objections thereto, if such a system shall be thought best; and in general to consider and report upon any and all things which relate to the matter of water supply and drainage of the city of Chicago.

"The commission should report on the whole matter committed to it in the most full and comprehensive manner, with maps, plans, and diagrams complete, and accompany the report with estimates of the first cost and annual requirements for the maintenance of the system proposed.

"The report of the commission should be made as early as practicable, and not later than the convening of the next session of the Illinois legislature in January, 1887.

"In consideration of the foregoing, be it

"*Resolved*, That the mayor be, and is hereby, authorized and directed to employ on behalf of the city one expert engineer of reputation and experience in engineering and sanitary matters, at a salary not to exceed $10,000 per annum, and also to employ such consulting engineers, not exceeding two in number, as may seem necessary, and such assistant engineers as may be required, all to be paid according to services rendered, for the purpose of carrying out the objects set forth in the preamble hereto. For the fees of said assistant engineers and for all expenses connected with said work there shall be allowed not to exceed the sum of $20,000. All fees, salaries, and expenses connected with said work shall not exceed in the aggregate the sum of $30,000, and the same shall be paid from the water fund of the city upon vouchers audited by the mayor and city comptroller."

In accordance with the terms expressed herein his honor Carter H. Harrison appointed Rudolph Hering as chief engineer, Benezette Williams and S. G. Artingstall as consulting engineers, who together should constitute a commission. Mr. Hering entered upon duty March 28, Mr. Williams September 17, and Mr. Artingstall December 21, 1886.

The investigation designated by the resolution was a formidable one, comprising no less a task than the consideration of the entire subject of the future water supply and drainage of Chicago. It appeared doubtful from the beginning that a report such as was demanded could be furnished within the specified time, for the simple reason, if for no other, that observations of the lake phenomena and of the flow of certain rivers should be extended over at least one year, covering four consecutive seasons, in order to draw satisfactory deductions.

But the large amount of work alone that was asked for made it impracticable to present a complete report in so short a time. It was expected, however, that results could be reached sufficient to indicate the character of legislation required to carry out any project that might be determined upon, and that therefore a preliminary report having this end in view could be made at the stated time, leaving to a later date the presentation of a report outlining the detailed features of the scheme recommended and embracing the minor results of the entire inquiry.

The present communication is to cover the ground indicated for the preliminary report, and besides containing the conclusions reached regarding the main features of the proposed project, it contains also a brief review of the work done during the past year and of what still remains to be done.

The month of April was devoted to a general examination of the subject of the territory to be investigated, and of the various suggestions that had been made toward effecting a solution of the problem.

The examination disclosed the fact that the city is sometimes greatly suffering from the offensive condition of parts of the Chicago River and its branches, caused by the discharge of sewage into the same, and from the occasional contamination of its water supply, brought about by the discharge of the polluted contents of the river into the lake. It also disclosed the fact that almost every conceivable way of dealing with these questions had been suggested and in some forms applied during the past thirty years.

The problem therefore demands the attainment of two ends—the protection of the water supply and the removal of the river nuisance. As the water must be taken from the lake, it is evident that both its pollution and the objectionable condition of the rivers should be prevented by a better disposition of the sewage. It is, therefore, the latter question which constitutes the main object of this investigation.

Among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy of an extended consideration, namely: A discharge into Lake Michigan, a disposal upon land, and a discharge into the Des Plaines River. The preliminary work has, therefore, been confined to these three projects, and was classed as topographic, hydrographic, and miscellaneous.

At the time when the present commission began its labors the topographical work had already received some attention. Surveys were being made of the Des Plaines River from Bridgeport westward under the direction of Mr. Artingstall, city engineer. These surveys were continued, and have now been completed as far as Joliet. They include contours of the entire valley and borings to rock between Bridgeport and Lemont. In order to understand the hydrography of the Des Plaines Valley above the point where the Chicago sewage could be discharged into it, and also to ascertain the probable magnitude and

effect of floods in the river, a survey was made of its bed as far north as Northfield township. To determine the area of the basin its entire divide was located. To ascertain the practicability of diverting the flood waters from the upper portion of the Des Plaines and North Branch watersheds directly into the lake, and thus avoiding the difficulties which would arise from their passing through the Chicago River, all feasible lines were surveyed. Finally, a few levels were taken of the area adjoining the city wherever no connected levels existed to show the general topographical features of the territory over which the future city will spread out and from which the drainage will require artificial removal.

The hydrographic work consisted in ascertaining the flow of the Des Plaines River, the rainfall upon its area, its flood discharges, the character of its bed, and the probable effect of discharging the Chicago sewage into it when diluted by a large and constant stream of water from the lake. It consisted, further, in examining the nature of the currents in the lake and in studying the rise and fall of its level, and in ascertaining the amount and character both of the sewage discharged into it and of the deposits in the river and lake in front of the city to determine the effects of the present sewage disposal.

Inquiry and surveys were made to show the feasibility of purifying the Chicago sewage by filtration on land. Land damages were carefully estimated for the different schemes; existing records were searched concerning borings and excavations made in and about the city, so that the practicability of certain lines of tunnels could be discovered; the probable growth of the city and its suburbs, as well as the probable distribution of the future population, received a careful attention, and, finally, a large number of data were compiled which pertain to the existing works of water supply and sewerage in Chicago and the adjoining towns.

In reporting the result thus far gained we will present them in the order most convenient for discussion, but before doing so will briefly describe the present manner and effect of the sewage disposal, as shown by this investigation.

PRESENT SEWAGE DISPOSAL.

The sewage works of Chicago and suburbs have been planned on what is called the combined system, in which the sewers serve for the removal both of sewage and rain water. In the town of Evanston they empty into the lake. In the town of Lakeview they partly discharge into the lake and partly into the North Branch. From the north and west divisions and part of the south division of Chicago, the drainage enters the Chicago River and its branches, and from the remaining part of the south division it flows into the lake at three outlets, situated, respectively, at Twelfth, Twenty-second, and Thirty-fifth streets. The sewers of Hyde Park discharge into the lake, excepting those of Pullman, where the sewage is disposed of on land. The town of Lake, including the Stock Yards district, drains into the South Fork of the Chicago River.

When the sewage works of this city were designed, in 1856, by Mr. E. S. Chesbrough, it was apprehended that ultimately some means would have to be found to change the water in the river from time to time or to keep the sewage entirely out of it. The first step toward improving the condition of the river was taken by deepening the Illinois and Michigan Canal, so as to cause a current from the lake to the Des Plaines River at Lockport. The next step was the building of the Fullerton avenue conduit in order to produce a circulation in the North Branch; and the last step was the erection of the canal pumping works to increase the flow in the river, which had become greatly polluted.

The influence of these works is confined to the main river and its north and south branches. But the south fork of the latter, receiving a large amount of sewage from Chicago and the town of Lake, and charged with the waste from the Union Stock Yards and packing houses, has no artificial means for a circulation of its water, and as a consequence is in a condition of great filthiness.

The accompanying diagram [a] has been prepared to show the present pollution of the Chicago River and its branches during the time when all of their water is discharged into the canal by the Bridgeport pumps. On the left are shown the main river and the north branch, one above the other, their combined waters forming the south branch, and reaching Bridgeport on the right, where they are lifted into the canal.

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[a] Omitted; printed in House Ex. Doc. No. 264, 51st Cong., 1st sess.

At the latter point the south fork is shown as joining it. The shaded portions indicate the amount of sewage entering and passing the respective points, and the blank portions the lake water diluting it. The degree of dilution is shown by the relative areas. It diminishes in the north branch from Fullerton avenue to the south branch, and becomes still less toward Bridgeport, and finally receives the foul waters of the south fork.

The depth and character of sewage deposits in the river and harbor, as might be expected, vary considerably. They are not great in the track of the vessels, but increase toward the docks and quieter portions of the slips, where they reach a depth of from 1 to 4 feet. While the deposits in the channel are of a heavier kind, such as cinders, those in the docks are mostly a foul mass of decomposing organic matter. No form of life is found to exist above Clark Street Bridge as far north as Clybourn place and as far south as Ashland avenue. The effect of this condition of the river is to endanger the purity of the water supply whenever the river, with its accumulated deposits, flows into the lake, which occurs when the rain water that finds its way into the river exceeds the amount pumped into the canal. If this excess is great, as in the spring and occasionally in the summer months, the contamination of the lake is considerable, and must constantly increase.

From the foregoing it is seen that the present method of disposal of the sewage from Chicago and its suburbs is partly by discharging it into Lake Michigan, but mainly, except during floods, by discharging it into the Des Plaines River.

FUTURE POPULATION.

The first question which required an answer, and upon which many of the subsequent inquiries depended, was the population which it is economical and advisable to consider at present, and the extent of territory upon which such a population will be located.

The growth of Chicago has been frequently quoted as phenomenal. Estimates made thereof for various purposes have turned out to be rather under than over the actual result.

It is taken for granted that Chicago and its suburban towns will have to dispose of their sewage so that the water supply for the entire community residing near the lake from the south line of Hyde Park to the north line of Evanston will be guarded against pollution by the sewage from any one of its separate communities. For this purpose the whole populated area within the above limits is considered as forming one city with a common interest.

The growth of this metropolis was obtained partly from the United States census and partly from the school census of Cook County, which gave a record up to the summer of 1886. In order to forecast the probable ratio of the future increase it was desirable to compare this growth with that of other cities. By considering the ratio in increase elsewhere, and including the natural suburbs of each city, a fair and instructive basis of comparison was obtained; and by realizing the respective natural advantages for growth in each of the communities the probable ratio for Chicago was determined with a satisfactory degree of exactness.

The accompanying diagram shows the results of this comparison. It represents by curves the population of the largest cities in the country since 1790, not as usually quoted from the census, giving the inhabitants on certain arbitrary areas fixed by law, but as virtually making up the population of the respective municipalities, by including adjacent towns and natural suburbs. the only method which enables the true growth of the great cities to be recognized. For instance, the New York center naturally includes Brooklyn, Jersey City, Hoboken, Newark, and other suburbs, and Chicago, the entire territory from Hyde Park to Evanston.

The diagram indicates that the character of growth of the different cities permits them to be divided into two distinct classes. Philadelphia, Boston, St. Louis, and Cincinnati show very much the same character of increase, and represent by comparison the more conservative communities. New York and Chicago, on the other hand, while showing a remarkable resemblance to each other, form quite a contrast to the rest of the cities, and might be called the more progressive communities. The diagram finally indicates the time when the Chicago curve, which was the lowest one prior to 1864, intersected in turn those of St. Louis, Cincinnati, Boston, and there is a high degree of probability of its intersecting the Philadelphia curve in or before 1891—i. e., in four years from now—after which Chicago will be the second largest center of population in America.

As it is not practicable in so young a city as Chicago to forecast a definite line of growth, it is preferred to give the probable maximum and the probable minimum between which the true line will most likely be contained. The minimum line represents a growth resembling that of New York and the maximum line assumes the ratio of increase per decade to be constant instead of gradually decreasing as in most other cities. The result indicates that the population of Chicago and suburbs will be 2,500,000 between the years 1905 and 1915, or about three times the present population in eighteen to twenty-eight years.

In providing public works for large communities it must be borne in mind that it is economical to invest only such sums as will bring a return within a certain number of years, leaving expenditures for benefits that will be realized only at a later time to a later generation. This fact, together with the probable growth of Chicago, shows it to be economical and judicious at present to plan works sufficiently extensive to dispose of the sewage of not less than 2,500,000 inhabitants.

In addition to the population the area that will be occupied by it has to be determined. While this is a far more difficult task, owing to the many accidental causes influencing the distribution of the population, it is possible nevertheless to outline the area sufficiently close for present purposes.

The future metropolis, with a population three times as great, will be distributed along the lake from South Chicago to Evanston, and will reach inland to the Blue Island Ridge in the south to the Des Plaines River in the center, and to the higher parts of Niles Township in the north. Outside of these general limits, a more or less dense population will extend for some distance along the lines of railroad.[a]

As inferred above, it is proper to consider at this time the wants of the population that will reside upon this entire territory.

DISCHARGE OF THE SEWAGE INTO LAKE MICHIGAN.

To discharge the sewage from cities into comparatively large bodies of water is not only the usual, but often the best method for its disposal. Dilution and dispersion thoroughly expose it to the action of the oxygen contained in both the water and the superincumbent air; it is thereby gradually oxidized. Where the body of water is a large river with a strong current, the best conditions for such purification are found. Where it is a lake in which the circulation is slight and irregular, the efficacy of the method is less and depends for its success on the character of the currents and the relative amount of sewage to be discharged into it.

The hydrographic surveys of the lake made during the past season were therefore partly for the purpose of ascertaining, if possible, the laws governing the currents, so that we would know their effect in dispersing the sewage discharged into the lake. The trend of the shore currents was actually ascertained by daily recording the direction of spar buoys placed at the Chicago waterworks crib, at Michigan City and at St. Joseph. A large number of bottle floats were thrown into the lake at different points and different times for the same purpose. They were partly single surface floats and partly double, the lower one being placed at varying depths, according to the depth of the water. More than half of them have been picked up and returned, with place and date noted. The currents were also observed by meeans of large can buoys from an anchored tugboat at different points in the lake extending from Hyde Park to Evanston, about 6 miles from the shore. Two general lake trips were undertaken, one to St. Joseph and back to Grosse Point, and another one parallel with the shore around the head of the lake.

When the observations are completed and compiled in detail, some valuable information will be available for the question of water supply. Light will be thrown on the movement of the water under different winds and the sudden changes of temperature of the water at the crib and on the turbidness of the same.

The following results have a bearing on the question of sewage disposal: Where not affected by local conditions, the currents practically go with the winds in water of moderate depth and quickly respond to any change. In deep

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[a] Here occurs a diagram showing the "growth of several population centers in the United States," not here reproduced.

water also the surface currents run with the wind, but at the bottom and even at mid-depth the direction is usually different. The prevailing current along the shore of Cook County during the past summer has been observed to be toward the north, but it is possible that this result may be different during the winter months. In the open lake wave action seems to be effective in preventing the permanent deposits down to a depth of about 60 feet; inside of the breakwater sewage deposits are found on the bottom.

The general deduction from these results is clear that, as no constant current exists which would carry the sewage away in one direction, it should be discharged into the lake at one end of the future city, while the water supply should be obtained as far away from it as practicable toward the other end, a conclusion which is being acted upon in the other large lake cities. The proper place from which to bring the water would be opposite Grosse Point, and the sewage discharge should be east of Hyde Park. While it might be practicable to allow the sewage in its crude form to enter the lake under such conditions for many years, the necessity would arise later for clarifying it at least partially previous to its discharge. It could not be allowed to run into the river as at present, but the dry weather flow and a considerable amount of storm water would have to be intercepted and carried to the outfall through many miles of special conduits. This entire quantity would have to be raised by pumping in order to get sufficient head to empty into the lake, while the diluted sewage during storms, in excess of the capacity of the intercepting sewers, would be allowed to discharge directly into the river.

The water supply would have to be brought from Grosse Point in large conduits to the several pumping stations scattered over the city and its present suburbs. The circulation of the water in the Chicago River and branches would have to be maintained practically as it is at present, because the removal merely of the dry-weather flow of sewage would not altogether prevent its pollution.

DISPOSAL OF LAND.

We shall not at this time enter into a general discussion of the principles underlying land purification of sewage, or make historical references showing the success or ill success of the method as practiced elsewhere. We will simply state that with good management under ordinarily favorable conditions a disposal on land proves satisfactory, so far as the purifications of the sewage is concerned, and that with proper conditions in the way of good markets and a favorable soil and climate sewage farms can be operated on a large scale after the sewage is delivered upon the same without financial loss.

In speaking of a sewage farm of the magnitude required for the metropolitan area of Chicago, it is not understood as being land devoted primarily to the raising of crops, using the sewage only when and where it would most promote the growth of vegetation. The primary object would be the purification of the sewage on an area of land as small as could serve the purpose. Technically speaking, the sewage disposal would be by means of intermittent filtration rather than irrigation. To carry out such a scheme for Chicago involves the following:

(1) The acquirement of sufficient land suitable for the purpose.

(2) A comprehensive system of intercepting and collecting sewers carrying the sewage to the farm.

(3) Pumping works of a capacity to handle all the dry weather flow of sewage and a certain proportion of storm water.

(4) A thorough underdrainage, leveling, and preparing of beds for the filtration areas.

5. A system of underground conduits and surface carriers for distributing the sewage over the ground, and a system of open ditches for removing the purified water to the nearest water courses.

6. Buildings, roads, and a complete farming outfit.

7. An organization for properly distributing the sewage, for carrying on the farming operations, for conducting the business of disposing of the crops in the best market.

In making estimates for the size of intercepting sewers, conduits, pumps, and area of land required we have used as a basis a population of 2,500,000 people, with an average dry-weather sewage discharge of 150 gallons, or 20 cubic feet, per head daily, and made provision for storm water equivalent to one-fifth of an inch in twenty-four hours over all portions of the district now drained or likely

to be drained by a combined system of sewers, allowing surplus water to escape into the rivers and lakes.

The dry-weather flow of sewage would therefore be 50,000,000 cubic feet per day, and the maximum flow of storm water 65,000,000 cubic feet per day, making a total maximum discharge of 115,000,000 cubic feet.

From an examination of rainfall tables we conclude that the annual amount of storm water that would be carried off by such an intercepting system would range from 9 to 12 inches, an average of which in round numbers may be taken at 40,000 cubic feet per acre per annum over the area drained by a combined system of sewers. It is practicable, however, to exclude the storm water from the sewers over a large portion of the future city by adopting the separate system of sewerage. The area north of the town of Jefferson and of the middle of Lakeview may be treated to advantage in this way, and also a large portion of Hyde Park, Lake Calumet, and other adjoining towns.

Assuming that the area which does not allow the storm water to be entirely excluded is 140 square miles, the average daily amount becomes 10,000,000 cubic feet, which gives, when added to the sewage, 60,00,000 cubic feet, or 24 cubic feet per head of population per day to be provided for on the farm.

As the amount of land required to purify sewage can only be determined by experience, and as this has been very limited in our own country, we are forced to rely mainly upon that of Europe. Without going into details at present, we will simply state that a fair consensus of this experience justifies us in the conclusion that from 10,000 to 15,000 acres of land would be required to dispose of the sewage from the entire metropolitan area.

The only available territory for sewage filtration in the neighborhood of Chicago consists of two sandy ridges in the town of Thornton, extending across the State line into Indiana, and in a sandy ridge crossing the town of Niles. The soil is quite favorable, but the character of the surface is such that the necessary preparation to make it suitable for filtration beds would be comparatively expensive. An enormous cost is, however, represented by the fact that the sewage would have to be collected by large intercepting sewers, lifted altogether some 90 feet, and carried about 20 miles before reaching the farms. We therefore consider such a project entirely impracticable.

The land treatment can only be seriously thought of in connection with the sewage disposal from the smaller areas mentioned above and comprising the extreme northern and southern parts of the future metropolis. The drainage of parts of Evanston, Lake View, and Niles might be taken to the sandy ground in the latter town, and that of the Calumet region to the sandy ridges in Thornton, should this method be found most advantageous when compared with others.

The preliminary invesigation made for this purpose consisted in an examination of the grounds, in the projection of a farm, and in an estimte of the cost of preparing the same and delivering the sewage to it by intercepting sewers and conduits.

DISCHARGE OF THE SEWAGE INTO THE DES PLAINES RIVER.

A third solution of the drainage problem is rendered practicable by the fact that the divide between Lake Michigan and the Mississippi Valley lies about 10 miles west of Chicago, with so slight an elevation that it is not a difficult matter to carry the sewage from the city westward into the Des Plaines River, and thence into the Mississippi River. The method of disposal, as previously explained, is in fact mainly the present one, most of the sewage now being carried across the divide by the Illinois and Michigan Canal.

There are two low depressions between the future metropolis and the Des Plaines River—the Mud Lake Valley, with the present canal, and the Sag Valley west of Lake Calumet. Neither is more than 10 feet above the lake, nor do they present any engineering difficulties for canal construction. It is therefore quite feasible to carry all the drainage from the territory ultimately to be occupied by the metropolis, extending from Lake Calumet to Evanston, into the Mississippi Valley through these depressions, avoiding thereby all possible lake pollution and permitting the supply of water to be drawn from any number of convenient points in front of the city.

The possibility of this solution was recognized as early as 1856 by Mr. E. S. Chesbrough, and the first step toward its adoption was taken, as already mentioned, by turning the sewage into the Illinois and Michigan Canal. Not until quite recently, however, has it become practicable to consider the construction

of a special waterway for sewage removal, because when the population was smaller the expense of the undertaking was too great.

The sanitary requirements demand a flow of water large enough to dilute the sewage sufficiently to make it inoffensive along the river at all times. Beyond this, any increase in the size of the channel to provide for the storm water which naturally enters it should be kept at a minimum. A glance at the map and an examination of the ground show the possibility of diverting the greater part of the storm water from the metropolitan district without serious difficulty. Both branches of the Calumet River can be diverted west of the Indiana State line into Wolf Lake, and thence into Lake Michigan. The Des Plaines River can have its flood waters diverted into the North Branch near the north line of the town of Jefferson, and the combined waters can be led from Bowmanville directly into the lake. Salt Creek, a branch of the Des Plaines River, can readily be turned southwardly near Western Springs, through a water course known as Flag Creek, at one time evidently its old bed, discharging into the Des Plaines opposite Sag, and thus reducing the necessary storm-water capacity in the new channel between Sag and Summit.

In order to determine the probable quantity of flood water which can thus be excluded, it was necessary to ascertain the maximum flood discharges from all the watersheds in question. This requirement called for a gauging of Des Plaines, North Branch, and Calumet rivers; a gauging of the rainfall, which is a measure of the stream flow; a survey of the water sheds and an examination of the river channels. It was also necessary to make a reconnaissance of all possible lines for diverting the Des Plaines, the North Branch, the Calumet rivers, and Salt Creek, and a survey of those which were most important.

The results indicate that each one of these diversions is both practical and economical. By adopting the "separate system" of sewerage for the territory lying north of the proposed Bowmanville channel, the surface drainage from this territory can be safely turned into the lake.

A second branch of the investigation extends to the elements governing the proper size of the waterway from which a large proportion of the storm water has been excluded. The area still draining into it will consist largely of paved streets and roofs, allowing of no absorption and shedding the water rapidly. It requires a careful consideration to determine the maximum quantity of water that may enter the proposed channel, and for which an ample allowance must be made to prevent a back flow of the polluted water to the lake.

The proper degree of sewage pollution in the new channel demanded a careful investigation. When sewage is mingled with a sufficiently large quantity of water it not only becomes inoffensive, but readily finds the oxygen which gradually purifies it. When the surface is covered with ice a greater dilution is necessary for this purpose than at other times when there is a constant replenishment of oxygen from the air. The proposed waterway should, of course, provide immunity from offense at all times.

The information upon which definitely to decide this question will be given in the final report, as the data have not yet been all collected, owing to the necessity of making actual tests of the oxidization of the canal water under the ice, which is being done for the use of the commission by Dr. J. H. Rauch, secretary of the State board of health. The summer conditions are presented in his late report on the water supply and sewage disposal of Chicago. The result of these analyses will be compared with those of other streams that are also polluted with sewage in order to show the rate of oxidization with varying degrees of dilution and aeration.

For the purpose of estimating the cost of the water channel we have assumed 3,600 square feet for the cross section and a velocity of the water 3 feet per second, or 2 miles per hour. This gives a discharge of 600,000 cubic feet of water per minute, or 24,000 cubic feet for each 100,000 persons, which we believe equal to the maximum requirements of a population of 2,500,000 people.

A third branch of the inquiry covers the selection of routes for the proposed canals.

Between Chicago and Summit three lines are practicable—one following the west fork and Ogden ditch, and another extending from the southwestern end of the south fork in a westerly direction to the Ogden ditch, and thence to Summit, and a third being an enlargement of the present canal. We are of the opinion that eventually both the first and second of these lines should be adopted, but that the second one should be built first in order to secure circulation in the south fork. From Summit westward the bed of the river and the present canal

were the only lines to be considered. The best location has not yet been finally determined.

For the drainage of the Calumet region a simple inspection shows that a canal should start from the river at the southern point of Blue Island, and extend almost directly westward to the Des Plaines Valley at Sag.

A fourth branch of the inquiry relates to the study of such data as have reference to securing a proper circulation for the waterways within the city.

To throw light upon this point the variations of the lake level have been recorded since last spring by means of an automatic gauge indicating an almost continual fluctuation, averaging several inches, and recurring at periods of about twenty minutes. During a low pressure of the atmosphere the amplitude of these oscillations increases, and not unfrequently reaches several feet. The accompanying diagram [a] shows the level of the lake on August 16, 1886, at a time when an area of low barometer passed over it. From 6.40 a. m. to 6.55 a. m.—that is, in fifteen minutes—the water fell 2 feet 10 inches.

A rising level causes an inflow to the river and drives the water of the latter into the slips, where it deposits a portion of its suspended sewage matter and becomes foul. A falling level reverses the flow, and the slips empty their foul water into the river and lake. During heavy fluctuations of the latter, such as the one referred to above, it has been traced more than a mile in the direction of the crib.

As the proposed canal from Bowmanville to the lake will lower the water of the North Branch at this point to the lake level, provision must be made for its circulation. The size of the Fullerton avenue conduit is not sufficient to furnish the water required for a current in both directions, nor would such an arrangement be satisfactory or economical. It will be necessary to establish a flow toward the South Branch from the lake opposite Bowmanville in order to prevent a future lake pollution by the proposed channel. This can be accomplished by placing a lock in the North Branch at any point that may be found most desirable and raising the water at the same time about 1 foot. If such a lock is placed at Fullerton avenue the present pumping works, with slight modifications, can be utilized.

Finally, it must be mentioned that circulation can be secured in the proposed waterways of the Calumet region, into which the sewage is discharged, by a gravity flow from Lake Michigan into the Des Plaines Valley through Lake Calumet and the sag. The detailed features of this project have not yet been wholly matured, the estimates of cost being based on a channel having a capacity of 1,000 cubic feet per second.

COMPARISON OF PROJECTS.

In the foregoing we have outlined the main features of the only three feasible methods of disposing of the metropolitan sewage, and have given the results of the investigation reached to date. A general conclusion as to the preferable method may be given at present, and also an approximate estimate of cost. But we are not able as yet to give either conclusions or detailed statements of the probable expense regarding all parts of the proposed work, and must defer them until the final report.

In comparing the projects we will first mention their probable cost and then their relative advantages.

The discharge of the sewage into the lake from a population of 2,500,000 in the manner described above, including the extra expense, otherwise not necessary, of taking the water supply of Grosse Point, would cost at least $37,000,000, with an annual expense for interest and operation of at least $2,400,000. It would require an immediate investment of about $20,000,000.

To dispose of the entire metropolitan sewage by filtration on land would require an investment of about $58,000,000, with an annual expense of over $3,000,000 for interest, pumping, and maintenance, after deducting the profit from the sale of crops. It would be necessary to invest at once about $34,000,000. Land disposal for the sewage from the Calumet region alone, with a future population of 300,000, would require an investment of about $4,000,000 and an annual expense of at least $250,000.

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[a] Omitted; printed in House Ex. Doc. No. 264, 51st Cong., 1st sess.

Finally, the cost of the Des Plaines project is approximately estimated as follows:

1. A channel from the South Fork to Joliet of the capacity heretofore given will cost between $17,000,000 and $21,000,000.

2. A diversion of the flood waters of the Des Plaines, the North Branch, and Salt Creek will cost between $2,500,000 and $2,800,000.

3. Pumping works and locks for the North Branch will cost about $150,000.

4. A separate system of sewers to collect the sewage now discharged directly into the lake and to carry it into the river will cost about $600,000.

5. A channel from Lake Calumet to Sag will cost between $2,500,000 and $3,000,000.

6. A diversion of the flood waters of the Calumet River will cost between $350,000 and $400,000.

The total cost of the Des Plaines drainage project would therefore be, for the main district, between $20,250,000 and $24,550,000; for the Calumet district, between $2,850,000 and $3,400,000. The annual cost, including interest, etc., is estimated at about $1,300,000 per annum.

The pollution of the lake can be decreased and the present condition of the Chicago River, and particularly of the South Fork, can be improved by the immediate construction of the following works, which, with the exception of the pumping works at the South Fork discharging into the Illinois and Michigan Canal, are all a part of the final plan.

1. Channels diverting the flood waters of the Des Plaines, North Branch, and Salt Creek, as described above.

2. A modification of the Fullerton avenue pumping station and the construction of locks for the purpose of getting circulation in the North Branch.

3. A separate system of sewers to collect the sewage now flowing into the lake from the south division and to discharge it into the South Fork.

4. A waterway extending from the western end of the South Fork to the Illinois and Michigan Canal, with a new pumping station to promote circulation.

5. By raising the banks of the canal and by removing deposits this capacity can be increased 40 per cent at a small cost, and thus provide for a greater flow of water in the same.

The cost of the works comprised under these five items is estimated to be between $5,000,000 and $5,500,000. They could be finished in three years, and would greatly lessen the liability of polluting the water supply, while the sewage would be disposed of in the best practicable manner until the final completion of the Des Plaines project.

It therefore appears that this project is decidedly the least expensive one for the present as well as for the future.

Besides the economical advantage of the Des Plaines scheme, its superiority is still further emphasized by advantages of another kind. The proposed canal will, from its necessary dimensions and its regular discharge, produce a magnificent waterway between Chicago and the Mississippi River, suitable for the navigation of boats having as much as 2,000 tons burden. It will establish an available water power between Lockport and Marseilles fully twice as large as that of the Mississippi River at Minneapolis, which will be of great commercial value to the State. The Calumet region will be much enhanced in value by having a direct navigable channel to the Des Plaines River and by a lowering of the flood heights of Calumet Lake and River. Within the city the water of the Chicago River and its South Branch will get a much better circulation if it flows by gravity than if it has to be pumped, the necessity for which would remain even if the sewage should be discharged through intercepting sewers, either into the lake or upon land. Upon either of the latter conditions an occasional overflow from the sewers into the river during heavy rains would be more objectionable than a constant discharge of sewage into a more rapidly flowing stream. Flood waters entering the lake by way of the Chicago River would carry into it much filthy matter, either suspended or deposited, notwithstanding the existence of intercepting sewers, but the proposed diversion of such waters before reaching the populated districts will for all time obviate this undesirable occurrence. Lowering the level of the North Branch at Bowmanville by its diversion to the lake will be equivalent to raising the low prairie extending toward Evanston and Niles and greatly benefit parts of these towns.

THE WATER SUPPLY.

In reaching the conclusion that the sewage of the city should be discharged into the Mississippi Valley the question of water supply is materially simplified, because the lake will then at all times furnish good water wherever intakes are desired for an extension of the works.

The preliminary inquiry made with a view to ascertain the main features of an increased supply comprised, first, a compilation of data concerning the existing works both in Chicago and its surburban towns, which were collected mainly through the courtesy of the respective authorities; and, secondly, a study into the most economical method of distributing the water over the metropolitan area. The following is a brief description of the existing works:

The present intake for the public water supply of Chicago is located in Lake Michigan about 2 miles from shore and the water is conducted to the city in two circular brick tunnels 5 and 7 feet in diameter. They extend parallel to each other under the bed of the lake, and 50 feet apart, to the north pumping works, where they are connected and where the 5-foot tunnel terminates. The 7-foot tunnel is continued under the city for a distance of 20,500 feet, to supply the west works, on Ashland avenue near Twenty-second street.

The tunnels from the source to the shore are built at a depth of 80 feet below city datum, or low water in the lake, and the 7-foot tunnel is continued on the same level for a distance of about 11,500 feet, where, to avoid rock excavation, it is inclined upward until, at the west pumping station, the top is but 21 feet below city datum. The economical capacity of the two tunnels is between 90,000,000 and 100,000,000 gallons per day, or less than the present average daily consumption of water. Their maximum capacity is reached when delivering about 150,000,000 gallons per day, which is now nearly equaled by the demand during the hours of greatest consumption, and at the present rate of increase it is estimated that during the summer of 1887 the maximum demand for water will be at the rate of 145,000,000 gallons per day; during 1888, 150,000,000 gallons per day; during 1899, 167,000,000 gallons per day; and in 1890 180,000,000 gallons per day.

To provide against accident or obstruction from ice or other cause in the main tunnels, and to provide against an inadequate supply in the near future, which appeared inevitable, a new tunnel is in progress of construction. The intake is located 1,500 feet from shore, and connection is made with the other tunnels at the north pumping works.

The distribution of the water is effected by pumping it directly into the water mains at the north and west stations. At the north works the three tunnels are so arranged and constructed that any one of them can be emptied when desired for repairs or cleaning, and both the pumping stations still be supplied with water from the other tunnels. The total pumping capacity of this station is at present 67,000,000 gallons per day, but it will be increased to 91,000,000 gallons per day as soon as the new pumps now in process of erection are in operation.

The connections between the pumps, standpipes, and the distribution mains at these works have become so complex by the successive additions to the plant that an unnecessary loss of head is the consequence. As this can be remedied to some extent without great expense, we recommend that it be done at the first favorable opportunity. The station being on the shore of the lake, is not centrally located with reference to any part of the city, which renders it necessary to use a greater length of main pipe, with a consequent loss of pressure, to reach the consumers than would otherwise be the case. The total pumping capacity of the west side station is 60,000,000 gallons per day, and the connections between the pumps, standpipes, and mains are simple and effective, and the loss of pressure from this cause is a minimum. The location is better adapted to secure economical and satisfactory results than that of the north works, and with reference to additional pumping stations, which will later be necessary in other parts of the city, these works are well situated.

The following table compiled from the annual reports for 1884 and 1885 gives a detailed comparison of the cost of pumping at two stations, anthracite coal being used at the north side and good bituminous coal at the west side:

Cost of pumping 1,000,000 gallons 1 foot high.[a]

Nature of expenditures.	1884.		1885.	
	North side.	West side.	North side.	West side.
Salaries	$0.01488	$0.02022	$0.01560	$0.01667
Fuel	.05313	.02855	.04590	.02482
Lubricants	.00064	.00186	.00057	.00160
Miscellaneous	.00323	.00417	.00133	.00401
Total	.07188	.05480	.06340	.04710

The hydraulic merits of the system are shown on the diagram of water pressures from a survey made in December, 1886. The pressures have all been reduced to a common height above city datum and to a uniform height of water at the works. That diagram shows a greater loss of head in the vicinity of the north side station than at the west side. This is accounted for by the complex arrangements heretofore mentioned, and also by the relatively small area of mains, being only 16½ square feet at the north side and over 21 square feet at the west side. Nearly equal quantities of water are pumped at each of the stations during the middle of the day.

The following table shows the pumping capacity of all the suburban towns having a public water supply, and the pressure ordinarily maintained at the works. With the exception of South Evanston, all take water from Lake Michigan:

Locality.	Individual pump capacity.		Total pumping capacity per day.	Ordinary head at pump, in feet.
	Pumps.	Capacity per day.		
		Gallons.		
Hyde Park	2	3,000,000	.....	.....
Do	1	12,000,000	18,000,000	103 to 150
Lake	2	4,000,000	.....	.....
Do	2	2,000,000	12,000,000	100 to 190
Lake View	1	5,000,000	.....	.....
Do	1	3,000,000	10,000,000	92
Do	1	2,000,000	.....	92
Village of Evanston	1	3,000,000	3,000,000	92
Total	11	.....	43,000,000	.....

At the artesian well supplying the village of South Evanston there is a head of about 53 feet.

The pressure at different parts of the pipe system is very irregular. In Hyde Park it varies from 165 feet at the pumps to 10 or 12 feet at Forty-third street. In the Town of Lake the average head at the town hall is reported about 10 feet, with 188 feet at the pumps. In Evanston, South Evanston, and Lake View the difference of head in various parts of the villages is not very great.

The following table gives a comparison of the consumption and cost of water in Chicago and the suburban towns:

Locality.	Year.	Average head at pumps.	Average daily pumpage.	Cost per 1,000,000 gallons, delivered.	Cost of pumping 1,000,000 gallons 1 foot high.
Chicago (North Side)	1885	113	38,369,134	$7.17	$0.06034
Chicago (West Side)	1885	105	53,280,880	4.95	.04071
Evanston (village)	1886	113	787,000	17.00	.15000
Lake View	1886	.....	1,983,000	11.85	.....
Town of Lake	1886	163	7,292,023	8.80	.05400
Hyde Park	1886	.....	3,410,000	8.92	.....

[a] Here appears a "diagram showing water pressure in the Chicago water pipes." Not here reproduced.

The second point of inquiry was a study into the most economical method of distributing the water over the metropolitan area. We will at present refer to it but very briefly, mentioning only such conclusions as pertain to the immediate demands and leaving a fuller discussion of the details of this important question to the final report.

The comparatively level area upon which the city is located, and the practicability of taking the water from the lake along the city front at any desired point, after the sewage has been diverted, permits the most economical distribution to be ascertained by mathematical investigation to a much greater degree of exactness than is usually possible.

It is found to be less expensive for the densely populated areas to have pumping stations about 2 or 3 miles apart, because the loss of head and cost of mains and pumping to obtain the least allowable pressure are thus reduced to a minimum. In planning new works this fact should be considered, and locations so selected that they will be advantageous for the future as well as for the present.

The localities which we believe to be most suitable for additional pumping stations are near Twelfth street, in the central part of the city; near the Union Stock Yards; near Humboldt Park, and near Fullerton and Racine avenues.

When it is considered that at the present time the pumps are delivering during the busy part of the day at the rate of 120,000,000 gallons in twenty-four hours, which is nearly the maximum capacity of all the machinery, and that even with this large consumption of water it is impossible in some parts of the city to obtain water in the second story of the buildings, it becomes evident that an increased supply is imperatively required, and being a work of years to build new tunnels, inlets, buildings, and machinery, the necessity of deciding upon the location of the new works as soon as possible is readily seen. The locality which is suffering most from the want of water is the business section and the south part of the city, the lowest pressure extending from Twelfth street to the city limits. It will become necessary in the future to have two stations in this territory, one beween Harrison and Twelfth streets and the other to be somewhere east of the Union Stock Yards. We are strongly of the opinion that of the two stations it will be advisable and most advantageous to build the one north of Twelfth street first, for the following reasons:

1. It will require a shorter tunnel from the lake to the proposed station and less expenditure for main discharge pipes to connect with the present system than would be the case with the proposed southern station. This is equivalent to less cost and a saving of time in construction.

2. If the southern station is built first it will require mains of larger capacity leading toward the city than will be ultimately necessary when the central station is built.

3. The location recommended is near the center of the greatest consumption of water, and will be a gain not only in obtaining greater pressure in the business district, but in removing the cause for complaint on the south side by increasing the pressure so that the water will flow to the upper floors of the highest dwellings.

4. All other parts of the city will gain by the construction in this location, as the north and west works will be relieved of he enormous drain upon them to supply water for the business part of the city. They will be better able to give a good head on the north and west sides, where the population is increasing very rapidly, and which will very soon be in the same unsatisfactory condition as now obtains in the southern end of the city, unless relief is afforded in the manner indicated.

The other pumping stations will gradually become necessary as the population increases, and for a population of 2,500,000 there will be a need for a total combined capacity of 375,000,000 gallons to provide for a daily consumption of 150 gallons per head. With several intakes and tunnels the danger from stoppage of the water supply by ice or accident will be reduced to a minimum, as it is not probable that more than one of them would be so endangered at the same time.

We believe that a submerged intake will afford a more reliable and safer structure so far as injury from passing vessels and stoppage by ice are concerned than a structure projecting above the water.

With the sewage kept out of the lake there is no need of locating the intake farther than 2 miles from the shore, where water can be obtained sufficiently free from suspended earthly matter, and where a depth of about 30 feet is generally found, which is the least depth desirable for a submerged inlet.

GENERAL REMARKS.

After presenting the results thus far gained, indicating the general solution of the Chicago drainage and water-supply problem, it remains to point out certain facts which may be useful in discussing some of the legal measures required to carry out the proposed work. We desire to state that in order to reach the best results it is imperative to have all the main drainage works, such as intercepting sewers, waterways, and pumping stations, executed and maintained under a single management. It would be economical also to design and operate the main works for supplying water to the entire metropolitan area on a uniform plan and under one management, for the same reason that it is economical to keep the north and west side pumping works under one control, thus giving facilities as far as practicable for a supply proportioned to the demand to the entire metropolitan area, including the towns not bordering on the lake. We do not wish to imply, however, that such a general authority need necessarily extend further than to the construction and maintenance of the tunnels and conduits furnishing water to the respective pumping works.

Regarding the limits for metropolitan drainage, the investigation has shown, as already indicated, that topographical conditions clearly define two districts for the future metropolis. The main district extends from the line of Eighty-seventh street on the south to the north line of Evanston and from the lake westward to the Des Plaines River. Its sewage is collected into one channel and discharged into the Des Plaines Valley at Summit. The Calumet district extends over the natural drainage area of Calumet Lake and River south of Eighty-seventh street, and has its outfall channel running from Blue Island to Sag.

The final report will contain several maps, showing certain features of the metropolitan area, namely, the distribution of the population in 1886, the existing works and main distribution pipes for water supply, and the existing main sewerage works and 5-foot contour lines over nearly the entire area. It will also contain maps and profiles of the proposed waterways and storm-water-diversion channels mentioned in the present report, and a map showing the lines of the main collecting and intercepting sewers of the proposed drainage districts, and also the lines of new tunnels and the general distribution of the water supply.

In carrying on the present investigation its various branches are placed in charge of the following gentlemen, of whose ability and industry we desire to make special mention: Mr. L. E. Cooley, principal assistant, had special charge of the hydrographic work; Mr. Charles H. Swan, of the sewage disposal on land; Mr. Francis Murphy, of the topographical work; Mr. O. Guthrie, of the river pollution, land damages, etc., and Mr. T. T. Johnson, of the water supply, sewerage, and miscellaneous work.

Respectfully submitted.

RUDOLPH HERING,
Chief Engineer.
BENEZETTE WILLIAMS,
SAMUEL G. ARTINGSTALL,
Consulting Engineers.

APPENDIX B.

CHICAGO, *June 29, 1906.*

DEAR GENERAL: On May 28 I replied at length to your inquiries of May 26 concerning the final report of the drainage and water supply commission and the disposition of the materials which had been collected. Under date of May 31 you now ask for—

"The sanitary authority upon which rests the requirement of the Illinois State law that 20,000 cubic feet per minute must be diverted into the Chicago Drainage Canal for every 100,000 inhabitants."

And again—

"How much water is really required to dilute the sewage?"

The proper answer to your questions involves a review of the considerations which determines the ratio of dilution in the sanitary district law and the

justification for the same. I have therefore delayed this answer in order to consult original documents and memoranda. I have not undertaken to refer exhaustively to my records, as I am pressed for time, and my memory is entirely clear upon the essential facts.

The essence of the law is contained in sections 20 and 23 of "An act to create sanitary districts and to remove obstructions in the Des Plaines and Illinois rivers" (passed May 29, 1889, in force July 1, 1889). Section 20 states: "Any channel or outlet * * * shall be of sufficient size and capacity to produce a continuous flow of water of at least 200 cubic feet per minute for each 1,000 of the population of the district drained thereby, and the same shall be kept and maintained of such size and in such condition that the water thereof will be neither offensive or injurious to the health of the people in this State." Section 23 states: "Such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district."

Section 23 states further: "Such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, * * * and if any portion of any such channel shall be cut through a territory with a rocky stratum * * * such portion of said channel shall have double the flowing capacity above provided for."

You will see that the law insists on a sanitary condition, and that the flow of water shall be continuous (at all times), and that the minimum dilution shall be (not less than) 20,000 cubic feet of water per minute for each 100,000 people. This indicates that the general assembly did not regard the ratio of dilution as a positive determination, and this accords with the facts. You will note further that the channel was to be cut through the rock with a minimum capacity of 600,000 cubic feet per minute, and that the channel in the clay was to be subject to progressive enlargement from a capacity of 300,000 cubic feet per minute with the growth of population above 1,500,000.

As a matter of fact, the rocky stratum extended from Lockport to Summit, and the channel was actually constructed of the larger capacity, leaving only 7.76 miles between Summit and the waters of the Chicago River for future enlargement. When the channel was opened January 17, 1900, the population of the district exceeded 1,500,000 and was, in fact, 1,637,972 by the Federal census of 1900. By act of the general assembly in 1903 the district was enlarged, and the population by census, within the new boundaries, was 1,775,596.

I had everything to do in determining the prime essentials of the sanitary district law above quoted. I projected the work in its substantial outlines in a report which I drafted for the committee of the Citizens' Association in September, 1885. (Ossion Guthrie, Dr. Frank Reilly, and Lyman E. Cooley were a subcommittee to examine the situation and report.) As chief assistant to the Drainage and Water Supply Commission in 1886-87, I had charge, among other things, of the canal solution. I was consulting engineer to the State board of health in 1887–1889, and again in 1891 while its elaborate chemical investigation of the stream between Lake Michigan and St. Louis was under way. I was consulting engineer to the joint committee of the legislature (mayor of Chicago, ex-officio, chairman) that framed the sanitary district act, and as such determined the features of the law referred to. I later represented before the general assembly the several organizations of Chicago which were engaged in promoting legislation.

The state of our information in 1887 in regard to dilution and the capacity of channel required is discussed at some length in my testimony of April 7, 1887, before the joint committee of the general assembly. A few hundred copies of this were printed, but I do not know where an extra copy is to be had. I refer to this especially because it is the only published matter of that period after the preliminary report. I will also refer you to an elaborate paper which discusses the subject-matter, read on June 10, 1896, before the National Conference of State Boards of Health at Chicago. This was published by the secretary at Columbus, Ohio, and is hard to get. There were, of course, many fugitive and fragmentary discussions not considered worthy of preservation.

You will note in the preliminary report and in later testimony, that the Drainage and Water Supply Commission refers to a dilution of 24,000 cubic feet per minute as ample for a sanitary condition, and I believe that Mr. Horing, the chief of that commission, has stated that was his personal view of

the requirements. As a matter of fact, the capacity of the channel was fixed at that time at 600,000 feet as required to remove the flood water from some 420 square miles of territory (after the diversion of the upper Des Plaines River), and prevent the same from backing into the lake. The basis of population used in considering land disposal and other alternative solutions proposed was 2,500,000, and this figure was applied to the proposed channel capacity, giving the ratio of 24,000 cubic feet per minute for each 100,000 people as above stated. At that time only preliminary consideration had been given to the question of dilution, as the chief force of the investigation had been applied to other alternative solutions.

I think it is also in evidence before the joint committee of the general assembly in 1887, by Doctor Rauch, secretary of the State board of health, that 14,000 cubic feet per minute would be sufficient. Doctor Rauch had undertaken an investigation of the subject preliminary to the elaborate studies of 1888–89. After the adjournment of the legislature and the failure of the Hurd bill in 1887, little further attention was given to the matter until it was taken up by the special committee appointed to frame a law and report to the next general assembly.

This committee had several hearings, and developed much diversity of opinion. Personal opinions ranged from 14,000 feet per minute to 30,000 feet, and some wished to leave the matter entirely open. As no agreement could be reached, the whole subject was referred to the consulting engineer late in 1888, and after a painstaking investigation, he reported, and the results were embodied in the draft of the bill and subsequently became law.

The data available are referred to as follows:

"Special investigations of the filth-producing industries of Chicago, and an elaborate investigation of the Chicago River and branches in the autumn of 1886, and after the flood of 1887, also the Illinois and Michigan Canal; a careful investigation of the history and condition of sewage in the Des Plaines and Illinois rivers for the fifteen years prior to 1887, between Joliet and La Salle; the chemical investigations by the State board of health, over the route from Lake Michigan to the city of St. Louis, and of tributary streams, and a special investigation of the conditions produced by the distillers at Peora and Pekin."

The above data were probably more ample than had ever been brought before to the consideration of a similar problem. In addition, there were the following documents: Reports on the condition of the Seine at and below Paris; reports on the sewage-disposal works at Berlin, then being inaugurated; three reports by parliamentary commissions on river pollution in Great Britain; reports on pollution of streams by the State board of health of Massachusetts; reports by Doctor Chandler on the pollution of the Passaic River, New Jersey.

In addition, the consulting engineer had made special notes on the low-water condition of the Ohio River and of the Upper Mississippi River, and on several other streams, in comparison with population.

The general result arrived at was that 14,000 cubic feet per minute would be adequate for a normal city population such as usually obtained in New England and in Europe, but that this ratio should be increased about 50 per cent on account of the special industries characteristic of Chicago and the quality of her site—flat topography, with impermeable subsoil. At that time—and we still have great industries based on animal and other organic products—the wastes coming from the stock yards and rendering establishments alone were estimated as the sewage equivalent of a normal city of 700,000 people. Every effort had been made, and is still being made, to utilize these organic wastes, and great progress had been made in the previous twenty years, but nevertheless it was thought wise to provide sufficiently for all conditions rather than subject any industry to special burdens. These considerations raised the dilution ratio to 20,000 cubic feet per minute as a minimum, and it was so recommended.

At that time we had distilleries in Chicago which were serious offenders, but they have since closed down. I examined the distilleries at Peoria in 1891, when 40,000 head of cattle were fed on the slops, and I found that the fish were destroyed for 24 miles down the river in the low-water season. It was noted that the conditions were worse when the raw slops were run directly into the river, as the cattle were not then present to reduce the decomposition by several stages. In this industry I understand that these wastes are now evaporated and pressed into cake and sold for stock food.

In the rendering business there is a highly concentrated effluent from the tanks, which would resemble consumé soup if it were filtered and deodorized, and this has defied all chemical science for its salvation. Hopes were enter-

tained of converting it into commercial ammonia by destructive distillation, but this did not prove practicable on a commercial scale. I believe that sometime these valuable wastes will be commercially utilized, and when this is done a great burden will be taken off the Chicago Drainage Canal. It seemed to me that if it was not possible to make an economic use of these concentrated effluents, the profitable disposal of household sewage with the enormous volumes of water used in American cities was absolutely hopeless. At that time the sentiment of sanitarians was very strongly against what we proposed as a barbarism. The experience of nearly twenty years since has fully borne out the noneconomic character of sewage-disposal works, and the Chicago solution has come to be accepted as rational where the conditions permit.

I was not satisfied with our data in regard to the stock-yards district, and when chief engineer of the sanitary district in 1890 I undertook a special chemical investigation, continued over a period of time, of every outfall entering the South Fork. The work was completed, but I ceased to be chief engineer before the results were fully worked out. At the same time I made a continued series of chemical analyses of the Illinois and Michigan Canal, which was then being operated to a capacity of over 50,000 cubic feet per minute. These investigations cost some $6,000. I became satisfied that I had not overestimated the special source of filth. It was my intention to carry the inquiry over the entire city and do what had never been done before—ascertain the sewage of a great municipality as a whole. If I had had my way in the matter we would have had more positive data as to the sewage equivalent and the volume of Lake Michigan water required. Our boards of trustees have not since encouraged the resumption of any such work, and indeed it has been regarded as needless by those in authority after the sanitary-district law had been passed and the work actually entered upon.

No extended investigations were again undertaken until the biological and chemical examinations of 1899 and 1900 were made by the cooperation of the health department of the city of Chicago, the Chicago University, and the University of Illinois.

This investigation was instigated by Dr. Frank W. Reilly, then and now assistant health commissioner of Chicago, after consultation with the writer. Doctor Reilly was assistant secretary of the State board of health during the investigations of 1881–1885, and in 1886 collated the results of Prof. J. H. Long's chemical examinations of the contents of the Illinois and Michigan Canal and of the Illinois River and its tributaries as far south as Peoria. These examinations were projected by Dr. J. H. Rauch, secretary of the State board, and were directly supervised by Doctor Reilly. His study and collation of Professor Long's analyses demonstrated that all trace of Chicago sewage pollution disappeared in a flow of 48 miles from its source—that is, between Bridgeport at the entrance of the Illinois and Michigan Canal and the town of Channahon on the Des Plaines River, after this stream had received the discharge from the canal. This demonstration completely upset the time-honored dictum of previous water analyses "that no river on earth is long enough to purify itself after it has become contaminated with organic wastes." Six years later, in 1892, Pottenkofer fully corroborated Doctor Reilly's demonstration.

Doctor Reilly and myself were associated in all the early promotion of the sanitary project, and he is the only person that I know upon whom you can call for a history of the subject-matter of this letter.

The biological examinations were entirely confirmatory of the results of the investigations of 1888–89, but have the merit of less confusion in interpretation. The State board of health has since recompiled and extended the results of its stream examinations and published a report in 1903. The University of Illinois has been making for several years past a biological investigation of the waters of the Illinois River, but with no special reference to the matters under consideration. I do not refer to data of an ex parte character gathered in the Chicago-St. Louis suit recently decided by the United States Supreme Court.

None of this later material nor the added experience and reflection of nearly twenty years has changed my mind in regard to the ratio of dilution as given in 1888 and incorporated in the sanitary district law. I do not think I could make a better determination at this time. I feel bound to say, however, that we have not yet had the final demonstration of experience. We shall not positively know until the intercepting sewer system is completed and in operation, the South Fork in active circulation, and also the North Branch, so that the

canal receives the entire output of the city north of Eighty-seventh street in a comparatively fresh condition. I have been apprehensive that these contributions would be made before the Chicago River is sufficiently improved to furnish the necessary volume of water to promptly dilute the same. The analyses show a higher ratio per capita for chlorine and nitrogen, but this was anticipated. They also show a large proportion down the old canal, which, owing to the situation of its inlet, receives largely the output of the South Fork, but this was also anticipated. The evidence as to chlorine is to be taken with caution on account of the large use of salt in many of our industries, but the indications are that Chicago sewage may be even richer than I had presumed in comparison with the sewage of normal cities. I have no forebodings, however, other than as to the policy which may be pursued by the authorities of the sanitary district. Based on the advice of the consulting engineer the law is abundantly cautious in stating the ratio of dilution and the capacity of channel as minimums, and in insisting on a continuous flow, but unhappily there has been a disposition in many quarters to interpret these minimum requirements as maximums.

You will find in the testimony of 1887 and the paper before the National Conference of State Boards of Health in 1896, persistant reference to the necessity of maintaining the flow in the winter time. The investigations show clearly that the sewage travels farther down the stream in the winter season and is more dangerous to fish life when the oxygen can not be renewed owing to an ice cover. The necessity for dilution is then paramount. In the original studies of an economic channel, made under my direction, first by William A. Lydon in 1886–87, and later by Thomas T. Johnston in 1890–91, the carrying capacity of a channel covered by ice was fully considered. On the present channel the capacity will be reduced by nearly 40 per cent, or to something over 60 per cent of the capacity of an open channel.

In making the studies for the main channel we adopted the most conservative coefficients. The channel depth was made nominally 22 feet, with an allowance of over 2 feet for fall between the lake and the head of the channel at Robey street, but it was understood that any proper improvement of the Chicago River and by other inlets would give a depth of 24 feet or more. The channel itself was made of better character than originally anticipated, owing to the use of the channeling machine. The effect has been to give a channel of nearly 40 per cent greater capacity than the minimum stated in the law. It was my hope and intention to produce a channel 30 feet deep, with a capacity of 1,000,000 feet, but I was not able to reach farther than I have stated.

Under the original theory the channel is not sufficient even now to carry 600,000 feet of water per minute under an ice cover. It has been ingeniously answered that this objection could be removed by the use of ice boats, but I have a mental resistance to all solutions of sanitary problems that are not automatic in action, for sooner or later they go awry, to the prejudice of the public health.

It is fair to say, however, that thus far little ice has formed upon the main channel and that the flow has been little interfered with from this cause. This has been attributed to the large volumes of warm water from households and from manufacturing plants, and it is supposed also that active sewage decomposition may have something to do with it, and, further, that a surface film of oleaginous matter may afford some protection. Perhaps these explanations are after the facts, and therefore speculative. Whatever may be the cause, the effects should be relatively less when the channel shall be carrying the full volume. And, again, the grand law of average will give us more severe winters than we have been having since the channel was opened.

The estimates of the carrying capacity of the main channel are based as follows (report of expert commission; see proceedings of board of trustees of sanitary district, June 19, 1901, p. 7248):

"Within the past two weeks the results of special observations made since this commission was organized, and other relevant data, has enabled an approximate determination of coefficients by which to determine the capacity of the main channel under the conditions specified. To determine these matters finally, however, requires a special set of observations under better weather conditions and with the canal operated for this purpose."

The expert commission of 1901 estimated the capacity of the channel on a depth of 24.4 feet at Willow Springs, at 836,280 cubic feet per minute, in conjunction with a radical improvement of the Chicago River such as would furnish the entire supply of water without detriment to navigation. The same commis-

sion estimated the capacity on a depth of 24.2 feet at Willow Springs, at 827,040 cubic feet per minute in conjunction with a moderate improvement of the Chicago River north of Sixteenth street and an inlet direct to the lake adjacent to Sixteenth street on the south. In both cases the lake was assumed at Chicago datum, or low water of 1847. Both of these treatments were in harmony with the theory of the law and the original project.

The sanitary district has adopted, at least for the present, a channel through the Chicago River 200 feet wide, which the expert commission estimated would carry 390,000 feet of water per minute without detriment to navigation. I understand that it is expected to feed to the channel 600,000 feet through the Chicago River and the Thirty-ninth street conduit, and that one-fifth of this is to come by way of the conduit and the South Fork. I understand further that it is proposed to construct a channel from the Calumet region through the Sag, with a capacity of some 240,000 feet of water per minute. The total is 840,000 per minute, or the 14,000 feet per second which has been mentioned in the hearings at Washington and before your commission.

You will note in the testimony of 1887 that the considerations which originally fixed the channel at a capacity of 600,000 cubic feet per minute, was the flood volume from an area of 420 square miles. Assuming the channel to have a capacity of 840,000 cubic feet per minute, the flood equivalent would represent a territory of not over 700 square miles. To add more territory is sure to result at some time in the backing of the waters into the lake. Sewage pollution is to be regarded as most dangerous when the sewage is carried out in a fresh condition during floods and when the city is virtually taking a bath, and it was such eruptions of flood waters from the populated area which the drainage and water supply commission sought particularly to avoid.

I am therefore strenuously opposed to all propositions which propose to add unlimited territory to the present channel, and which propose in any manner to sacrifice part of its capacity in the carrying of floods from upland and rural territory. All the great filth-producing industries and the great population is now tributary, and will so remain, to the Chicago River, its branches, and the main channel; and I do not think that the provision which has been made for this territory is more ample than should have been provided for a reasonable future growth. The capacity on the present scale of minimum dilution, presuming it to be sufficient, is the equivalent of a population of 4,200,000. This may not actually be realized, but I feel sure that the progressive saving of wastes will eventually reduce the per capita output of sewage to more nearly the normal for other cities. We know that such utilization has already taken place in connection with the distilleries. We also have the police power, and can compel the care of specific sources of nuisance when necessity requires; but as already remarked, such a policy in connection with our great industries has not been considered wise.

I anticipate, therefore, that as conditions develop in the future, the channel may prove sufficient for five or six millions of people, provided the original plans can be carried out in their integrity. That means, however, that the capacity of the main channel shall be reserved substantially (and it has been planned and constructed on that idea) for the territory of the original district, and that only such provision shall be made for outlying territory as the actual necessities of its people require. If we study the relative growth of population and the character of the industrial development in such outlying territories, we shall be persuaded that such a policy will do no injustice and will conserve the sanitary purpose in the highest degree.

What is to be the future population of Chicago, no man can foresee. I think we may rest for the present on an assumption of five to six million people. In laying out the main channel its tangents were made parallel to and at a fixed distance from the Illinois and Michigan Canal where the same was possible. The idea under this location was that the old canal would maintain the reservation for future use, and that the time might come when another canal alongside would be desirable. My thought in this matter was not so much an ultimate thought on the sanitary question as it was that we might wish to carry more water to the Illinois River in the interest of deeper navigation. If any such proposition is considered beyond the provision which has already been made, the whole continent should join, and we may dismiss it from present consideration. I do believe, however, that the time will come when public opinion on this continent will be sufficiently broad to make the best use possible of the waters of the Great Lakes, in the interest of the deepest possible navigation from the Gulf of St. Lawrence to the Gulf of Mexico, and I do believe that the

project which Chicago has so happily inaugurated as the incident of a sanitary necessity, which will come to be looked upon as a monumental foresight.

I think I have covered the subject-matters of your inquiry. If you wish the documents which I have especially referred to, I will loan them to you, as I do not know where duplicates are to be had.

Yours, very respectfully,

LYMAN E. COOLEY.

General O. H. ERNST,
Chairman of American Section
International Waterways Commission, Washington, D. C.

APPENDIX C.

Summary of net receipts and expenditures, sanitary district of Chicago, from organization to December 31, 1905.

RECEIPTS.

Taxes collected for general purposes	$30,712,708.65	
Taxes collected for water-power development	2,014,730.57	
		$32,727,439.22
Bond account (bonds outstanding):		
First issue	700,000.00	
Second issue	1,200,000.00	
Third issue	1,350,000.00	
Fourth issue	1,800,000.00	
Fifth issue	400,000.00	
Sixth issue	440,000.00	
Seventh issue	200,000.00	
Eighth issue	190,000.00	
Ninth issue	700,000.00	
Tenth issue	750,000.00	
Eleventh issue	1,875,000.00	
Twelfth issue	1,600,000.00	
Thirteenth issue	1,275,000.00	
Fourteenth issue	1,350,000.00	
Fifteenth issue	1,350,000.00	
Sixteenth issue	2,000,000.00	
		17,180,000.00
Interest on bank balances		362,785.73
Tax levy, 1896 (warrants outstanding)		5,212.91
Dock and land improvement and rental account (rent of land)		40,123.78
American Crushed Stone Company		1,000.00
Western Stone Company		3,278.00
Total receipts		50,319,839.64

EXPENDITURES.

Right of way		$6,983,944.14
River diversion construction	$1,000,186.38	
Bridge construction, river diversion	142,486.20	
Main channel construction	18,547,408.95	
Bridge construction, main channel	1,978,536.38	
Controlling works, Lockport	331,253.65	
Bridge construction, controlling works	7,873.35	
Joliet project	1,309,063.46	
Bridge construction, Joliet project	271,351.16	
Chicago River, dredging, docking, etc	2,027,221.78	
Bridge construction, Chicago River	2,498,383.03	
Illinois and Michigan Canal improvement at Bridgeport	77,016.08	
Thirty-ninth street pumping station	211,604.85	
Improvement of Kampsville and La Grange dams	16,920.27	
Raising roadway of Brandon's bridge	5,882.68	
		28,425,188.22

Water-power development	$1,346,085.92	
Bridge construction, water-power development	112,362.44	
		$1,458,448.36
Capitalization and maintenance of bridges	403,354.60	
Maintenance of highway bridges	12,613.89	
Maintenance account	164,775.95	
		580,744.44
Interest on bonds	6,821,647.58	
Interest on tax warrants	468,453.69	
		7,290,101.27
Taxes on land:		
Cook County	3,248.19	
Dupage County	1,209.07	
Will County	27,310.28	
		31,767.54
Engineering department	2,064,007.21	
Engineering department, water-power development	97,778.20	
Clerical department	173,361.87	
Law department	1,031,154.12	
Treasury department	41,832.39	
Police department	400,160.69	
General account	867,944.19	
		4,685,238.67
City of Chicago		14,079.20
Land damages		76,331.84
Marine damages		9,647.32
Personal-injuries account		4,087.50
Bridgeport pumping works		90,388.80
Special commission, Chicago Drainage Canal		33,075.97
Telephone line		12,292.13
Telephone line repair account		104.00
Weir, McKechney & Co		22,118.14
E. D. Smith & Co		2,400.00
Total expenditures		49,719,957.54
Emergency funds in hands of department officials	$10,400.00	
Due from F. M. Blount, treasurer (deposit in National Bank of Illinois)	22,043.48	
Due from John J. Hanberg, county collector	45,727.38	
Due from collector, town of Niles	1,660.32	
Balance in hands of C. L. Hutchinson, treasurer, December 31, 1905	520,050.92	
		599,882.10
		50,319,839.64

APPENDIX D.

[Permit of July 3, 1896.]

4554.] IMPROVEMENT OF CHICAGO RIVER.

JULY 3, 1896.

SIR: I have the honor to acknowledge the receipt of your letter of 16th ultimo, requesting permission to make certain changes in the capacity of the channel of the Chicago River for drainage purposes at points indicated on the map accompanying the application, and in reply beg to say that upon investigation it is found that the permission requested can be granted upon the following conditions:

1. That while the general plan is approved, the sanitary district of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each by-pass, and each new dock or wharf proposed to be built, in order that the Secretary of War may act intelligently in each case.

2. That this authority shall not be interpreted as approval of the plans of the sanitary district of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submited for consideration.

3. That it will not cover obstructions to navigation by reason of this work while in progress or when completed.

4. That the United States shall not be put to expense by reason of this work.

5. That this authority will expire by limitation in two years from date unless extended.

Very respectfully,

JOSEPH B. DOE.
Acting Secretary of War.

B. A. ECKHART, ESQ.,
President the Sanitary District of Chicago, Rialto Building, Chicago, Ill.:

[Permit of May 8, 1899.]

Whereas by section 10 of an act of Congress approved March 3, 1899, entitled "An act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes," it is provided that it shall not be lawful to alter or modify the course, location, condition, or capacity of the channel of any navigable water of the United States unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same;

And whereas the sanitary district of Chicago, a municipal corporation organized under the laws of the State of Illinois, has constructed an artificial channel from Robey street, Chicago, to Lockport, and has heretofore been granted permission by the Secretary of War to make certain improvements in the Chicago River for the purpose of correcting and regulating the cross section of the river so as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of 1¼ miles an hour, it being intended to connect the said artificial channel with the west fork of the South Branch of Chicago River at Robey street in the said city of Chicago;

And whereas the said sanitary district of Chicago has now applied to the Secretary of War for permission to divert the waters of the said Chicago River and cause them to flow into the said artificial channel at Robey street, as aforesaid;

And whereas the said sanitary district of Chicago represents that such movable dams and sluice-gates as are necessary to at all times secure absolute and complete control of the volume and velocity of flow through the Chicago River have been constructed;

Now, therefore, the Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said sanitary district of Chicago to open the channel constructed and cause the waters of Chicago River to flow into the same, subject to the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the sanitary district of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it become apparent that the current created by such drainage works in the South and Main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

3. That the sanitary district of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River.

Witness my hand this 8th day of May, 1899.

[SEAL.]

R. A. ALGER,
Secretary of War.

JOHN M. WILSON,
Brigadier-General, Chief of Engineers, U. S. Army.

[Permit of April 9, 1901.]

Whereas, under date of May 8, 1899, the Secretary of War granted permission unto the sanitary district of Chicago to open the artificial channel from Robey street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, upon the following conditions, inter alia:

"2. That if, at any time, it become apparent that the current created by such drainage works in the South and Main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch;"

And whereas it is alleged by various commercial and navigation interests that the present discharge from the river into the drainage canal sometimes exceeds 300,000 cubic feet per minute, causing a velocity of nearly 3 miles per hour, which greatly endangers navigation in the present condition of the river;

Now therefore, this is to certify that the Secretary of War, upon the recommendation of the Chief of Engineers, hereby directs said sanitary district to regulate the discharge from the river into the drainage canal so that the maximum flow through the Chicago River and its South Branch shall not exceed 200,000 cubic feet per minute.

Witness my hand this 9th day of April, 1901.

[SEAL.]

ELIHU ROOT,
Secretary of War.

[Permit of July 23, 1901.]

THE SANITARY DISTRICT OF CHICAGO,
SECURITY BUILDING.
Chicago, July 15, 1901.

SIR: I have the honor to request, on behalf of the sanitary district of Chicago, that your order of April 9, 1901, restricting the flow of water through the Chicago River to 200,000 cubic feet of water per minute, may be so amended as to permit the controlling works at Lockport, the outlet of the main drainage channel, to be so regulated as to permit at that point a flow of 300,000 cubic feet of water per minute between the hours of 4 p. m. and 12 o'clock midnight.

The board of trustees of the sanitary district have rigidly observed the restrictions of your order of April 9, 1901, but the result has been that the water in the main drainage channel has become greatly polluted and very offensive both to sight and smell and is working such hardship upon the valley communities as to evoke frequent protests from various cities and municipalities along the Des Plaines and Illinois valleys.

By such a modification of your restricting order as is herein petitioned, it would be possible for the sanitary district to secure much better drainage of the city of Chicago and the purification of the waters of the Chicago River without any hardship or inconvenience whatever to the interests of navigation, as the opening of the controlling works to a flow of 300,000 cubic feet of water per minute would produce no appreciable affect upon the current of the Chicago River until three hours thereafter and would not produce the full effect until about eight hours after the opening of the gates. Therefore, by again diminishing the flow at midnight to the requirements of your order, or to 200,000 cubic feet of water per minute, the normal condition in the Chicago River would be restored before 6 a. m. on the following day and thus no hardship or inconvenience occasioned to the navigation interests of the Chicago River.

I have the honor to be, very respectfully, yours.

ALEX. J. JONES, *President.*

To the Hon. ELIHU ROOT,
Secretary of War, Washington, D. C.

[Second indorsement.]

OFFICE CHIEF OF ENGINEERS, U. S. ARMY,
July 22, 1901.

Respectfully returned to the Secretary of War.

By an instrument dated April 9, 1901, the Secretary of War directed the sanitary district of Chicago to regulate the discharge from the Chicago River into the drainage canal so that the maximum flow through the Chicago River and its South Branch shall not exceed 200,000 feet per minute.

The sanitary district now asks that this order be so amended as to permit an increase of the flow into the canal to 300,000 cubic feet per minute between 4 p. m. and 12 midnight, daily.

It is the opinion of Major Willard, expressed in the accompanying letter of the 16th instant, that the request should be granted subject to revocation by the Secretary of War in case the increase be found dangerous to navigation.

I concur in this opinion and recommend that the order of April 9, 1901, be modified accordingly.

G. L. GILLESPIE,
Brigadier-General, Chief of Engineers, U. S. Army.

[Third indorsement.]

WAR DEPARTMENT,
July 23, 1901.

Approved as recommended by the Chief of Engineers.

E. ROOT,
Secretary of War.

[Permit of December 5, 1901.]

Whereas under date of May 8, 1899, the Secretary of War granted permission unto the sanitary district of Chicago to open the artificial channel from Robey street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, upon the following condition, inter alia:

"2. That if at any time it becomes apparent that the current created by such drainage work in the South and Main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch."

And whereas the Secretary of War subsequently directed said sanitary district of Chicago to regulate the discharge of water into the Chicago Drainage Canal so that the maximum flow through the Chicago River shall not exceed 200,000 cubic feet per minute from midnight to 4 p. m., nor 300,000 cubic feet per minute from 4 p. m. to midnight.

And whereas said sanitary district of Chicago has applied to the Secretary of War for permission to increase the flow between midnight and 4 p. m. daily to 250,000 cubic feet per minute, and the Chief of Engineers has recommended that the increase applied for be granted, but that the rate of flow from 4 p. m. to midnight be reduced to 250,000 cubic feet per minute, so that the flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the twenty-four hours of the day:

Now, therefore, this is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto said sanitary district of Chicago permission to regulate said discharge so that the maximum flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the twenty-four hours of the day, upon the following conditions:

1. That this permission shall be in lieu of the present authorized rates of flow as stated above.

2. That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

3. That said sanitary district of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

Witness my hand this 5th day of December, 1901.

WM. CARY SANGER,
Assistant Secretary of War.

[Permit of January 17, 1903.]

Whereas, under date of December 5, 1901, by an instrument supplementary to the original permission granted by the Secretary of War May 8, 1899, to the sanitary district of Chicago to open the artificial channel from Robey street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, the Secretary of War, pursuant to authority reserved in said permission of May 8, 1899, gave permission to the sanitary district of Chicago to regulate said discharge so that the maximum flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the twenty-four hours of the day, upon the following condition, inter alia:

"That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require."

And whereas the said sanitary district of Chicago has applied for permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute during the closed season of navigation, in order to carry off the accumulations of sewage deposit which line the shores along said city:

Now, therefore, this is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto said sanitary district of Chicago permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute until the 31st day of March, 1903, after which date it shall be reduced to 250,000 cubic feet per minute, as now authorized, upon the following conditions:

1. That the permission herein given shall be subject to such modifications as in the opinion of the Secretary of War the public interests may from time to time require.

2. That said sanitary district of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

Witness my hand this 17th day of January, 1903.

[SEAL.]

WM. CARY SANGER,
Assistant Secretary of War.

APPENDIX E.

Resolved by the Senate, the House of Representatives concurring herein:

1. That it is the policy of the State of Illinois to procure the construction of a waterway of the greatest practicable depth and usefulness for navigation from Lake Michigan via Des Plaines and Illinois rivers to the Mississippi River, and to encourage the construction of feeders thereto of like proportions and usefulness.

2. That the United States is hereby requested to stop work upon the locks and dams at Lagrange and at Kampsville, and to apply all funds available and future appropriations to the improvement of the channel from Lasalle to the mouth, with a view to such a depth as will be of present utility, and in such manner as to develop progressively all the depth practicable by the aid of a large water supply from Lake Michigan at Chicago.

3. That the United States is requested to aid in the construction of a channel not less than 160 feet wide and 22 feet deep, with such a grade as to give a velocity of 3 miles per hour from Lake Michigan, at Chicago, to Lake Joliet, a pool of the Des Plaines River immediately below Joliet, and to project a channel of similar capacity and not less than 14 feet deep from Lake Joliet to Lasalle, all to be designed in such manner as to permit future development to a greater capacity.

Adopted by the Senate May 27, 1889.

Concurred in by the House of Representatives May 27, 1889.

Appendix F.

REPORT TO THE INTERNATIONAL WATERWAYS COMMISSION ON THE DISPOSAL OF SEWAGE OF CHICAGO AND VICINITY, BY RUDOLPH HERING AND GEORGE W. FULLER, DECEMBER 18, 1906.

New York City, *December 18, 1906.*

To the International Waterways Commission:

Sirs: In response to your recent request we beg to report herewith upon several propositions connected with the question of extending the method of disposing of the sewage of Chicago and vicinity by means of dilution with Lake Michigan water. Your instructions may be briefly summarized as follows:

1. Examination into the sanitary situation at Chicago so far as it is affected by sewage disposal.

2. Latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive.

3. Is the extension of the dilution method to the outlying territory the only way to preserve the lives and health of the people of Chicago?

4. For the Calumet area, are there not other methods of sewage disposal which may be applied at a cost not exceeding much, if at all, the cost of the method of dilution proposed, and which will be equally effective in preventing the pollution of the lake waters?

5. Description of the various systems of sewage disposal which are available for the Calumet area, with a statement of their relative efficiencies.

6. Statement of the approximate relative costs of the last mentioned so far as they can be given without the preparation of detailed plans.

You further state clearly in your letter of instructions that you do not desire an investigation into the effect of the present method upon the navigation interests of the Great Lakes, as that has already been officially considered by yourselves. Further, you state that you accept as a fixed fact the Chicago Drainage Canal as designed and built, with its attendant diversion of 10,000 cubic feet per second of lake water through the Chicago River and its branches.

In accordance with further instructions we have not given consideration to questions of a legal or legislative nature. We have viewed this problem solely as an engineering proposition without regard to inter-State questions and other features associated with the fact that a portion of the future metropolitan area of Chicago will obviously lie within the State of Indiana. It is further understood that under the existing circumstances we are to give you our opinion without entering into such details as would be required by additional surveys or other field work beyond a personal inspection of the areas.

SEWAGE DISPOSAL AT CHICAGO.

Drainage canal.—Nearly all of the sewage from the population of Chicago now connected with sewers is diluted with Lake Michigan water, which, since January 17, 1900, has been allowed to flow through the new drainage canal and thus reach the valley of the Illinois River. This method of disposal is the outcome of various investigations, particularly of a commission on the drainage and water supply of Chicago in 1886–87. It was formally adopted in 1889 by State legislation, creating the "Sanitary District of Chicago," specifically providing that the volume of lake water for purposes of dilution shall be 3¼ cubic feet per second for each 1,000 of population connected with the sewers, or 20,000 cubic feet per minute for each 100,000 population.

Early methods.—In early days part of the sewage of Chicago flowed directly into the lake and part into the Chicago River and its branches. From the latter a portion of the water and sewage, beginning over thirty-five years ago, has been pumped at Bridgeport into the Illinois and Michigan Canal, as is true to some extent to-day. It is understood that the old canal is to be discontinued by legislative action as soon as equivalent transportation and power facilities can be arranged for by means of the new canal.

Area of sanitary district.—In 1903 an act of legislature was passed extending the area of the sanitary district from 185 to 358.1 square miles, and including the "north shore addition" of 78.6 square miles, and the "Calumet addition" of 94.5 square miles. The area of the city of Chicago is 190.638 square miles, leaving 167.462 square miles as the area of the present sanitary district outside of the city limits.

There are several features to be noted in connection with the method of sewage disposal of the city of Chicago as adopted in 1889. It had been found to be the cheapest method then available for disposing of the sewage so that it would not pollute the public water supply, which was then and is now derived from Lake Michigan through a series of intake cribs located at various distances from shore.

Intercepting sewers.—To prevent such pollution it was of course necessary first to divert all of the sewage into the Chicago River. A pure-water commission was appointed by the mayor in 1897 to consider the question of intercepting sewers for that purpose. It recommended among others a large intercepting sewer to collect the sewage from the area along the lake front between Seventy-third and Thirty-first streets, and about a year ago a 20-foot conduit was completed on Thirty-ninth street, through which the diluted sewage from this area now passes to the south fork of the south branch of the Chicago River. At present there is a gravity flow of lake water ordinarily of about 40,000 cubic feet per minute. Pumps are now in process of erection by which ultimately there will be pumped through this conduit about 120,000 cubic feet of lake water per minute, or 2,000 cubic feet per second.

On Twenty-second street there was formerly a main sewer draining the area bordering on the lake front between Thirty-first and Sixteenth streets, and discharging into the lake. In 1898 the flow in this sewer was reversed so that its contents now discharge into the river.

On Twelfth street in 1898 the flow in the main sewer was also reversed.

In the heart of the city, or business section, the sewers have always discharged into the river and not into the lake. The same is true of a considerable area lying north of the Chicago River and along the lake shore. To facilitate this discharge a conduit was put in service in 1880 at Fullerton avenue, through which there has been pumped about 12,000 cubic feet of lake water per minute into the North Branch of the Chicago River.

At the present time there is no sewage entering the lake between Surf street (just north of Lincoln Park) on the north side and Seventy-third street on the south side of Chicago.

Plans are under way for the construction of the necessary works to collect the sewage along the lake front between Seventy-third and Eighty-seventh streets and to pump it into sewers west of Halsted street, which lead to the Chicago River. There is very little or no sewage from this area now reaching the lake, as the district is yet practically unsewered.

On the north side there is an area between Surf street and the northern city limits and between the lake shore and the ridge between the lake and the river, which now discharges sewage into the lake, but which will be diverted next summer. This sewage is to be collected by interceptors conducting it to Lawrence avenue, where will be located a pumping station and a conduit for pumping the sewage and about 35,000 cubic feet of lake water per minute into the North Branch of the Chicago River.

Farther north, at Wilmette, a conduit is proposed to be built with a pumping station near the Northern Railroad bridge in Evanston, where about 60,000 cubic feet of lake water per minute will be diverted into the North Branch of the Chicago River.

Summary of flow to canal.—The projected flow of the lake water to the canal through the Chicago River and its branches to the drainage canal may therefore be divided and summarized as follows:

	Cubic feet, per minute.	Cubic feet per second.
Main stream, Chicago River	373,000	6,217
Thirty-ninth street conduit	120,000	2,000
Fullerton avenue conduit	12,000	200
Lawrence avenue conduit	35,000	583
Wilmette conduit	60,000	1,000
Total	600,000	10,000

The volume for the main stream of the Chicago River as above stated is obtained by deducting the remaining quantities from the total.

REQUIREMENTS FOR THE REVERSAL OF FLOW IN THE CHICAGO RIVER.

The satisfactory disposal of the sewage of Chicago by means of the new drainage canal requires that, at and after heavy rainfalls, the storm water and sewage from the watershed of the Chicago River shall not flow into Lake Michigan, and therefore it is necessary to secure a practical reversal of the original flow in the Chicago River.

The drainage area of the Chicago River is about 270 square miles. Flood flows in the river have reached a maximum of about 10,000 cubic feet per second, or 600,000 cubic feet per minute, and this fact was also an important element in fixing the minimum size of the present drainage canal.

As to the efficiency of arrangements for the reversal of flow, our inquiries lead us to believe that this has been accomplished in a satisfactory way. Up to the present time, and owing to the insufficient waterway of some parts of the Chicago River, the volume of Lake Michigan water going through the river has not approached the volume above stated. But there have been times when a continuous flow of the Chicago River has been toward Lake Michigan for perhaps two or three hours. This time is necessary to properly regulate the water level at the controlling works near Lockport.

POPULATION OF CHICAGO NOW SEWERING INTO THE DRAINAGE CANAL.

We find that the present population of Chicago is, in round numbers, 2,000,000 people, of which between 100,000 and 200,000 reside south of Eighty-seventh street, tributary to the Calumet district, but within the city limits. Of the remaining population about 300,000 reside in the southern lake front district. This area is tributary to the Thirty-ninth street pumping station, which, since about January 1, 1906, has brought about the diversion of the sewage from the lake into the South Fork of the south branch of the Chicago River.

There is still an area in the northwestern part of the city north of Lincoln Park, spoken of as the northern lake front district, which drains directly into the lake. Its population may be very roughly estimated at 70,000.

There is a considerable area south of Seventy-third street and west of Halsted street, and also a portion of the northwestern part of the city, which are of a semi-suburban character. Some portions have been provided with sewers and receive the overflow from cesspools.

So far as we are able to ascertain from local officials and without making a personal canvass as to details, it appears that there are now, in round numbers, about 1,500,000 people sewering into the drainage canal. In addition to the sewage there enters it a considerable quantity of trade wastes, notably about 2,000,000 gallons from the stock-yard district, and from quite a number of other industrial establishments, such as tanneries, wool-pulling establishments, etc., as stated by the sanitary inspector in the last report of the health department.

It is our understanding that the present sewage disposal project for Chicago is not intended to provide for the disposal of trade wastes now discharged into the sewers. While comparatively little has been done as yet to remove them from the sewers, we have been informed that it is proposed to take up this matter actively.

INFLUENCE OF SEWAGE ON CHICAGO WATER SUPPLY.

The city of Chicago receives its water supply from Lake Michigan through a series of tunnels of various lengths, ranging from about 1 to 5 miles from shore. Most of them extend from the shore about 2 miles. The total pumping capacity for this supply is stated to be 529,000,000 gallons in twenty-four hours. In 1905 the average daily pumpage was recorded as 399,000,000 gallons.

Since the removal of the sewage through the drainage canal was systematically begun in January, 1900, the appearance of the water of the Chicago River has shown marked improvement.

The effect of the drainage canal upon the hygienic quality of the public water supply may be studied in connection with the typhoid fever death rates at Chicago, which are recorded in the next table, together with corresponding death rates for a number of other American cities. It is not to be assumed that typhoid fever is entirely due to the pollution of the public water supply at Chicago or elsewhere, as it is well known that there are other means of transmitting this disease. But its relation to the public water supply is so intimate that it gives, perhaps, the best general idea of the sanitary quality of the water, and therefore it frequently has been used as a rough means of such measurement.

There are other factors beside the drainage canal to be considered carefully in connection with the typhoid fever statistics at Chicago, and some of which should be mentioned here. Prior to 1900 there was a substantial improvement in the public water supply, partly due to the extension of some of the intake cribs and tunnels farther into the lake and partly to the reversal of the flow of a number of the sewers from the lake into the river, such as those at Twelfth and Twenty-second streets, in 1898. These are important factors in explaining the absence in the late nineties of such excessive typhoid death rates as were noted at the beginning of that decade.

Since the opening of the drainage canal typhoid fever at Chicago has been rather unusually prevalent at times. This was especially true in 1902–3, when, it is understood, portions of the supply became contaminated after leaving the intake crib. These accidental pollutions have since been corrected.

The report of the city chemist of Chicago, as given in the last annual report of the department of health, shows that on an average in 1905 the city water supply was considered by him to be safe about 85 per cent of the time.

While there has been a marked improvement in recent years in the quality of the Chicago water supply, due to the progressive elimination of sewage from the lake, there is still room for more improvement. These improvements refer to the pollution along the lake front north of Lincoln Park, which is being corrected, and to the "Calumet area" south of Eighty-seventh street, which is now under consideration.

Comparison of the annual number of recorded deaths from typhoid fever per 100,000 population at Chicago and other American cities, 1890–1905.

Year.	Chicago.	Milwaukee.	Detroit.	Cleveland.	Buffalo.	Toronto.	Boston.	New York.	Philadelphia.	Baltimore.	Washington
1890.....	83	33	18	69	44	80	43	21	64	57	89
1891.....	160	33	13	50	56	90	33	22	64	34	86
1892.....	103	31	64	59	38	40	25	14	40	42	72
1893.....	42	37	29	52	37	40	26	20	40	47	72
1894.....	31	26	27	29	62	20	23	17	32	49	72
1895.....	32	25	24	35	28	30	32	17	40	28	69
1896.....	53	18	23	43	22	24	32	16	34	37	51
1897.....	29	11	15	23	19	18	33	16	33	37	42
1898.....	38	17	18	34	29	16	34	20	51	38	64
1899.....	26	17	13	32	26	19	30	16	75	30	82
1900.....	20	21	18	54	27	19	25	21	35	37	77
1901.....	29	21	20	36	27	16	25	20	33	27	67
1902.....	44	16	17	33	33	13	35	21	44	42	79
1903.....	31	17	17	114	35	15	20	18	70	36	48
1904.....	19	13	16	48	91	22	18	17	.....	36	43
1905.....	16	20	12	15	23	.....	20	16	48	36	45

LATEST CONCLUSIONS AS TO THE REQUIRED DEGREE OF DILUTION FOR THE DISPOSAL OF SEWAGE WITHOUT NUISANCE.

The disposal of sewage by dilution depends on the amount of oxygen in the diluting water being sufficient to prevent putrefaction of the organic matter in the sewage as the latter undergoes bacterial decomposition. If the oxygen is deficient bacterial decomposition produced what is called "putrefaction," with its various attendant bad odors, such as noted for years in Chicago at "Bubbly Creek." If there is a sufficient amount of oxygen dissolved in the water to combine with this organic matter, decomposition goes on without any foul odors and the organic matter is reduced to inert matter in an inoffensive way.

This question is one of balancing the amount of oxygen in a given volume of water with the amount of decomposing organic matter in the sewage, which naturally must vary greatly.

There are many observations of more or less accuracy available to give figures for this relation. The Massachusetts State board of health made a special inquiry into this subject for all local rivers in 1902, with conclusions, stated on page 452 of their annual report for that year, as follows:

"The results of the investigations show that where the quantity of water available for the dilution of the sewage in a stream exceeds about 6 cubic feet per second per 1,000 persons discharging sewage, objectionable conditions are

unlikely to result from the gross pollution of all the water of a stream in dry weather. Under favorable circumstances, such as in cases where the sewage is discharged at many outlets into a large body of water, objectionable conditions may not result where the dilution is somewhat less than 6 cubic feet per second per 1,000 persons; but objectionable conditions have resulted in all of the cases thus far examined where the flow has been less than 3.5 cubic feet per second per 1,000 persons discharging sewage into the stream."

These conclusions apply for the most part to comparatively small streams into which much manufacturing waste is discharged and upon which mill ponds are situated.

There are times when the flow of water in the drainage canal appears to have been insufficient to eliminate objectionable odors entirely. How far this may be explained by confusion on the part of the observers of the putrefactive odors emanating from the Illinois and Michigan Canal with those of the new canal, and how far it may be due to temporary reductions in the rate of flow in the new canal and river to facilitate construction work, and also to the effect of rainfalls and to old deposits in the South Fork, we are unable to say.

The new canal appears to serve at present about one-half the population for which it was designed, and through it flows a volume of lake water which is variable, but which averages not far from one-half of the ultimate quantity.

It is our judgment that for large canals with the trade wastes eliminated a dilution of $3\frac{1}{3}$ cubic feet per second for each 1,000 population connected with the sewers also receiving storm water is as low a figure as it is now possible to state. Local conditions, especially temperature, which affects bacterial activities and the coefficient of absorption of oxygen by water, and still other matters, bear upon this question, the detailed discussion of which is not now necessary. We feel certain that a dilution of $2\frac{1}{2}$ cubic feet per second would cause offense at times, and probably also a dilution of 3 cubic feet per second.

FUTURE POPULATION ON AN AREA TRIBUTARY TO THE CHICAGO RIVER AND DRAINAGE CANAL WITH REFERENCE TO SEWAGE DISPOSAL.

On the basis of the diversion of 10,000 cubic feet per second of Lake Michigan water, on the present assumption of $3\frac{1}{3}$ feet per second as being the volume to be provided for each 1,000 population connected with the sewers, and on the assumption of eliminating objectionable trade wastes, the present method of disposal may serve until the population on the drainage area of the Chicago River reaches 3,000,000 people.

On the further assumption that through the Chicago River and various conduits connected with its branches there will be a flow equal to 14,000 cubic feet per second, which is the capacity of the rock section of the drainage canal, the maximum population which might be taken care of in this way is about 4,200,000 people.

With a large portion of the 270 square miles draining into the Chicago River, but not yet built up, even on a suburban basis, it is evident that in future years there will be a much greater population than now exists.

We have considered the rate of growth of Chicago from various viewpoints, notably the density of its population, and have compared its growth with that of other metropolitan districts. There is, of course, no way of predicting accurately how rapid will be the growth of Chicago in future years; but it is a reasonable assumption that before many years it will become a city of some five or six millions of population. It seems reasonable to infer that the population residing upon the area tributary to the Chicago River and its branches will ultimately exceed both the 3,000,000 and 4,200,000 estimates above mentioned. In other words, the present dilution method will certainly not alone for all time take care of the crude sewage of this area.

There are several available methods for the purification of sewage, depending upon the degree of purification desired, as will be noted beyond in connection with the Calumet area.

It is not probable that the sewage of the old part of Chicago will ever be purified by artificial means, as it would be proportionately much more difficult and expensive to deliver the sewage to suitable sites for purification than to continue the present dilution method. It is different with the outlying districts tributary to the Chicago River. In the future, when these districts become built up so that the population exceeds the limits above stated, the installation of sewage purification works will necessarily follow.

PROPOSED CALUMET CANAL.

The more essential features of this proposed canal, as obtained from local officials, may be summarized as follows:

Location.—The canal would extend from a point on the Little Calumet River near Blue Island, through the Sag Valley, and enter the drainage canal near Sag Station.

Territory tributary.—The total drainage area of the Calumet River is 825 square miles, of which 473 are in Indiana. Within the limits of the sanitary district of Chicago and south of Eighty-seventh street, the area is 94.5 square miles, with a population of about 100,000 in 1900. It is stated that the population has nearly doubled within the past six years, and it is expected to reach a million people or more within a fairly short period, as the conditions for a manufacturing district are very favorable.

Size.—The size of this canal, as proposed, is such as to give a flow of 4,000 cubic feet per second.

Reversal of flow.—The natural flow of the Calumet River exceeds 12,500 cubic feet per second. It is proposed, if suitable legislation can be secured, to construct a dam below Thorn Creek, at the southern boundary of the sanitary district, and divert into Lake Michigan, through a channel to be built about 17½ miles east of the State line, the flow of this stream, with a drainage area of about 587 square miles. The size of the proposed Calumet Canal is too small to secure at all times a reversal of flow of the remaining portion of the area, which is about 240 square miles. It is proposed to put a controlling lock on the canal east of Blue Island to prevent flood waters from this lower area entering the canal, at which times sewage entering the river on the lake side of the lock would go into the lake.

The proposed canal is insufficient to carry in the future all the storm flows of the Sag Valley itself. These would, at least, in part, require diversion through present or other channels.

Cost.—The estimated cost of this proposed canal is $12,000,000.

Population to be served.—On the assumption already stated, this canal, by dilution, would dispose of the sewage of about 1,200,000 people, not including objectionable trade wastes. This makes the cost of sewage disposal $10 per capita for the entire future population, or about $60 for the present population. The sewage would for the most part reach the canal by gravity through the Calumet River, so that the cost of maintenance would be comparatively small.

In passing, we may say that the Calumet area, both in Illinois and Indiana, is certain to develop rapidly, and its population will eventually far exceed the above figure.

RELATION OF SEWAGE DISPOSAL FOR THE CALUMET AREA TO THE WATER SUPPLY OF CHICAGO.

For the reasons above stated in connection with the reversal of flow, the sanitary effect upon Lake Michigan water at the Hyde Park intake and vicinity of this proposed Calumet Canal would not be nearly as effective as that of the main canal for the Chicago River territory and neighboring intakes. This fact is important in connection with the degree of sewage purification required by artificial purification works to give a sanitary effect equal to that of the proposed canal.

There seems to be no doubt that at times the sewage entering the Calumet River under present conditions from this district pollutes the lake water from the Hyde Park intake crib. It may pollute the water at other intakes, but our evidence is not conclusive. In the future, when the Calumet area is built up, it is possible that intake cribs may be built nearer to the mouth of the Calumet River than is the Hyde Park intake.

In view of the fact that the proposed Calumet Canal can not keep all sewage out of Lake Michigan at times of heavy rainfall, it is important to note that the water supply of this section of Chicago will eventually have to be purified by modern filtration works. This can be done at moderate cost, and it will be the cheapest and best solution of this problem to filter the water supply of this district and to purify the sewage to such a degree that the effluent will be fairly clear and nonputrescible, that is, free from disagreeable odors. With additional expense the sewage effluent (of the quality just stated) can be given a supplementary purification, making it practically free of bacteria by treating it with a germicide or by filtering it according to water purification practice.

Under existing conditions we are firmly of the opinion that all the purification required of the sewage of the Calumet district is to make it fairly clear and nonputrescible.

AVAILABLE METHODS OF SEWAGE DISPOSAL OTHER THAN THAT OF THE DILUTION METHOD PROPOSED FOR THE CALUMET AREA.

The degree of purification of sewage by various forms of treatment differs naturally under different local conditions, but from general experience approximate results may be compared, substantially as follows:

Method.	Percentage purification.		
	Suspended matter.	Organic matter.	Bacteria.
Fine screens (30-mesh or finer)	15	10	15
Sedimentation	65	30	65
Septic treatment	65	30	65
Chemical precipitation	85	50	85
Contact filters[a]	85–90	65–70	80–85
Sprinkling filters[a]	85–90	65–70	90–95
Intermittent sand filters[a]	95–99	90–98	98–99

[a] The figures for the last three forms of treatment are on the assumption that the sewage is given some form of preparatory treatment before it is applied to the filters, and that with the sprinkling filters the effluent is allowed to settle.

It is to be stated that none of the first four treatments above tabulated will by itself give a nonputrescible effluent. Therefore they can be used here only in connection with some form of filtration.

For large works filters can be more economically operated if the sewage is first clarified in part, as stated in connection with the above summary. The most appropriate method for this preparatory or preliminary treatment is considered by most sanitary engineers in this country and abroad to consist of septic tanks, which is the expression applied to sedimentation basins in which the deposited sludge is allowed to accumulate to undergo bacterial action.

There are several forms of filters, the most widely known of which, in this country, is the intermittent sand filter, sometimes mentioned as the so-called "land treatment" for sewage disposal. This method was considered in 1886–87 for the entire Chicago area and reported upon unfavorably on account of its being more expensive than the adopted method of dilution.

Local experiences.—We find that a feeling appears to prevail among some persons at Chicago against land treatment of sewage, due perhaps to the unsuccessful operation of the sewage farm at Pullman, which is situated within this Calumet area.

We are familiar with the facts and experiences at Pullman, and are clearly of the opinion that they are not necessarily a criterion for the Calumet area. This opinion is based partly upon the small size of particles of the soil at the Pullman farm, and partly upon the fact that the farm was devoted principally to agricultural rather than sewage purification purposes.

Sand areas.—We have examined the tracts of lake sand which are found in Indiana and to a limited extent in the township of Thornton, Ill. The latter areas are too limited in extent and too shallow to be considered for present purposes. The only areas of suitable porous sand for land treatment of the Calumet sewage are in Indiana.

We have collected five samples of this sand for mechanical analysis, and have obtained the results as to size of sand grains. Representative results average substantially as follows:

	Millimeters.
Effective size	0.15
Uniformity coefficient	1.40

If we disregard the State boundary line, a large tract of sand of a suitable character is available for the disposal of the sewage of this district. The best area lies between the Little Calumet and the Grand Calumet rivers, and extends east of Hammond for many miles.

Within the past six or eight years great strides have been taken in the field of sewage purification in connection with works of wholly artificial construction. We refer particularly to filters of coarse, firm material, such as broken stone,

slag, or clinker, and usually spoken of as "coarse-grained filters," as distinguished from fine-grained sand filters.

Coarse-grained filters are of two types, spoken of as "contact filters" and "sprinkling filters," according to the method by which the sewage is applied to them. These filters produce an effluent which will not putrify when they are operated at a rate far greater than that which is possible for sand filters.

We shall describe briefly each of these types of sewage-purification methods and state their approximate cost of construction on suitable sites for the Calumet area, based upon unit prices in accordance with experience elsewhere.

An outline is first required, however, of the intercepting sewers, pumping stations, and rising mains necessary to collect and deliver the sewage to the filter sites, of which there are several available.

Regardless of the particular kind of filter found most suitable for the Calumet area, there are a number of features common to all methods, and which may be stated as follows:

Separate sewers.—With the adoption of sewage filters for this district we are clearly of the opinion that it would be advisable hereafter to build a separate system of sewers for domestic sewage only. Some, if not all, of the existing main sewers could be used for the removal of storm and surface water only, and new sewers parallel them for sewage removal; or, some of the existing sewers could be utilized for sewage removal, requiring new structures for storm-water removal. Trade wastes should be excluded from all sewers. We have obviously not included in the cost of purifying the sewage any expense for the main sewers or laterals to collect it and deliver it to the interceptors.

Volume of sewage.—We have assumed that the sewage of this district will approximate 130 gallons per capita daily on an average. With a population of 1,200,000 the total volume of sewage would therefore be about 156,000,000 gallons daily. We have also allowed for ground-water seepage up to 1,000 gallons per square mile per day.

Interceptors.—For purposes of making approximate but liberal estimates of cost of purifying the sewage of this district, we have prepared sketches showing the intercepting sewers which will be required in order to collect the sewage of the district at four or more centrally located pumping stations. We have assumed that these intercepting sewers will be built of concrete, and when flowing full have a capacity of 250 gallons per twenty-four hours for each person resident upon the area tributary to the interceptor. When full, these interceptors have been assumed to have a velocity of 2.5 feet per second. We have also assumed, after excluding that portion of the Calumet district reached by extreme high water in the lake, that on an average the population contributing to the four or more pumping stations would be about 20 to 25 persons per acre. On this basis the length and size of the necessary intercepting sewers have been obtained.

Pumping stations.—For convenience we have located four main pumping stations near Riverdale, Harvey, South Hammond, and South Chicago. There will be required, when the district is built up to the extent herein considered, a total pumping capacity of about 340,000,000 gallons daily, including necessary reserve capacity at each station.

Septic tanks.—Regardless of the type of filter adopted, the sewage would be screened at the pumping stations, and then flow through septic tanks having a capacity of eight hours' flow on an average. These tanks would be about 12 to 15 feet deep, built of concrete, and arranged in compartments, so as to facilitate septic action on the deposited sludge, but without such action taking place in the flowing sewage itself. Owing to the severe winter climate in this vicinity, it is our opinion that it would be wise to cover these tanks.

Of the solid matters in suspension in the sewage about 65 per cent would deposit in the septic tanks, and of these deposited solid matters about one-half would be liquified and gasified by bacterial decomposition.

The sludge, which would be removed at intervals of once a year or so from the tanks, is estimated to contain about 85 per cent water and to amount to about 2 cubic yards per 1,000,000 gallons. Bacterial action converts this sludge to a practically inert mass which can be pumped in thin layers on to adjoining land and allowed to dry.

This is the form of preliminary treatment in use in some 40 places in this country, including Plainfield, N. J., Saratoga, N. Y., Mansfield, Ohio, Champaign, Ill., etc. It is the preliminary step in the works under construction at Columbus, Ohio, after elaborate tests of different methods were made for a

period of nearly one year. It has also been adopted recently at Baltimore, Md., Reading, Pa., and Waterbury, Conn., and has been recently proposed for Paterson, N. J., in a somewhat modified form.

This form of preliminary treatment has been and is now extensively used in Europe with satisfactory results where the tanks are built and operated to meet local conditions as to volume and strength of sewage.

The odors from large open septic tanks are seldom noticeable a few hundred feet away. Under good management a septic effluent can be applied to sprinkling filters so that no objectionable odors should be carried one-quarter of a mile.

The cost of building and operating septic tanks would be substantially the same for all filter projects, and is considered under each as a common factor.

INTERMITTENT SAND FILTERS.

This well-known method consists of applying the partially clarified sewage coming from the septic tanks to areas of porous sand, below the surface of which at depths of from 3 to 5 feet are underdrains of open-jointed pipe to convey the purified sewage to the nearest water course. The sewage is applied only at intervals of once a day or so to a depth of perhaps 6 inches. Between applications the sand layer is allowed to drain so that its pores may fill with air, This aeration of the pores of the sand allows bacterial processes to convert the organic matter to a large extent to harmless mineral matter. The effluent is practically free of noticeable suspended matter and objectionable organisms and can be discharged directly into the nearest water course.

This method is now in successful use in 40 to 50 places in this country where porous sand areas are available. It serves a total population of about 350,000 people. Well-known plants are to be found at Framingham, Brocton, Clinton, and Worcester, Mass.; Pawtucket and Woonsocket, R. I.; Meriden and New Britain, Conn.; Saratoga, N. Y., etc.

From time to time it is necessary to rake, harrow, or plow the surface of intermittent sand filters and to remove the scum which slowly accumulates there. At intervals it is necessary to scrape off several inches of the upper portion of the sand layer when it is found that they are so clogged that harrowing and plowing no longer prevents the surface from remaining covered with sewage.

With crude sewage it appears from Massachusetts evidence, especially from the tests conducted for a period of nineteen years at the Lawrence Experiment Station, that it would be necessary to provide 1 acre of intermittent sand filters for each 500 persons connected with the sewers. When the sewage is given a preliminary treatment in septic tanks and when the filters are operated under intelligent supervision the area may be reduced so as to provide 1 acre per 1,000 persons.

The most suitable natural site for sand filters for the Calumet area is to be found in the State of Indiana, between the Little Calumet and the Grand Calumet rivers, east of the city of Hammond.

It is possible to build artificial sand filters within the Calumet district, but the cost would be much greater than for any of the projects considered in this report.

Based upon our knowledge of these filters elsewhere, and without considering inter-State complications, we estimate that the cost of installing and operating such a plant, with its various appurtenances, East of Hammond, and of a capacity of about 180,000,000 gallons daily to serve a population of 1,200,000 people, would be as follows:

Estimated cost of constructing sand filter plant and appurtenances.

Intercepting sewers, pumping stations, and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$5,070,000
Septic tanks, 60,000,000 gallons capacity, covered, including sludge-disposal facilities	950,000
Intermittent sand filters, 1,200 acres, with distributors, drains, office, laboratory, etc	3,600,000
	9,620,000
Contingencies and supervision, 15 per cent	1,443,000
Total	11,063,000

Annual cost of operation.

Pumping, fuel, labor, and repairs	$300,000
Supervision, analytical and clerical assistants, etc	25,000
Care of septic tanks, including sludge disposal	36,000
Care of sand filters	480,000
Supplies and miscellanies	25,000
	866,000

Capitalizing the operating expenses at 5 per cent per annum there is obtained $17,320,000, which, when added to the estimated construction cost, makes a total sum of $28,383,000 for the sand-filter project.

CONTACT FILTERS.

These filters consist of beds of broken stone, slag, or cinders, placed in uncovered basins to a depth of from 3 to 5 feet. The size of material ranges from about one-fourth to 1 inch.

The filters are ordinarily operated upon the fill and draw plan, that is, the gate on the outlet pipe is closed until the voids of the bed are filled wih sewage from the septic tanks. After filling, the filters are allowed to stand full for an hour or so, then the sewage is allowed slowly to drain out, and this cycle of operation is repeated once or twice a day.

When the filtering material is drained the voids fill with air, and it is during these perlods of draining that bacterial processes accomplish the purification of the organic matter, which to a large degree is lodged upon the surfaces of the filtering material as the sewage is slowly withdrawn from the bed. The rates of filling and drawing the beds may be satisfactorily controlled by a number of automatic devices on the market and which are in successful use in a number of places.

Contact filters are an English adaptation of studies made some fifteen years ago upon the gravel filters by the Massachusetts State board of health at the Lawrence Experiment Station. These studies were begun about thirteen years ago at London. As an outcome of these and numerous other investigations, contact filters have been adopted and are in successful use for dozens of English cities, the largest of which is Manchester, with a population of about 600,000.

In this country contact filters have been installed for a dozen or more small cities and numerous institutions. Perhaps the best known plants are at Plainfield, N. J., Mansfield, Ohio, and Charlotte, N. C. They are especially applicable to projects where only a small amount of head is available and where pumping would be required for sprinkling filters.

For large projects, and where pumping is not a factor, recent experiences with sprinkling filters show that as a rule they are more economical. Notwithstanding this, contact filters have served and will serve a useful purpose in the field of sewage disposal in this country. There convenience of operation makes them especially suitable for small installations.

Many contact-filter plants have their beds arranged in terraces so that the sewage may be passed successively through two or three filters. There are a number of advantages of this arrangement, but it is not applicable to the Calumet district, owing to the level area of the available sites. One of the advantages of the double and triple contact filters is that they may be operated from below during winter weather and thus guard against reductions in the rate of filtration due to freezing.

The most available and suitable local sites are: A tract west of Harvey and between the Illinois Central and Rock Island railroads; a tract west of Hammond and the local branch of the Fort Wayne Railroad; and a tract between lakes Calumet and Wolf.

As to the rate of filtration, we have assumed that contact filters should be 5 feet in depth and that they would satisfactorily purify the effluent from septic tanks at the rate of 600,000 gallons per acre per twenty-four hours. This means that 1 acre of contact filters should be provided for every 4,000 persons connected with the sewers.

The effluent from contact filters operated under these conditions would be ordinarily free from objectionable amounts of suspended matter, and the

amount of organic matter would be so reduced that it would not putrefy upon standing. On an average about 15 to 20 per cent of the bacteria in the crude sewage would be present in the effluent. It would not be improper to discharge such an effluent as it came from the filters directly into the nearest water course.

The amount of attendance required for contact filters is not great, and is covered mainly by the necessary gatemen, analysts, and foremen. At intervals of all the material would have to be removed from the filters, washed, and replaced.

The approximate cost of building and operating a contract-filter plant with all needed appurtenances of a capacity of about 180,000,000 gallons daily to serve 1,200,000 people may be estimated as follows:

Estimated cost of constructing contact-filter plant and appurtenances.

Intercepting sewers, pumping stations, and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$3,300,000
Septic tanks, 60,000,000 gallons' capacity, covered, including sludge, disposal facilities	950,000
Contact filters, 300 acres, with all piping, appurtenances, office, laboratory, etc	6,000,000
	10,250,000
Contingencies and supervision, 15 per cent	1,537,500
Total	11,787,500

Annual cost of operations.

Pumping, fuel, labor, and repairs	$200,000
Supervision, analytical, and clerical assistants	30,000
Care of septic tanks, including sludge disposal	36,000
Care of contact filters	260,000
Supplies and miscellanies	25,000
Total	551,000

Capitalizing the operating expenses at 5 per cent per annum there is obtained $11,020,000, which when added to the estimated construction cost makes a total sum of $22,807,500 for the contact-filter project.

SPRINKLING FILTERS.

Sprinkling filters differ from contact filters principally in the method of application of sewage, which in our northern climates is discharged upon them in the form of spray from a series of fixed sprinkling nozzles placed about 12 to 15 feet apart. The filters are usually deeper and of somewhat coarser material than contact filters.

These filters also are an English adaptation of the Lawrence investigations with gravel filters some fifteen years ago. The English studies began at Salford in 1892 and have resulted in the adoption of this form of filter for many of the principal cities in England, the largest of which is the metropolitan district of Birmingham, with a population of over 900,000. Some of these filters have been in successful practical operation for more than eight years. On the Continent this method is being adopted for portions of the suburbs of Paris and Berlin.

In this country this method has been studied with care at Lawrence, Mass.; Columbus, Ohio; Boston, Mass., and Waterbury, Conn. Filters of this type are now under construction at Columbus, Ohio, and Reading, Pa. They have been recently adopted for Baltimore, Md.; West Chester, Pa.; Washington, Pa., and Waterbury, Conn. They have been recommended for use also at Paterson, N. J.

The important element of aeration is secured in sprinkling filters partly by applying the liquid as a spray and partly through the use of coarse material with voids of a size so that there is a vertical circulation of air through the filtering material at all times.

Suspended mineral and organic matters and some of the dissolved organic matters are retained upon the surface of the filtering material as the liquid

passes in thin films over the surface of the particles. Bacterial activities reduce the organic matter to a material degree, and from time to time the remaining inert material cracks and peels and passes through the filter bed to the bottom. In order to be able to remove this accumulated matter, it is necessary to provide false bottoms for these filters. Filters of this type have been in successful use for more than eight years without cleaning, and it is believed that under favorable conditions cleaning is not required oftener than once in ten or fifteen years.

The amount of suspended matter in the effluent of sprinkling filters due to this unloading of stored material is sufficient to require passing the effluent through settling basins, holding about two hours' flow, before discharging into the nearest water course. The settled effluent, of satisfactory appearance and with its organic matter so reduced that it will not putrefy, usually contains less than 10 per cent of the bacteria in the crude sewage.

There is a considerable range in size of broken stone and in depth of material as adopted in various large plants now built or building. Avoiding extremes, it may be stated that the depths average about 7 feet, and the size of material ranges from about 1 to 2½ inches, mean diameter. We have assumed these figures for sprinkling filters for the Calumet area, to be built of broken stone at the sites already mentioned for contact filters, namely, west of Harvey, west of Hammond, and between lakes Calumet and Wolf.

We have carefully considered the climatic conditions at Chicago and compared them with temperatures where practical experiences with sprinkling filters have been obtained. There is no trouble from the freezing of the sprinkler nozzles through which sewage is applied under a head of 6 or 7 feet. During zero weather some frozen sewage accumulates on the surface of the filter and at such times it is necessary to have some reserve area. We have assumed that under these local conditions one acre of sprinkling filters should be provided for every 15,000 people connected with the sewers, making a rate ordinarily of about 2,250,000 gallons per acre per twenty-four hours. As was demonstrated at Columbus, such rates for several weeks at a time may be doubled and still obtain a satisfactory nonputrescible effluent. This rate, expressed in persons served per acre-foot of sprinkling filter material, is only about one-half of that provided for at Columbus, Ohio, and one-third of that in several plants in England.

The approximate cost of building and operating a sprinkling filter plant with all needed appurtenances, of a capacity of 180,000,000 gallons daily, to serve a population of 1,200,000 may be estimated as follows:

Estimated cost of constructing sprinkling filter plant and appurtenances.

Intercepting sewers, pumping stations and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$3,300,000
Septic tanks, 60,000,000 gallons' capacity, covered, including sludge-disposal facilities	950,000
Sprinkling filters, 80 acres, with all appurtenances, office, laboratory, etc	3,600,000
Settling basins, 15,000,000 gallons' capacity	200,000
	8,050,000
Contingencies and supervision, 15 per cent	1,207,500
Total	9,257,500

Annual cost of operation.

Pumping, fuel, labor, and repairs	$200,000
Supervision, analytical and clerical assistants	30,000
Care of septic and settling tanks, including sludge disposal	54,000
Care of sprinkling filters	110,000
Supplies and miscellanies	25,000
Total	419,000

Capitalizing the operating expenses at 5 per cent per annum, there is obtained $8,380,000, which when added to the estimated construction cost makes a total sum of $17,637,500 for the sprinkling filter project.

CONCLUSION.

In recapitulating the substance of the foregoing inquiry and referring specifically to your instructions, summarized at the outset, we conclude as follows:

1. The examination into the sanitary situation at Chicago, so far as it is affected by sewage disposal, revealed that since removing the sewage through the drainage canal the appearance of the water of the Chicago River has shown marked improvement. As regards the hygienic quality of the public water supply there has also been an improvement, due to the progressive elimination of sewage from the lake, which elimination should be completed within a few years.

2. The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive, are that a dilution of 3¼ cubic feet per second for each 1,000 persons connected with the sewers, as provided for in the enactment of the Illinois legislature in 1889, is as low a figure as it is now possible to state. We believe that with the elimination of objectionable trade wastes and the occasional dredging of the river, this amount of dilution will be sufficient to prevent offensiveness.

3. The extension of the dilution method to the outlying territory is not the only way to preserve the lives and health of the people of Chicago. The application of this method with flows of 10,000 and 14,000 cubic feet per second, respectively, for the area tributary to the present drainage canal will serve populations not exceeding 3,000,000 and 4,200,000, respectively. For greater populations, other methods of sewage disposal will be required.

4. For the Calumet area, as well as other districts, there are several methods for the disposal of sewage, as effective as the present method of dilution in preventing the pollution of the lake waters.

5. All of these methods involve intercepting sewers and pumping stations to collect and deliver the sewage at suitable sites. Septic tanks are used for partially clarifying the sewage, which may then be applied to any one of three methods of filters, viz, intermittent sand filters, contact filters, and sprinkling filters.

All of these filters, if well built and well managed, remove the suspended and organic matters so that the effluents are practically clear and are nonputrescible. The removal of bacteria by these three types of filters averages at least 98, 80, and 90 per cent, respectively. Such effluents may be discharged directly into any of the water courses of the Calumet region.

6. The approximate total costs, liberally estimated, without the preparation of detailed plans, for a population of 1,200,000, are as follows:

A.—*Intermittent sand filters.*

Construction	$11,063,000
Annual cost of operation, $866,000, capitalized at 5 per cent	17,320,000
	28,383,000

B.—*Contact filters.*

Construction	11,787,500
Annual cost of operation, $551,000, capitalized at 5 per cent	11,020,000
	22,807,500

C.—*Sprinkling filters.*

Construction	9,257,500
Annual cost of operation, $419,000, capital at 5 per cent	8,380,000
	17,637,500

The present population on the Calumet area of the sanitary district being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expended at the outset.

Of the available methods of disposing of the sewage of the Calumet area, other than by dilution, the sprinkling filter method, being the cheapest, both in cost of construction and of operation, and accomplishing an adequate degree of purification, is clearly the most advantageous one.

Very respectfully,

RUDOLPH HERING,
GEORGE W. FULLER.

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