A REPORT

TO

The Chicago Real Estate Board

ON THE

DISPOSAL OF THE SEWAGE AND PROTECTION OF THE WATER SUPPLY

OF

CHICAGO, ILL.

BY

MESSRS. SOPER, WATSON, AND MARTIN

1915

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GEORGE A. SOPER
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THE CHICAGO REAL ESTATE BOARD

earnestly commends to the careful consideration of public officials, civic organizations, and the thoughtful citizenship of the City of Chicago the within report of the Board of Sanitary Experts, made to its Harbor and River Improvement Committee.

GEORGE H. TAYLOR,
PRESIDENT.

Chicago, June 15, 1915.

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REPORT OF THE HARBOR AND RIVER IMPROVEMENT COMMITTEE

To the President and Members of the Chicago Real Estate Board:

Gentlemen:

Your Harbor and River Improvement Committee, acting, as we then believed, in the best interests of our city and with a view of calling the attention of the public to the importance of better thought and direction in our sanitary expenditures, made a report to your body on Jan. 6th, 1914, outlining the existing sanitary situation as it appeared to your Committee, and suggesting the appointment of Engineering Experts to consider these important problems. These suggestions met with the approval of the Real Estate Board, and as a result of the public spirited munificence of one of the members, funds were placed at the disposal of the Committee for this purpose, and the following gentlemen were selected:

Mr. George A. Soper, Sanitary Engineer and late President of the Metropolitan Sewage Commission of New York City.

Mr. Arthur J. Martin, Sanitary Expert of London, England, and Past President of the British Sanitary Institute of Sanitary Engineers.

Mr. John D. Watson of Birmingham, England, President of the Institute of Sanitary Engineers, and long Chief Engineer of the Birmingham, Tame and Rea District Drainage Board.

These gentlemen, having signified their williness to serve, were constituted as a Board to report to your Committee on the matter of a proper future sanitary policy for Chicago.

A preliminary report was made to your Committee on May 1st, 1914, and duly printed in the Proceedings of the Board.

The final report of these gentlemen, under date of May 24th, 1915, is now received, and has been ordered printed and distributed to the members of the Board and those citizens of Chicago who are interested in this subject.

The Board's report, which we now publish, is not only very able, thorough, and conclusive, but has been written within a compass which makes what is really a treatise and easily readable pamphlet. It is well fitted, therefore, to disseminate in the community a correct knowledge of our sanitary problems, and to incite intelligent interest in their practical solution. The expenditure for sanitary purposes has been, is now, and will be more and more extremely large, and it is the wish of the Real Estate Board to do what it can to secure, in return for this heavy outlay, really efficient sanitation, well supervised and maintained, so that the public health of our city shall be conserved, our environment made decent, and our neighboring communities shall be without just complaint.

Respectfully submitted,

HARBOR AND RIVER IMPROVEMENT COMMITTEE,

HYDE W. PERCE, Chairman.
HENRY H. WALKER,
JOHN W. ALVORD,
JOSEPH DONNERSBERGER,
LOUIS A. SEEBERGER,
FRANK G. HOYNE,
EDWARD S. JUDD,
EMIL RUDOLPH.

LETTER OF TRANSMITTAL

Committee on River and Harbor Improvement,
The Chicago Real Estate Board,
Chicago, Ill.

Gentlemen: March, 1915.

We present herewith the final report of our study of the sanitary aspects of the scheme of sewage disposal and water supply protection which is now followed by the City of Chicago. These investigations were begun early in 1914, and have occupied us about one year.

Our opinion is that the present means of protecting the water and getting rid of the sewage are not, and cannot be made, satisfactory, and that decided changes are needed both as to policy and procedure.

It is wrong in principle and in practice (a) to use the unpurified lake water for drinking purposes, (b) to discharge the crude sewage into the waterways and (c) to flush crude sewage into the Illinois valley.

The existing policies have not given the city a safe drinking water, nor eliminated the insanitary conditions in the Chicago River. They have made impossible a wholesome condition of the Desplaines and Illinois Rivers for about one hundred miles.

An inquiry into the history of the existing scheme of sewage disposal and a careful examination of the law which provided for the construction of the Drainage Canal, have convinced us that the intention of the State Legislature in passing the Sanitary District Act was to prevent many of the evils which now exist, and which must become greatly magnified with the increase of population, unless radical changes are made.

We have been unable to find anything in the situation of Chicago, as regards drainage, or the sociological condition of its inhabitants which warrants the adoption of lower sanitary standards than are suitable for the most enlightened communities. To attain to these standards, the city needs works of main drainage and sewage disposal such as other great centers of population have found it necessary to construct.

The building of the Sanitary and Ship Canal was an excellent beginning, but it has not afforded a complete solution of the sewage problem. If properly used, the Canal will always prove to be an invaluable asset in the sanitation of Chicago, but its proper function is that of a river, not a sewer. Considerations of health and decency require that it be not called upon to serve as both.

Intercepting sewers are needed to take the sewage from the present collecting sewers and convey it to suitable points for disposal and treatment works are required in order to fit the sewage for discharge. At first, and for the most part, the removal of the suspended matters will probably afford all the purification required. The works should be capable of extension and development as the conditions of the future require.

The water supply can, and should be, improved in order to protect it against such pollution as the immense population of Chicago and vicinity and the extensive commerce upon the lake render unavoidable. Inasmuch as the water is at times turbid and unsafe for a public drinking water supply, we advise that it be filtered. Strenuous efforts should be made to curtail the waste of water which now amounts to over 100 gallons per day for every man, woman and child in Chicago.

Both the sewage disposal works and the purification plants for the water should, in our opinion, be built gradually and in accordance with plans made at the earliest practicable time. Much of this planning will be long in advance of the actual requirements of the works. In this way the cost, being anticipated, can be provided for and so distributed as not to prove too serious a burden.

We recommend that steps be at once taken to prepare a general plan and policy of sewage disposal which will give to the water supply all the protection which is practicable and get rid of the sewage without unnecessary danger or offence.

Respectfully submitted,

GEORGE A. SOPER,
JOHN D. WATSON,
ARTHUR J. MARTIN.

May 24, 1915.

A REPORT ON THE DISPOSAL OF THE SEWAGE AND PROTECTION OF THE WATER SUPPLY OF CHICAGO, ILLINOIS

Part I

1.—AUTHORITY FOR THE INVESTIGATION.

At the monthly meeting of the Chicago Real Estate Board, held November 5, 1913, a resolution was adopted providing for the appointment of three engineers to make a thorough study of the question of disposing of the sewage of Chicago in a sanitary manner. In consequence of this action, the following were appointed: George A. Soper of New York, John D. Watson of Birmingham, England, and Arthur J. Martin of London.

The point of view of the Chicago Real Estate Board in authorizing this investigation is shown in the following report of its Committee on Drainage, which was presented on January 6, 1914, and adopted:

2.—REPORT OF THE DRAINAGE COMMITTEE OF THE CHICAGO REAL ESTATE BOARD, LEADING TO THE APPOINTMENT OF THE SANITARY EXPERTS.

Gentlemen:

Your Committee on Drainage, appointed December 29, 1913, having been impressed with the seriousness of the sanitary situation in this city, is moved to make the Board a progress report as to the present situation.

(1) The condition of our water supply during the past few months has been such as to impress nearly everybody with the fact that we are not obtaining in our households water of that clarity and cleanliness that are desirable and necessary in a great city of the size of Chicago.

(2) There has been a distinct and disconcerting rise in the typhoid death rate in this city during the past year, which is causing uneasiness to those in immediate authority. Typhoid fever is so frequently originated by impure drinking

water that its increase always causes suspicion to be first cast upon the water supply as its cause.

(3) Health Commissioner Young has formally stated, in the daily press, that each year we suffer a loss of approximately 17,000 citizens from diseases which are preventable. This, he says, is equivalent to a Titanic disaster almost every month. It is apparent that a considerable proportion of these diseases may be caused either directly or indirectly from an impure water supply.

(4) The City Council of Chicago has been stirred by these conditions to investigate the subject, through its Health Committee, and an agitation has been started to prevent the dumping of impure material promiscuously in the lake.

(5) Trustee Sullivan of the Drainage Board, in a preliminary authorized review of the work of the Sanitary District, published in a morning newspaper of January 1st, states that 121,000 cubic yards of septic sludge were removed from Bubbly Creek (the Stockyards District) during the past year, and carried out into the lake, and deposited behind bulkheads, where the new Field Museum of Natural History is to be erected. If this statement be correct, it would appear that our sanitary authorities have shown most regrettable judgment in the protection of our water supply.

(6) In an exhaustive and carefully prepared report, dated November 25, 1910, by Mr. Wisner, Chief Engineer of the Sanitary District; Mr. C. D. Hill, C. E., Engineer of the Board of Local Improvements; Dr. W. A. Evans, former Health Commissioner, and others, the following conclusions seem to have been well demonstrated:

1st. That the present drainage flow is insufficient in amount to purify effectively the sewage which now reaches it.

2nd. That large quantities of filth produced in the Stockyards District and in the North Branch of the Chicago River, as well as the west fork, are not now brought within the influence of the channel flow or purified by it, and are a growing menace.

3rd. That the legal capacity required in the channel, viz., 20,000 cubic feet per minute per 100,000 population, is an insufficient ratio for dilution in Chicago.

4th. That by a series of chemical tests the purifying capacity of the channel flow is shown to have been for some years exhausted, especially in summer time, by reason of its depletion of its dissolved oxygen.

5th. That steps should immediately be taken for additional and further relief in the near future by artificial

purification in aid of the channel, which additional works will cost the city a probable further expenditure of from 20 to 25 million dollars.

(7) Your Committee is further impressed with the fact that the United States has never authorized the Sanitary District of Chicago to withdraw from the Great Lakes at a rate of more than 4,167 cubic feet per second of dilution water, and that the State law creating the Sanitary District explicitly requires the withdrawal of 20,000 cubic feet per minute per 100,000 population, which requirement at the present time cannot be much less than 8,000 cubic feet per second, or about double the amount permitted by the U. S. Government.

(8) Your Committee is creditably informed, and, in fact, has in its possession, evidence tending to show that not only at this time, but for some years past, the Sanitary District has withdrawn from Lake Michigan at most times between 7,000 and 8,000 cubic feet per second, or very nearly the entire requirements of the State law, all in spite of the fact that this is in violation of the requirements of the general government.

(9) The report of Mr. Wisner, above referred to, is conclusive that not even this amount of flow is sufficient to effectively purify the sewage actually reaching the main channel in summer, while the sewage from important areas, such as the Stockyards, cannot at such seasons be brought into contact with the flow of the main channel until putrefaction is completed, to the great and general nuisance of that vicinity.

(10) The Sanitary District has brought suit against the general government in the hope of obtaining the authorization for a flow of 10,000 cubic feet per second, which amount was adopted by the International Waterways Commission as all that could properly be allowed the city of Chicago for its sanitary needs, but it is evident that even should the Sanitary District of Chicago be successful in this suit and could compel the general government to allow 10,000 cubic feet per second to be withdrawn, this amount of flow would only slightly exceed the amount which the Sanitary District is now withdrawing, and which amount has been declared insufficient for the present purpose of purification, by the Chief Engineer of the Sanitary District.

Under these circumstances, your Committee feel that the city is facing a grave situation, in which there is no apparent, immediate, practicable relief, and that although the drainage channel has been in operation only about thirteen years, it has, in fact, reached the limits of its capacity for the present population.

To add to this dilemma, the policy of the Sanitary District

for some years has been to extend the limits of the District far beyond that for which the channel was originally designed, taking in through the supplementary Sag Canal, large territories to the south, and the supplementary Evanston channel, large territories to the north which will, in the future, materially add to the embarrassments under which we now labor. All this in spite of the fact that the International Waterways Commission declared, on the authority of expert advice, that these territories could be suitably and economically cared for by methods of sewage purification.

Under these circumstances your Committee feel that the Real Estate Board should be made aware of the facts, and should carefully consider what steps should be taken to outline a proper future policy for the sanitary protection of this city.

Your Committee is of the opinion that the time is ripe for a thorough, impartial and unbiased investigation by a board of the highest class of sanitary experts that can be obtained in this country or abroad, and preferably not connected with or committed in any way hitherto with this problem, all to the end that some authoritative and careful statement may be made as to our present condition, and some definite proper and studied policy for our sanitary protection may be presented and adopted, for the furtherance of this city's future growth and prosperity.

All of which is respectfully sumbitted,

JOHN W. ALVORD,
HENRY H. WALKER,
HYDE W. PIERCE,

Committee on Drainage, Chicago Real Estate Board.

January 6, 1914.

3.—QUESTIONS SUBMITTED TO THE EXPERTS AND THEIR ANSWERS.

The following list of questions was prepared by the Committee on Drainage of the Chicago Real Estate Board and submitted to the Board of Experts for their consideration. Most of the questions are so comprehensive as to be incapable of brief and complete answer from the investigation which has been made. Such replies, however, as are possible with the information at hand are here given.

Question 1: Assuming that all the sewage and trade wastes of the Sanitary District are to be dealt with by a dilution flow of Lake Michigan, what is the proper ratio of dilution for Chicago to count upon?

Answer: The sewage and trade wastes of the Sanitary District cannot be disposed of in a sanitary manner by merely discharging them with diluting lake water to the Illinois valley. No amount of dilution which it is practicable to effect is capable of rendering all of the sewage which is now produced by Chicago harmless and inert before a serious nuisance is caused in the Desplaines and Illinois Rivers. The sewage should be purified to some extent before it is discharged. The amount of purification required will depend upon how clean the waters of the Desplaines and Illinois Rivers must be kept and how much purification can properly be counted on in the Drainage Channel and other open waterways. It seems reasonable to insist that at an early date the rivers shall be made free from (1) discoloration due to sewage; (2) deposits of sewage sludge, and (3) solids and odors which are readily recognizable as of sewage origin. This means at least fine screening or sedimentation for all the sewage and, in addition, some form of oxidizing treatment for a large part of it.

Question 2: Assuming trade wastes and solids are to be separated from the sewage flow at the intercepting sewer outlets and treated, what is the best location and method for such treatment, and what ratio of dilution water in the main drainage channel may safely be allowed for the proper purification of the effluent water after such treatment?

Answer: The best means of local treatment is by means of screens and settling basins. The best locations for such works can be determined only after careful, detailed studies have been made of the surface and underground conditions. The ratio of dilution in the Main Drainage Channel should not be reduced below the present ratio, but increased, for it is desirable that the present conditions be improved. By screens and settling basins is here meant fine screens, well built and operated, and settling basins equal to any in practical efficiency.

Question 3: Is it the best course for the city to rely on full and complete treatment for the sewage from outlying territory, and the application of Lake Michigan flow to the sewage of the central districts of the city, or would it be better to partially purify all of the sewage by initial treatment in screens or tanks, or both, at a large number of stations throughout the district, leaving the flow from Lake Michigan to complete the treatment?

Answer: Partly purify it all. Completely purify some of it. The central districts of the city have the first claim upon the digestive capacity of the water for sewage.

Question 4: Is it best to concentrate the sewage flow for partial treatment at one or two main stations, or should it be

collected in a larger number of small districts and dealt with in smaller installations?

Answer: There should be one main station to the west of the city and various smaller installations. Their number and location can only be determined by comprehensive studies on the ground and a comparison of the cost and efficiency of various alternative projects.

Question 5: To what extent is it desirable to purify sewage, under our present conditions, in view of the uses and conditions of the channels and rivers into which our drainage is now discharged?

Answer: Floating solids, and solid matter which is capable of depositing in the channel and rivers, should be removed from the sewage and as much more improvement effected as can reasonably be accomplished presumably by means of screens and settling basins. This is a minimum requirement, and will serve for a beginning. The aim should be to comply with the State law as soon as practicable and not create offensive conditions in the Desplaines and Illinois valleys. This will require some form of oxidizing treatment to be employed to a considerable extent.

Question 6: To what extent is it desirable to construct branch dilution channels, receiving at their upper ends dilution water, in place of intercepting sewers reaching to the main channels?

Answer: No more should be constructed. Dilution channels are open sewers and are based on the mistaken theory that the crude sewage may be discharged into them providing that a large amount of diluting water is supplied. This theory is wrong in principle and in practice. The city should not be intersected with open sewers.

Question 7: To what extent has the dumping and spreading of dredgings from the river into the lake proved to be dangerous to the purity of the water supply, and to what extent should it be limited?

Answer: The dumping of dredgings from the river in the vicinity of the water works intakes has in times past been a dangerous practice and should be discontinued. Only clean material should be dumped behind bulkheads. Sewage sludge should never be dumped within the 8-mile limit. There are other places than the lake where dredgings can be dumped, as for example, along the route of the drainage channel on land belonging to the District. If the sewage is treated by screening or settling, the amount of sewage sludge which will have to be dredged will be reduced.

Question 8: What should be done to improve sewage.

conditions in such specially objectionable districts as the South Branch in the Stockyards District, and the West Fork and the North Branch in the factory district?

Answer: The sewage should be intercepted, taken away, and, as a minimum procedure, screened or settled. It should finally be discharged directly into the Drainage Channel.

Question 9: Should trade wastes be dealt with at private or public expense, and how may they best be treated under the conditions here?

Answer: Trade wastes should be treated at private expense when, and to the extent that, they increase the cost of disposing of them over the cost of disposing of an equal volume of domestic sewage. The manner in which they should be treated must depend upon their composition and other conditions which require special study.

Question 10: Assuming that the General Government will restrict the amount of water to be drawn from the Great Lakes for Chicago's sanitary purposes to 10,000 cubic feet per second, what supplementary works will be necessary, how soon should they be begun and what will be their approximate cost?

Answer: Whether the Government allows 10,000 cubic feet, more or less, plans should be made at once to install intercepting sewers, screens and settling basins to improve and protect the water of the Chicago River, Drainage Channel, and Desplaines and Illinois Rivers. The completeness of these works and of the protection which they afford, as well as the rapidity with which they are constructed, should depend upon the limits of pollution to be permitted for the waterways and the amount of diluting water which is available. The works required should consist of intercepting sewers and, as a minimum, means for extracting all the solid matter which it is practicable to extract without undue expense. The Drainage Channel can, and should, be made to carry on some of the process of final disposition. The extent to which it can be made use of in this way should be determined by investigation and experiment.

Question 11: To what extent should reliance be had for a pure water supply upon the preventing of accidental pollution of the lake by steamships and commerce carriers, or from the deposit of dredgings, and when should reliance be had on the purification of the water supplies by filtration, sterilization, or other purification methods?

Answer: Absolute reliance should not be placed upon the preventive measures suggested, since the means of enforcing them cannot be made perfectly effective and the consequence

of pollution might be fatal to many lives. The water supplies are occasionally polluted at the present time. The water should be purified by mechanical filtration. This method of treatment will not only make the water clean and wholesome, but will remove the turbid appearance at times of storm. The city should look forward to the filtration of the entire water supply in course of time and should proceed to acquire the land and make the plans and other preparations for the gradual construction of the filtration works.

Question 12: Will a harbor on the lake front prove to be in any way a menace to our water supply as at present located and derived, and if so, what steps can be taken to prevent the contamination of the water supply from this source?

Answer: The filtration of the water will protect the city water supply if the other precautions recommended in this report are carried out. Filtration will not do away with the need of exercising reasonable care in the disposal of the sewage and other wastes in such localities as are likely to affect the quality of the water before it is filtered. With filtration there should be adopted a system of conservancy for the lake water which will keep it as clean as practicable.

4.—PLAN OF THE INVESTIGATION.

The experts arrived in Chicago on the 18th of April, 1914, and for a fortnight gave their unremitting attention to the investigation. Subsequently thirteen months were spent in studying the extensive literature on the subject and in drafting the final report. A preliminary report was presented to the Committee of the Chicago Real Estate Board on May 1, 1914.

The scope of the inquiry has included the conditions under which the sewage is discharged and disposed of and the water supply procured. Inspections have been made of the Chicago River and Drainage Channel throughout their length, the Desplaines River from Joliet to the Kankakee, and the Illinois River as far as Henry—the total distance thus covered in following the course of Chicago's sewage being approximately one hundred and twenty-eight miles. The experts have made extensive tours of inspection through the Chicago Drainage District as far as Wilmette at the north and Riverdale at the south. The location of the pumping stations which supply flushing

water from the lake and the effects of this water on the condition of the branches of the Chicago River which receive it, have been noted. The position of the intake cribs through which the drinking water supply is obtained has been examined with reference to the possibility of pollution from the shore, from the Chicago River, from the Calumet River, from the dumping of dredgings and from the discharge of polluted waters and sewage from passing vessels. The quality of the water as revealed by analysis has been studied with much care.

The location of the various industrial and residence sections has been examined and the probable future development of Chicago has been considered with reference to the disposal of the sewage and the procurement of a supply of satisfactory drinking water.

The condition of the Chicago River and the channel of the Sanitary District as it exists today and is likely to exist in the future, in case the present plan of sewage disposal remains unaltered, has received the Board's attention.

The possibility of various methods of disposing of the sewage, other than by the present plan, has been discussed at length with the information which has been available. A large amount of literature, consisting of reports, public addresses, maps, diagrams and correspondence, has been examined and the Board has obtained many facts and opinions from the numerous persons with whom it has come in contact.

Officials of the Sanitary District and of the City have, without exception, supplied generously and apparently without reserve, such information and opinion as the Board has desired. Interviews have been held with the President and Trustees of the District, their Consulting Engineer, the Chief Engineer and his predecessor, the Division Engineer in charge of the sanitary work, and the Chief Chemist and Bacteriologist of the District force. The City officer in charge of the construction of sewers, the City Engineer in charge of the water supply, the Commissioner of Health of the City, the Director of the State

Water Survey and his principal assistants have been interviewed and have rendered valuable assistance. Meetings have been held with the engineer officer of the United States Government in charge of the navigable channels, and the attorneys for the United States and the Sanitary District, who are engaged in the suit concerning the power of the District to take the quantity of water which is desired from Lake Michigan through the Drainage Channel. The voluminous record in the case of the United States vs. the Sanitary District has been examined.

A large number of engineers and other citizens, and particularly the members of the Committee on Harbor and River Improvement of The Chicago Real Estate Board, have given access to official reports and other data which they have collected, and have facilitated the investigation in many ways.

In conducting its inquiries and in formulating its opinions, the Expert Board has believed that it could be of most service if it confined itself chiefly to the large and essential aspects of the problems before it. Special attention has been devoted to the sanitary history of the city, since a knowledge of the efforts which had been made to solve the water and sewage problems was considered necessary to an understanding of the possibilities of further development. The Board's point of view has been that of engineers familiar with the principles and methods of sanitation in use in other great cities and available for Chicago. In arriving at an opinion upon the points at issue, due regard has been given to the work which has been done and to the intentions for the future, so far as they have been expressed by those who are in official charge of the sewage disposal and water supply of Chicago.

Part II

THE CHICAGO REGION AND ITS WATERWAYS

1.—SITUATION OF CHICAGO AND THE SANITARY DISTRICT.

The City of Chicago, with a population of about two and one-half million and an area of about one hundred and ninety square miles, lies in the State of Illinois, near the southern end of Lake Michigan. The long southward projection of the lake suggests that at one time its waters flowed to the sea by way of the Mississippi River and the Gulf of Mexico. This is probably true, for that part of the watershed which is in the vicinity of Chicago and is tributary to Lake Michigan is low and separated from the Mississippi drainage area by a rise of but slight elevation. This circumstance has had a profound influence on the location of the City of Chicago and the solution which has been sought for its sewage problem.

A direct water route from Lake Michigan to the Mississippi existed from time immemorial, beginning at Chicago, running up the Chicago River, with a short portage over the low divide and thence down the Desplaines and Illinois Rivers to the confluence near St. Louis.

The Illinois River, which is formed by the Desplaines and Kankakee, flows through a valley which is about one hundred miles wide and whose length extends completely across the State of Illinois. This valley contains about one-half the population of the State, that of the City of Chicago being taken out of the calculation.

Practically the whole lake shore of Illinois, about sixty miles long, is occupied by cities, towns and villages. In the State of Indiana, which adjoins Illinois on the

south, the settlements are numerous, large and growing rapidly. Chicago may be said to be the nucleus of a vast population, a large part of which has endeavored to locate itself on or near the lake front for the transportation facilities and other advantages which are there afforded.

The land upon which Chicago is situated is low and flat. It is drained by the Chicago River, a short and naturally narrow and sluggish stream with various branches which discharge through a short main trunk into Lake Michigan. Immediately to the south is a larger, and in many respects similar, watershed which is drained by the Calumet River. At times of heavy rain and melting snow both streams originally discharged large volumes of water into the lake. Since 1901, the flow of the Chicago River has been diverted to the Desplaines.

A low ridge a dozen miles to the west of Chicago separates the water which flows to Lake Michigan from that which finds its way to the Desplaines, Illinois and Mississippi rivers.

Natural harbors suitable for commercial vessels do not exist in Lake Michigan within one hundred miles of Chicago. Harbor facilities are afforded by enlarging, protecting and deepening the mouths of the rivers and, in some cases, by constructing wholly artificial waterways from the lake into the low, marshy shores.

2.—SANITARY CONDITION OF THE GREAT LAKES.

In view of the enormous volume of water which the Great Lakes contain and the relatively small population whose drainage is tributary to them, it would seem that the pollution of the lake waters to the danger point for drinking purposes was a remote possibility. If self-purification can operate successfully anywhere, and dilution prove an effectual means of eliminating the chance of infection, it would seem capable of doing so here.

Implicit confidence, both in the original purity of the lake water and in its capacity to purify itself of any human wastes which may be discharged into it, has been felt by every city which has been situated on the shores. Most

of them have discharged their sewage into, and taken their drinking water from, the lakes and with fatal results. In many cases, the pollution has been local and easily traced; but studies which have been made of the movements of the water under the influence of wind and barometric pressure, and elaborate analytical investigations have recently shown that the harmful effects are not always confined to the immediate vicinity of the cities.

However restricted they may formerly have been, the zones of dangerous pollution have spread until, with the large amount of polluting material originating ashore and afloat, the general waters in some parts of the Great Lakes and rivers bounding the United States and Canada are not safe to drink without purification. The experts of the International Joint Commission, in dealing with the control of sewage disposal for municipalities on these boundary waters, testified that

> "The bacteriological tests which have been made in large numbers under the direction of the International Joint Commission indicate that in most places the boundary waters are such as to be a general menace to the public health should the water be used without purification as sources of public water supply, or should they be used for drinking purposes by persons traveling on boats."

The International Joint Commission is a permanent tribunal with powers of adjudication, created by treaty between the United States and Great Britain. Its powers are very broad and include the decision of practically all matters of dispute between Canada and the United States, including the pollution of the waters of the Great Lakes and the diversion of their flow.

The pollution of the Great Lakes is growing with the rapidly increasing population, and many considerations make it apparent that such efforts as can be made in future cannot succeed in keeping the waters pure enough for drinking without treatment.

3.—CIVIC CHARACTER AND PLAN.

Chicago is essentially an industrial city, but it is one in which a desire for higher civic standards makes itself

strongly felt from time to time. In all that stands for security of life and property, convenience of transit and sanitary well-being, Chicago should be, and intends to be, a leading city. The standards of cleanliness which are suitable for the other great cities of the world seem none too high to apply here.

Chicago is a leading center for the handling of grain, live stock and lumber, for the slaughtering and packing of meats, the manufacture of iron and steel, harvesting machinery and other commodities.

The waste products of the industries have contributed greatly to the pollution of the Chicago River. Up to the present time, there has been little restriction placed upon the discharge of the wastes into the waterways. In 1910 the value of the manufactures was $1,300,000,000. Of this total, $400,000,000 was in the slaughtering and packing industries, in which large quantities of liquid and semi-liquid wastes are produced.

Judged by other sanitary conditions than those of water supply and sewage disposal, Chicago cannot be said to be ahead of the other great cities of the world. The work of street cleaning and waste disposal has not yet been placed upon a plane of sanitary efficiency and the effect of this backwardness is widespread. The unpleasant odors which arise from the stockyards district are sometimes noticeable for miles.

Although generally regarded chiefly as a center of great industrial enterprise, Chicago may fairly claim distinction for its beautiful homes, handsome business blocks, libraries, universities, public schools, boulevards and parks. The number of pupils attending the public schools exceeds 332,000 and the cost of maintaining the educational system of the city exceeds $25,000,000 annually.

Like most great cities, Chicago has grown to its present size without definite plan. Plans have recently been made for future development and have received some official recognition. These plans have already had some effect in determining the manner of growth, convenience of transportation and beautification of the city, but there

is a great deal to be done before the city assumes the attractive and symmetrical appearance which is intended.

The railroads own large areas of land in the heart of the city, estimated at about $100,000,000, and it remains to be determined how the interests of the corporations and the public are to be harmonized. No railroad or railroad system runs a train through the city—all trains stop and are made up here for the journey or shipments beyond—Chicago is the absolute terminal of every railroad train that enters it.

Up to the present, the greatest business activity, aside from the large establishments whose land requirements have made it necessary for them to locate on the outskirts of the city, has been in the region immediately adjoining the river and between the South Branch of the Chicago River and Lake Michigan. The river has, in fact, had more influence upon the city's development than has any other local factor.

In width, depth and current resembling a canal rather than a natural water course, the Chicago River has served as a great highway for commerce and been a troublesome barrier to local transportation. Referring to it in his report on the traction problem, in 1902, Bion J. Arnold says:*

> "From the earliest period in the development of the city down to the present time, this water barrier has been the fixed condition that has been recognized and deferred to. Town governments were established on its lines; it is the boundary line of wards throughout its course; the water, gas and sewerage systems are laid out with reference to it; diagonal streets or avenues to the business center are determined by its course; it is primarily responsible for the congestion of the business center, limiting, as it does, by its movable bridges, the area to a little more than a square mile; the manufacturing district has grown up along its course, and naturally all lines of business that can be more profitably conducted through contact with navigation have sought its frontage—all of which growth has so increased the dock frontage that the Chicago River, with

*Report on the Engineering and Operating Features of the Chicago Transportation Problem, submitted to the Committee on Local Transportation of the Chicago City Club by Bion J. Arnold, M. S., M. Ph., E. E.; November, 1902, p. 24.

its movable bridges, must be considered as a permanent condition—especially so as the natural dockage of Chicago, the Lake Shore, is being continually and continuously appropriated for park and pleasure purposes."

A description of the Chicago River will be found on p. 37 and further references to it in many other parts of this report to the Real Estate Board.

4.—GOVERNMENT.

The governmental powers of Chicago are derived from a general act of the Illinois Legislature for the government of cities and villages. The central governing body is the Council, which is composed of two aldermen elected from each of the thirty-six wards into which the city is divided.

Most of the departments of the city government have been organized by ordinances passed by the council which has power to prescribe the duties of city officers, adopt regulations to promote health, define and abate nuisances, provide for the opening, cleaning and repair of streets, laying of water mains and sewers and perform many other duties of a legislative character which are often incorporated in the charters of American cities.

The city has authority to construct and maintain water works and to go outside of its limits for this purpose, the powers of the city being extended, so far as the authority of the State of Illinois will permit, for the prevention of the pollution of the sources of drinking water.

There are twenty-three departments of the city administration, including those of public works and public health, each of which is presided over by a Commissioner. There are several bureaus in the Department of Public Works and at the head of one is the City Engineer, who is in charge of the sewers, water works and the Chicago River, so far as improvements are made in that stream by the city.

The Commissioner of Health exercises jurisdiction over the sanitary condition of the city, including the collection of vital statistics, inspection of milk and other

food, analysis of drinking water, inspection of premises, medical inspection of schools, maintenance of hospitals, public baths, etc.

The Mayor is an elective officer and is required to execute the laws and perform such duties as the council may prescribe by ordinance. He appoints nearly all the heads of departments, subject to approval by the Council.

The control of parks, schools, charities, sewage disposal works and various other city undertakings, is not vested in the Council, but in special elective boards. To bring about satisfactory co-operation between the many independent and partly related bodies in the city government has long been regarded as a desirable, but very difficult matter.

Lying wholly, or chiefly within the city limits, are nineteen taxing bodies; the City, the Board of Education, the Public Library, thirteen Park Boards, the Sanitary District and the County; not to mention five Townships and various less important bodies.

Mayor Busse, in his annual message to the Chicago City Council, April 12, 1909, stated that of every $100 collected from the citizens for the purpose of government, $6.40 went to the Sanitary District, $6.80 went to the State, $10.61 went to the County, $11.35 to the Park Boards and $35.50 to the public schools.

The valuation of real estate and personal property in Chicago, as given by the Comptroller for 1913, was $981,787,576.00. Making allowance for the statutory requirement that, for purposes of taxation, property shall be valued at one-third of the true valuation, it appears that the total correct value of real and personal property in 1913 was $3,000,000,000.

The total tax collected in 1913 was $31,122,666.16 and the bonded indebtedness $28,216,000; the population was 2,388,500. In 1906, when the population was two million, the tax was about seventeen and a half million; in 1890, with about one million inhabitants, the tax was about nine and one-half million; in 1880, with a population of about half a million, the tax was about four million. The tax

had remained at or near this figure since the great fire in 1870, when the population was about three hundred thousand.*

5.—POPULATION.

The growth of the city has been phenomenal. It has been said that "within the memory of living men, Chicago has risen from a village sunk in the mud of a prairie creek to a great metropolis, ranking fifth in the roll of the world's greatest cities." This remarkable growth has been due to the geographical position of the city, the development of the Middle West as an agricultural region, the development of mining, lumber and live stock industries, the focussing of railroad systems and to the ability and enterprise of its citizens. It is situated at the head of the great agricultural lowland of the Mississippi and Great Lakes region and holds a commanding position as a center both for navigation and land transportation. Over twenty-seven railroad systems converge here. Seventeen steamship lines ply the waters of the lakes. Within a single night's ride by rail are 50,000,000 people.

In 1840 the population was 4,470; in 1850, 29,963; in 1860, 112,172; in 1870, 298,977; in 1880, 503,298; in 1890, 1,099,850; in 1900, 1,698,576, and in 1910, 2,189,525. In 1914 the population was estimated by the United States Census Bureau at 2,397,600. It is now increasing at the rate of about 150,000 per year.

The growth before 1850 was stimulated by the settlement of the prairies and by the opening of the Illinois and Michigan Canal in 1848. An era of railroad building existed between 1850 and 1860; great industrial activity attended the Civil War, 1863-1865.

6.—THE CRUDE AND CORRECTED DEATH RATES.

Comparing the vital statistics of Chicago with those of New York, Philadelphia and Boston, and the 34 foreign cities whose records are available for the period 1881 to

*Fifty-seventh Annual Report of the Comptroller of the City of Chicago, 1913, p. 237.

1910, it appears that, on the whole, Chicago has not been remarkably successful in protecting the lives of its citizens. Greater reductions have been made in the death rate by 18 cities, smaller reductions by 19. In the period mentioned, Chicago's reduction was 32.6 per cent, New York's 38.2 per cent, London's 28.7 per cent, Paris, 28.3 per cent, Berlin's 41.7 per cent, Amsterdam's 47.8 per cent, Vienna's 39.4 per cent.

When the annual crude death rate of this group of cities is brought together in the form of averages for the 5 year periods 1896 to 1900 and 1901 to 1905, it is found that Chicago's decrease was 1.0 per 1,000 persons living. This was less than the decrease in any of the other 37 cities referred to, except four.

For the most part, Chicago's crude rates both from general causes and from the so-called preventable diseases are low, but if due allowance is made for age and sex, the corrected rates are found to be considerably higher. Chicago is a city which attracts the young, vigorous and healthly-bodied who have their way to make in the world and are prepared to bring an abundance of vitality and resistance to the task. Like all great cities of its kind, it is not the resort of the old, feeble or very young, among whom the death rate is always high, and whose effect upon the death rate of the town wherein they live may be considerable.

According to the calculations of the United States Bureau of Census for 1911, there was a greater difference between the crude and corrected death rates for Chicago than for any other of the fifty cities of the United States which have a population of 10,000 or over, except four.

Among these fifty cities, there are about as many with higher as with lower corrected rates; but when the crude rates are compared, Chicago appears to be among the healthiest. Cities having higher corrected death rates include New York, Philadelphia, Boston, Baltimore, Cincinnati, St. Louis and Pittsburgh.* In 1911 Chicago's

*Department of Commerce, Bureau of the Census, Bulletin 112: Mortality Statistics, 1911, p. 21.

corrected death rate was 16.4; the crude rate 14.5; in 1914 the crude death rate was 14.18.

These corrected death rates are the rates which would have resulted if the sex and age constitution of the population had been identical with that of England and Wales, as enumerated at the census of 1901.

The corrected rates of New York, London, Paris and Berlin for 1909 were calculated for the Metropolitan Sewerage Commission of New York by Prof. Walter F. Wilcox,* who assumed as a standard the average population of England and Wales for the ten years 1891-1900. The results follow: London, 14.2; Berlin, 17.0; New York, 18.3; Paris, 18.9.

Vital statistics are generally taken to be a measure of the healthfulness of a city, but caution is necessary in applying this gauge. Excessively high rates generally point to some grave sanitary evil, but small fluctuations are of small importance. It would scarcely be fair to conclude that the healthfulness of Chicago varied as does its typhoid rate, nor that the success of the Drainage Channel as a sanitary measure was proved by this criterion alone.

7.—THE WATER SUPPLY AND THE DEATH RATES.

It has generally been found that the introduction of a material improvement in a city's water supply is followed by a decided decrease in the ordinary number of deaths, and it has often been remarked that not only are such water-borne diseases as typhoid so reduced, but reductions are made also in diseases which have no conceivable relation of this kind.† The following facts have been collected in order to determine what effect, if any, was produced upon the purity of Chicago's water supply by the opening of the Drainage Canal, so far as this effect is discoverable in the city's vital statistics.

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*Report of the Metropolitan Sewerage Commission of New York, April 30, 1914, pp. 271-286.

†Purification of Water for Domestic Use—Allen Hazen, Paper No. 48, International Engineering Congress, 1904, Transactions American Society of Civil Engineers, Vol. LIV, Part D; pp. 151-153.

The period between 1889 and 1893 was epochal in the history of Chicago. It was marked by a great expansion in the city's area, population and revenues. The area was quadrupled and the population and sum of money collected by taxation doubled. During this time, communicable diseases and death by violence were uncommonly prevalent. When the wave passed, as it did some years before the Sanitary and Ship Canal was opened, there was produced a far more profound effect upon the death rate than has occurred at any time subsequently. The general death rate, which had averaged 21.87 per 1,000 in the four years following 1889, fell to 18.26. Four years later it had declined to 14.63, and in the vicinity of that figure it has remained ever since. Among the marked declines in specific causes of death which followed the wave were: typhoid fever, from 53.5 to 37.5 per 100,000; pneumonia, from 196.1 to 116.1; scarlet fever, from 26.3 to 14.5; heart disease, from 88.3 to 79.3, and violence, from 151.7 to 118.4. Had there not been an epidemic of smallpox in 1894, the drop in the general death rate would have been still greater.

The sickly period from 1889 to 1893 and the reaction which followed are readily explained by the changing sanitary conditions of those times. In the territory which was annexed in 1889 were six municipalities which possessed water works of their own. Practically all their water was taken from the lake, in some cases through iron pipes which extended only a short distance from shore. The City of Chicago took over the management and reconstruction of most of these waterworks at once and set to work to improve the quality of the water.

The main supply of the city was at that time obtained from the Two Mile Crib, opposite Chicago Avenue, which had been constructed in 1867. In 1891 the Four-Mile Crib was put in operation and this was followed by the Lake View Crib in 1896, and the Carter H. Harrison Crib in 1899. The improvement produced by the Four-Mile Crib was unquestionable.

The connection between the condition of the water

supplies and the health of the city was so plain that in 1897 a commission, consisting of Samuel Artingstall, City Engineer, Lyman E. Cooley, George H. Benzenberg, William Sooysmith and Joseph Downey, Commissioner of Public Works, recommended that the sewage be diverted from the lake and that the intakes of the water works be all extended to a distance of four miles from shore.

8.—TYPHOID FEVER AND THE DRAINAGE CHANNEL.

The opening of the Drainage Channel seems not to have reduced any of the death rates materially. For the three years before the Canal was opened, the general rate was 15.0 and for the three years following 14.5 per 1,000. For the 13 years which have now passed since the Canal was opened, the average general death rate has been 14.8. In 1913 it was 15.1.

The average reduction in typhoid for the three years following the opening of the Canal was trifling, 32.4 to 31.1, and appears especially inconsequent when it is noted that this average of 32.4 contains the rate of 40.8 for the exceptional typhoid year of 1898. Since the Drainage Channel was opened, the average typhoid rate has been 19.2. In 1913, it was 10.4. The figures since 1893 have shown a persistent decline, but no sudden and permanent fall. There have been years when the rate has been a great deal higher than these average figures indicate, as for example, in 1902, when the rate was 44.5, and in 1903, when it was 31.8, and there have been nine years when it was less than the average. It is necessary to go back beyond the opening of the Canal, and beyond the epidemic year of the Spanish-American war (1898), in order to equal the rate which obtained in the 3rd year of the Canal's operation.

Looking through the printed list of specific causes of death, it does not appear that any rate was affected by the opening of the Canal so much as the rate for that indefinite group called diarrheal diseases, which includes diarrhea and enteritis among infants. The average death rate for diarrheal diseases for the three years preceding

the opening of the Canal was 257.4 and for the three years subsequently 209.5, a reduction of about 19 per cent. The decrease in the death rate among children under 5 years of age for the same period was 17 per cent. There is no reason to suppose that the deaths in this class bear a measurable relation to the sanitary condition of the city, since the statistics are made up largely of children whose diarrheal diseases are chiefly caused by local circumstances. It seems as unsuitable to ascribe the reduction which has occurred since 1900 in diarrheal diseases to the Drainage Channel as it is to charge up against it the remarkable increases which have occurred in the prevalence of Bright's disease, heart disease and violence.

Typhoid fever has become less prevalent since the Drainage Channel was opened than it was before, but before the decline is ascribed to that great work, it may be desirable to consider some facts outside of the Chicago death rates which have a bearing on this matter.

Typhoid is disappearing everywhere, except in those places where its spread is encouraged by gross sanitary neglect. In those parts of the United States where the vital statistics are collected with sufficient accuracy to be used by the Government Census Bureau, there has been an average decline in the typhoid rate of one-half since the opening of the Chicago Drainage Channel in 1900, that is, from 35.9 to 17.9 per 100,000 population. Were it not for the excessively high rates in some States, the average would be much lower. The average rate for the cities in New York State in 1913 was 9.9 and in Massachusetts 8.6.

In 1913 the typhoid death rate of New York City was 7.0 per 100,000; that of Boston, 8.2; Cincinnati, 6.8; Worcester, 5.6 and Seattle, 4.7. These are particularly low rates, but they are not lower than are proper for Chicago.

Chicago has had a number of explosive outbreaks of typhoid since the opening of the Drainage Channel,

notably in 1901-1902 and 1903, and the circumstances which have attended them have led observers to form the opinion that they have been water-borne, in spite of a general opinion to the contrary.

From a study of the seasonal incidence of typhoid in Chicago and in other cities with about the same rate, McLaughlin formed the opinion that the water supply was largely to blame.*

9.—THE FUTURE CITY.

How large Chicago will become within the period of years for which it is desirable to project works for water supplies and sewage disposal it is impossible to say with accuracy. Apparently the era of phenomenal expansion is passed, and it seems likely that the future increase in population will follow the rates of increase of other large cities of great industrial and commercial activity.

It is well known that after cities become very large they do not maintain the rapid rates of growth which sometimes attend their early development. There is a decreasing rate of increase after the population becomes great. If the rate of growth of Chicago was to continue, as in the past, the city would have a population of 13,000,000 in 1952. If it conforms to the law of decreasing rate of increase, as shown by Mr. Arnold for European cities of the greatest size, the population in that year would be 5,200,000.† Some figure between these two estimates will undoubtedly be realized.

According to the 1911 report of Mr. Wisner, Chief Engineer of the Sanitary District,‡ the population of Chicago up to the year 1942 may be estimated as follows:

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*Sewage Pollution of Interstate and International Waters with Special Reference to the Spread of Typhoid Fever, Hygienic Laboratory Bulletin No. 83, March, 1912, by Allan J. McLaughlin U. S. Public Health Service pp. 147-152.

†It has been estimated that the transient population of Chicago will be 300,000 per day by the year 1920.

‡Report on Sewage Disposal made to the Board of Trustees of the Sanitary District of Chicago by George M. Wisner, Oct. 12, 1911, p. 37.

Year.	Population.
1920	2,900,000
1922	3,000,000
1930	3,500,000
1940	4,100,000
1942	4,200,000

It is of great importance in planning sewage disposal works that the future populations shall be estimated with the utmost practicable accuracy, not only for the whole district to be covered, but for many parts of it, for in this way only can a correct idea be formed of the provisions which it will be necessary and sufficient to make for the sewage. If such estimates have not already been made, they should be prepared at once. Failure to forsee and provide for the remarkable growth in population which has occurred has, from the first, been one of the leading faults of those who have moulded Chicago's sewage disposal policies.

10.—THE CHICAGO RIVER.

The site of Chicago is low and flat with layers of clayey and sandy subsoil. Through the center of the city flows the Chicago River with a drainage area of 270 square miles and a discharge of 10,000 cubic feet per second at times of storm.

The Chicago River originally flowed into Lake Michigan, but it now flows, with a considerable amount of lake water, to the Illinois by way of the Sanitary and Ship Canal, which was completed in 1900, with the double object of affording means by which the sewage of the city could be kept from the water supply which is derived from the lake and providing a highway for commerce between the lake and the Mississippi. As yet no commerce of importance has followed this route—a fact which is said to be due to the unimproved portion of the river sections in the Illinois Valley.

Originally the harbor of Chicago could be used by none but the smallest craft and then only when temporarily deepened by scour due to freshets. Before improve-

ment, its mouth was nearly a mile south of its present location. The first improvement made in 1833 was to cut through a sand spit where the river made a sharp turn, and so connect the river with the lake. Breakwaters were then constructed in the lake to protect the river entrance and afford shelter to vessels. Subsequently, piers and bulkheads were built along the navigable portions of the river and a great deal of dredging was carried on. There is now a least depth of 21 feet at the harbor entrance and a width of about 470 feet, narrowing to about 200 feet, a short distance back from the mouth.

At a point of about 1 mile from its mouth the river bifurcates into a North and South Branch, both of which have been improved for a distance of about four and five miles, respectively. The South Branch is divided into the South and West forks, and the south fork into the east and west arms. There are other channels and divisions of lesser importance. The total length improved by the United States Government is 13.28 miles.* Along the main channels of these stretches are 22 miles of docks and wharves and 6.93 miles of slips.

The more important part of the river is spanned by 57 bridges, including 9 railroads, 38 highways, 1 elevated railway, 2 combined highway and elevated railways, and 5 temporary bridges. A turning basin, of 580 feet least diameter, is located in the North Branch and another, of 522 feet diameter, is in the South Branch.

The main trunk of the river lies in the very heart of the city and extends its length of about a mile in a direction perpendicular to the shore of the lake. Both the North and South Branches lie approximately parallel to the lake shore for a portion of their course. Of the two, the northern branch is the longer and less important: its total length is about 35 miles. The South Branch flows in a southwesterly direction and, at a distance between 5 and 6 miles from the lake, is divided into the South and

*Bulletin No. 23, Survey of the Northern and Northwestern Lakes, United States War Department, Corps of Engineers, 1914, p. 79.

West Forks, the former being of the greater interest in the present inquiry.

The amount of dredging done in the Chicago River is indicated in part in the following account of improvements by the United States, which is taken from a communication addressed to the Chairman of the Board of Experts by Lieut. Col. A. V. Judson, Corps of Engineers, U. S. Army.

The parts of the river which have been improved by the U. S. Government are as follows: The Main River to the junction; the North Branch to Belmont Avenue; the South Branch to Ashland Avenue, and South Fork to the Stockyards.

The first improvement by the U. S. Government was begun in 1896 and consisted in dredging the main river and its branches to a depth of 17 feet. Between 1896 and 1898 inclusive, the total amount dredged to that depth was 1,873,906 cubic yards. By Act of Congress approved March 2, 1907, the project depth for the river and its branches was fixed at 21 feet, and in 1908 the main river from the harbor to the Forks was dredged to that depth. In 1900 the Sanitary District Canal was opened and, under a permit from the Secretary of War, the South Branch was deepened and widened by the District authorities; no dredging has been done in the South Branch of the river by the U. S. Government since the original depth of 17 feet was secured in 1896 to 1898.

There is no yearly dredging done in the river and branches by the United States Government to maintain the project depth. Such work is done whenever appropriations are made and in places where most needed. It is, therefore, impracticable to give any definite statement as to regular yearly dredging required. In Col. Judson's opinion, however, an approximation might be obtained by comparison between the first time the 21-foot channel was secured in the North Branch and the time when the same channel was redredged to the same depth, and by dividing the amount dredged the second time by the intervening period. Thus, between 1912 and 1914 the greater portion

of the North Branch was redredged to 21 feet by the removal of 322,552 cubic yards and the balance of this branch is now under contract to be dredged to the same depth in the spring of 1915. The amount estimated to be removed under this contract is 203,000 cubic yards. If this amount is added to the amount given above, the total will represent approximately the fill during the period since the first time the 21-foot channel was secured, approximately 7 years. The said total amounts to 525,552 which, divided by 7, gives 75,077 cubic yards as the average fill per annum.

In addition to the dredging done by the government engineers, the Sanitary District has removed 1,500,000 cubic yards in widening the Sanitary and Ship Canal from Robey Street to Summit. In addition, there have been dredged by the District 567,390 cubic yards of material in 1910, 283,994 cubic yards in 1911, and 122,320 cubic yards in 1913. Of this amount, 693,334 cubic yards have been removed from the South Branch, and 280,380 cubic yards from the east and west arms of the South Fork, known as "Bubbly Creek." The grand total dredged by the Sanitary District, according to the foregoing, is 2,473,000 cubic yards.

During the last two years most of the material dredged from the Chicago River and the Drainage Channel has been placed behind bulkheads and the material not so placed has been dumped eight miles out into the lake in 60 to 70 feet of water, which is considered by the District to be of sufficient depth so that the wave action will not disturb the material on the bottom of the lake. The District states that the material taken eight miles from shore has been virgin clay and all sludge and sewage mud has been dumped behind bulkheads.

Vessels from Lake Michigan to the Mississippi pass through the main trunk of the river with its five bridges, and the South Branch with its twenty-one bridges, to the mouth of the Drainage Canal. Through this distance of six miles the shores are bulkheaded and for the most part compactly built up or occupied by railroad terminals.

The uses of the Chicago River are threefold: (1) It affords means for the through movement of boats; (2) It provides wharfage for the loading and unloading of cargoes, and, (3) It serves as an open sewer.

11.—THE WATER ROUTE TO THE MISSISSIPPI.

The construction of the Sanitary and Ship Canal, together with the improvements which have been made in the Chicago River, afford an important link in what is intended to be a deep waterway from the Great Lakes to the Mississippi, a distance of 327 miles, having a preliminary depth of 14 feet and an ultimate depth of 24 feet.

The Sanitary Canal joins the Chicago River at a point about 6 miles from its mouth and extends to Lockport, about 30 miles. For the first 7 miles the canal was built 110 feet wide, and for the next 7 miles 202 feet wide, at the bottom, with side slopes of 1 on 2. The remaining half is 160 feet on the bottom and approximately vertical at the sides. At the southern end of the canal are the regulating works and the power plant where the fall is converted into electric current.

From the Sanitary Canal the water route at present is by way of the Illinois and Michigan Canal, which follows the Illinois Valley to La Salle, where it joins the river, 63 miles from Lockport. In this reach there are 11 locks. Boats navigate the canal provided they do not exceed 100 feet in length and draw more than 4 feet 2 inches. The Illinois River is 223 miles long from La Salle to the Mississippi and is provided with four dams which have a total fall of about 27 feet.*

Most of the sewage-and-water mixture which is carried by the Sanitary and Ship Canal is discharged into the Desplaines River near the point where it connects with the Illinois and Michigan Canal. The Desplaines at this point is a small stream whose natural flow varies exceedingly.

*For brief description of hydrographic features and the discharges of the Illinois River and its tributaries see Report of Rivers and Lake Commission of Illinois 1914, Water Resources of Illinois, by A. H. Horton, Hydraulic Engineer, U. S. Geological Survey.

The Illinois River is formed by the junction of the Desplaines and Kankakee, 54 miles from Lake Michigan. The upper Illinois, including the Desplaines, flows through a rockbound valley from Joliet to Utica, 58 miles, in which distance the stream has a natural declivity of 104.6 feet. The lower Illinois, from Utica to the Mississippi, is 230 miles long and has a declivity of 28 feet.

The entire Illinois River basin contains about one-half the area and, with Chicago, about 70 per cent. of the population of the State. The topography is gentle and rolling; the soil is rich. The southern part contains about 350,000 acres of swamp or land which is subject to flood at periods of excessively high water.

The low water volume of the Illinois is about 633 second feet, and the flood volume 93,600 second feet, at La Salle. Dams and locks in aid of navigation have been built by the State at Henry and Copperas Creek, about 33 and 93 miles, respectively, below Utica, and by the United States at La Grange and Kampsville, about 152 and 198 miles below Utica, respectively.

Claims for damages to land from flooding have been awarded, lodged or preferred against the Sanitary District of Chicago, aggregating about $8,000,000. The claims pertain mostly to the first reach.

In November, 1908, the people of the State voted to authorize the issue of bonds not to exceed $20,000,000 "for the construction of a deep waterway along the route between Lockport and Utica and for the equipment and maintenance of dams, locks, bridges and power plants for the development and utilization of water power." The Sanitary District of Chicago has expended upon the Lakes to the Gulf Deep Waterway project something like $80,000,000. The United States has been asked to co-operate to the extent of $16,000,000.

12.—THE SANITARY DISTRICT OF CHICAGO.

The Sanitary District of Chicago was created in accordance with an act of the Illinois Legislature in 1889, authorizing the creation of sanitary districts "whenever

any area of contiguous territory within the limits of a single county shall contain two or more cities, towns or villages, and shall be so situated that the maintenance of a common outlet for the drainage thereof will conduce to the preservation of the public health."

The corporate authority of the District is lodged in a Board of Trustees composed of nine elective members. This body has full power to pass ordinances for the conduct of their business, which is to "provide for the drainage of such district by laying out, establishing, constructing and maintaining one or more channels, drains, ditches and outlets for carrying off and disposing of the drainage (including the sewage), of such district, together with such adjuncts and additions thereto as may be necessary or proper to cause such channels or outlets to accomplish the end for which they are designed in a satisfactory manner."

The Sanitary Act does not require that sewerage systems of incorporated cities within the Sanitary District should pass immediately under the control of the trustees, but upon the completion of the main channels and adjuncts all auxiliary channels and drains may pass under their control. The main object of the act is to provide for the construction of main channels through which the drainage and sewage of the District may be discharged, and the bringing of the sewage of the District into such channels.

The District may borrow money and issue bonds therefor, and may provide for the collection of a direct annual tax to pay the interest and retire the bonds covered by its obligations.

The area of the Sanitary District when it was instituted was 185 square miles; it is now twice this size. In 1903, large additions to the original territory were made to the north and south, and subsequently some land was added to the west. The total area in 1914 was 386.2 square miles.

The northern part lies in the drainage basin of the Chicago River and the southern in the basin of the Calu-

met. According to the United States Census figures, the population of the Sanitary District in 1910 was 2,311,810; of the Calumet, 134,370. The population of the District is about 97 per cent. of the population of the county.

The Calumet region comprises that part of Chicago which lies south of 87th Street, Chicago, the Township of Calumet and parts of three other townships which lie wholly in the Calumet drainage basin. The whole basin of the river is not confined to the Chicago Sanitary District or to the State of Illinois. Much of it lies in the State of Indiana, and the rapidly increasing population upon it is not capable of sanitary regulation by the District.

The Illinois Legislature which annexed the northern and southern territories to the Chicago Sanitary District provided that these two areas should be drained by canals through which the sewage should flow with dilution water at the same ratio as the sewage which flows through the main Sanitary and Ship Canal of Chicago. Authority was also given to construct such adjuncts to these drainage canals as might be "necessary or proper to cause such channels or outlets to accomplish the end for which they are designed in a satisfactory manner."

The main channel which reversed the flow of the Chicago River, controlling works, bridges and right of way had cost about $26,600,000 up to January, 1912. The Chicago River, between Lake Michigan and the beginning of the canal at Robey Street, was improved and bridges built at a cost of $10,920,000. The North Shore Channel, which runs from Wilmette and the lake to the North Branch of the Chicago River at Lawrence Avenue, and which provided an outlet for the sewage of the city of Evanston and the towns of Kenilworth, Glencoe, Winnetka and Wilmette, cost $3,205,000. The Calumet-Sag Channel, now under construction, is estimated to cost about $6,700,000.

In addition to providing for sewage disposal, the District has developed a large water power at Lockport, and is generating electric current which is furnished to the

City of Chicago, the County, the park governments and other municipal corporations.

13.—TOTAL COST OF THE WATER AND SEWAGE WORKS

The work done by the Sanitary District from its creation to January 1, 1913, has cost approximately as follows: Construction of the Drainage Channel and controlling works, $19,813,197; right of way, $9,703,018; bridges, $6,633,073; North Shore Channel and Wilmette Pumping Station, $1,450,986; Chicago River diversion and North Branch improvements, $3,666,720; flushing and sewers, $782,150; Joliet project, including bridges, $1,601,104; miscellaneous, $167,404; administration, engineering, legal and clerical expenses, $6,658,923; damages, lands, marine, personal, $276,782. The contract work and dredging in 1913 and 1914 was estimated at $2,386,085.

The city of Chicago is stated to have spent the following sums toward the completion of the main drainage scheme: Intercepting sewers, land, etc., $5,312,025; Fullerton Avenue Pumping Station, $115,309; Lawrence Avenue Pumping Station, $452,636; Thirty-ninth Street Pumping Station, $944,144.

By allowing bond interest and interest on the cost of construction pending the completion of the works, a total of $76,067,582 has been computed by the Sanitary District as the entire cost of the present scheme of disposing of the sewage. The annual cost of the project is stated to be $508,832.

It is estimated by the District that the total capitalization and construction cost of the Calumet-Sag Channel will be $19,449,470 when developed for 2,000 cubic feet.

The city of Chicago has spent on sewers, exclusive of intercepting sewers, $31,867,269 from 1855 to January 1, 1912. The sewers in the outlying towns have cost $5,246,764.

The water supply of Chicago up to January, 1913, had cost $49,948,318, and the outlying towns in the Sani-

tary District have spent about $2,000,000 additional on water works. No allowance is made for interest during construction in these figures.

Adding the expenditures of the Sanitary District, the City of Chicago and the outlying towns for sewage and water makes a total of $150,908,189.

Part III

WATER SUPPLY

The history of Chicago's water supplies is an account of efforts to get water of a sufficient degree of purity, and at the same time keep pace with an unprecedented increase in the consumption. From the time of its first settlement to the present day, the city has had trouble with the quality of its water supply, and although the supply has been greatly improved from time to time, the increasing quantities of filth to be disposed of and the more and more exacting requirements of purity have rendered the water problem peculiarly difficult.

To a considerable extent, the argument for the Drainage and Ship Canal was an argument for clean water, for although the commercial advantages of the undertaking had some weight and the desire to abate the nuisance of the Chicago River was also a strong moving factor, the need of keeping the sewage away from what has always been considered the only possible source of water for the city was felt to be a prime necessity.

Throughout its history, Chicago has looked upon Lake Michigan not only as the single source of drinking water available, but one which would be ideal, if it could be protected from sewage.

Practically every city and town on the Great Lakes which is large enough to have water works obtains its public drinking water from the lake upon which it is situated and into which it discharges its sewage, the total population thus supplied exceeding 5,000,000 in 1913. The next largest city after Chicago to use water from the lakes is Cleveland, on Lake Erie, with an estimated population in 1913 of 622,699 and typhoid death rate of 14.2. The Cleveland intake is about four miles from shore. Im-

proved methods of sewage disposal and the purification of the water are being introduced at both Cleveland and Milwaukee, the two great cities nearest to Chicago on the Great Lakes. Buffalo and Detroit, each with a population over 450,000, use lake water and their typhoid rates in 1913 were 15.8 and 17.3, respectively.

The intakes which are built by the lake towns run out from shore for varying distances up to four miles and into water seldom exceeding 50 feet. A depth of 50 feet is considered desirable in order to avoid turbid water. The Detroit intake is in 75 feet of water and the Oswego intake is in 83 feet, but these are exceptional. The largest intakes are tunnels; the smallest are pipes laid on the lake bottom.

In most cases, an attempt is made to avoid pollution by placing the intake as far as practicable from the principal locality where the sewage is discharged, and at such a point that the natural drift of the lake currents will carry the sewage away, and not toward, the intake. In most cases it is impossible to avoid occasional pollution for, in spite of the fact that a considerable amount of study has been given to the subject by various governmental agencies, comparatively little is generally understood concerning the horizontal and vertical movements of the water under the influence of wind and temperature changes. The surface and bottom currents may, and often do, flow in opposite directions.

In an admirable review of the conditions under which public water supplies are taken from the Great Lakes, Professor Whipple states as follows:*

> "The evidence is conclusive that natural methods of purification cannot be depended upon to protect the sanitary quality of the water supplies taken from the Great Lakes. Practically every city, whether great or small, that has depended solely upon the protection afforded by dilution and a supposedly remote location of the intake from the sewers has suffered from water-borne diseases. As a rule the smaller cities have suffered

*Sanitary Protection of the Water Supplies taken from the Great Lakes, by George C. Whipple, Eighth International Congress of Applied Chemistry, Vol. XXVI, p. 298.

more than the large cities as their water supply intakes and sewer outfalls are nearer together. The visitations of typhoid fever have often been intermittent, and their failure to occur at regular seasons engenders a false sense of security; but sooner or later, when the necessary combination of currents and infection occurs, every lake city that fails to protect its water supply is bound to suffer from water-borne diseases."

Dr. McLaughlin of the United States Health Service has classified American cities according to the typhoid statistics as having water supplies which are (1) safe, (2) subject to intermittent pollution with great dilution of polluting material, (3) liable to intermittent and occasionally gross pollution and (4) exposed to gross, constant pollution.

In class 3 are Cleveland, Detroit, Buffalo, Milwaukee and Chicago. Commenting on this class, Dr. McLaughlin says:*

"These water supplies are not safe. The pollution, though intermittent and diluted, may be responsible for many cases in the winter and spring months. In these big progressive cities the other conditions bearing upon typhoid prophylaxis are apt to be good, and a rather low typhoid rate is usually the result."

1.—THE FIRST PRIVATE SUPPLIES.

The first water supplies of Chicago were obtained from private wells dug in the sand and clay to a depth of from six to twelve feet. The excrement of the inhabitants was emptied into privy vaults which were sunk into the same soil and often in close proximity to the wells. As the vaults were seldom tight, and as dish water and other household slops were commonly thrown upon the ground on individual premises, or in the streets, where the wells were located, it is not strange that the drinking water of the growing municipality often became contaminated. The Illinois State Board of Health Report of 1901 quotes an early resident of Chicago, writing in the Sanitary News in 1884, as follows:

*Sewage Pollution of Interstate and International Waters with Special Reference to the Spread of Typhoid Fever, by Allan J. McLaughlin; Hygienic Laboratory Bulletin No. 77, July, 1911, p. 26.

> "In time the water drawn from the wells began to taste—a little brackish at first, then saltish and then it had a perceptible odor which ultimately became offensive. A well at length had the odors characteristic of a privy vault. When it rained, the water in the well and privy vault rose accordingly; unless the prudent householder 'banked' the latter it often overflowed."

The unsatisfactory water to be obtained from wells brought a new enterprise into existence. Water was brought from the lake in hogsheads mounted on wheels and drawn by horses. The vehicle was backed into the lake, often at the foot of Randolph Street, and filled by means of buckets. The driver then proceeded through the streets and sold the water to those who wanted it. This custom continued up to 1846, at which time the population was about 14,000.

The first official action toward a public water supply was on November 10, 1834, when the Board of Trustees of the Village of Chicago appropriated $95.50 for digging a public well on Michigan Avenue to supply a small colony on the North Side. According to Andrea's History of Chicago, "the settlers early cast longing eyes towards the lake, realizing that that source of water supply was the true one and not to be compared to the sluggish and unprepossessing river" from which many poor people from necessity were compelled to get their water.

In March, 1836, the Chicago Hydraulic Company was incorporated by special act of the Legislature, and in 1840 it laid an inlet pipe, about fifteen inches in diameter, five hundred feet into the lake at the foot of Van Buren Street. On shore was a tank of about 600 barrels capacity, raised slightly above the surface of the ground. A 100 horse-power engine raised the water into the tank, from which it flowed through a system of pipes made of pine logs bored by hand and bound with iron hoops. The company existed about fifteen years, although it appears that about 80 per cent. of the inhabitants obtained their water from wells or water carts.

2.—THE FIRST PUBLIC SUPPLY.

In 1847 the water supply was of a quality which called for purification, and in 1854 the city put its own water works into operation, having bought out the Hydraulic Company. The population was then estimated at 75,000. The water was taken from an inlet basin at the foot of Chicago Avenue, the basin being separated from the lake by a semi-circular breakwater with an opening to the southeast. The distance from this intake to the mouth of the Chicago River was about 3,000 feet. From the Board of Health Report of 1901, already quoted, it appears that:

> "Already the discharge of sewage into the lake from the river had caused annoyance and an alternative location for the pumping works at a considerable distance south of the Chicago river was suggested, but it was not considered of sufficient moment to change the location from that given above."

The rapid growth of the city, which occurred soon after the introduction of the sewerage system and the opening of the water works, together with the establishment of the packing industries, distilleries, etc., so increased the quantity of filth discharged into the lake by way of the river, that complaints began to be made of the offensiveness of the water supplied by the city pumping station. In 1860 there were over 100,000 people living in Chicago, and probably about 2,000 head of cattle, hogs and sheep were killed per day.

3.—ATTEMPTS TO SECURE UNPOLLUTED LAKE WATER.

During 1860 five plans were considered for obtaining water of the desired degree of purity: (1) By extending the intake one mile into the lake; (2) By building a tunnel one mile under the lake; (3) By locating the pumping works at Winnetka to the north of the city; (4) By constructing filter beds; (5) By erecting a subsiding reservoir.

The policy of attempting to avoid the pollution by taking the water farther from the source of the polluting

matter, on the theory that the dangerous materials would remain near shore, began at this time, 1862, and continued until the intakes could not well be located farther out in the lake. The desirable depth of 50 feet for water intakes cannot be obtained here at a distance less than from 10 to 15 miles from shore and to build tunnels that far into the lake is considered impracticable under the existing conditions.

In all, six intake cribs have been constructed, as follows: The Lake View Crib, which is soon to be abandoned, is at the northern extremity of the city and takes its water at a depth of 21 feet below the lake surface, at a distance of two miles from shore; the Carter H. Harrison crib, draws its supply 25 feet below the surface, three miles from shore; the Two Mile Crib has intakes 28 feet, 18 feet and 6 feet beneath the surface, two miles from shore; the Four Mile Crib takes its water 30 feet below the surface at a point about four miles from shore, and opposite the most densely populated portion of the city; the Sixty-eighth Street and Edward F. Dunne Cribs are two miles off shore, opposite the southern extremity of the city and take in their water 28 feet and 23 feet below the surface, respectively. From these cribs, tunnels extend under Lake Michigan to points on land, more or less removed from the shore, where pumping stations are located to pump the water through the distribution system. The Lake View Crib is to be abandoned. The cost of the water works, including the intakes, pumps and distribution system has been over $59,942,000.

More than half of the total consumption is taken from the Two Mile Crib and the Carter H. Harrison Crib, extending into the lake from a point on shore within one mile of the mouth of the Chicago River. The Four Mile Crib starts from a point a little more than one mile south of the river.

The water is pumped by means of twelve principal pumping stations, which are more or less connected with one another, directly into the mains which supply the consumers. The total pumpage in the year 1913 was 209,-

421 million gallons, of which the actual consumption in Chicago was 188,902 million gallons. The average daily consumption was 518 million and the maximum daily consumption was 608 million gallons. The per head consumption was 218 gallons per day. At the end of 1913, 22.5 per cent. of the consumption was metered.

Most of the water is delivered to the consumers without treatment. At the Lake View Crib, which supplies a part of the North Side, a permanent chlorination plant has been constructed and temporary structures for chlorinating the water of the Sixty-eighth Street and Edward F. Dunne Cribs were put in service in May, 1912.

4.—THE TWO-FOLD REQUIREMENTS OF PURITY.

The water supply problem consists in securing such a quality of water as will satisfy the needs of the city so far as health is concerned and satisfy reasonable aesthetic demands. Neither of these two can be neglected. The water must be wholesome and it must look so. It is not enough that it shall not produce any measureable effect upon the public health. If Chicago is not to take its place behind other cities of its class, if it is not to subject itself to the criticism of many of its own citizens and a very large part of the traveling public, the water must be bright and sparkling. Turbidity, such as occurs at times of storm, arouses distrust.

That the turbidity is explained on the ground of admixture with lake sediment stirred up by the waves in no wise reassures those who are familiar with the windy weather of Chicago and have seen the clouds of dirt and smoke which are blown from the city out over the water. The town is literally swept and cleaned by these breezes, and great quantities of refuse, not always finely comminuted, accumulate on the bottom, far out into the lake. The authors of this report have seen the nets of fishermen so filled with leaves and grass, when set at points ten miles from shore, that it has taken hours to clean them. It would appear that a considerable part of the turbidity which at times makes the water supply unsuitable

for drinking purposes, and much less inviting for bathing than it should be, is due to the dust and dirt of Chicago.

One element of the water problem, then, is the securing of a water from which the turbid appearance is eliminated.

5.—THE EXISTING DANGERS OF POLLUTION.

On the score of danger of disease, the facts indicate that there is some risk of pollution from the Chicago River, some from the dumping of dredgings, some from passing boats and perhaps some from the discharge of sewage which is contributed by communities over which Chicago has, and can have, no proper control. The character of these kinds of pollution is the same. None of these dangers is continuous or uniform; all are occasional. They depend upon conditions which come into action at intervals more or less frequent, depending largely upon accidents of weather and of navigation.

There is a danger in the occasional pollutions which is likely to be disregarded by persons who are not familiar with the history of epidemics. It is too often assumed that it is the average purity of a water supply which should be taken as the gauge of its excellence, whereas it is not so much this mathematical figure as the data which compose it that should be taken into account. It is necessary to know the worst conditions which are likely to occur and how often they may be expected. Commenting on this aspect of the case, the sanitary experts of the International Joint Commission well say:*

> "It is difficult for some officials to understand, without a severe lesson, that it is not sufficient to have a water supply that is safe for 360 or 361 days in the year, and to these officials it seems scarcely justifiable to require expensive purification for the sake of the four or five days in the year which, due to weather conditions, pollution may take place. Such a supply, with a favorably placed intake, may escape pollution for more than a year. There was no evidence of serious pollution of the water supply of the city of Erie from 1909 to De-

*Progress Report of the International Joint Commission on the Pollution of Boundary Waters, January 16, 1914, p. 22.

cember, 1910, yet the appalling disaster of January and February, 1911, showed that pollution could take place under certain weather conditions. Many similar examples might be cited."

6.—POLLUTION FROM THE CHICAGO RIVER.

It is scarcely supposable that the water of the Chicago River never discharges into the lake. In view of the fluctuations of the lake level which occur and particularly of heavy rainfalls and sudden strong winds from the west, it would appear inevitable that some of the water of the main stream should be carried out into the lake and not pass back through the Sanitary and Ship Canal. In connection with this matter, it is to be remembered that the level of the water in the river can be intentionally changed only by raising or lowering the dam at the regulating works at Lockport and that it takes an appreciable time for the effect of this movement to be felt at the lake end of the Chicago River. Observations are lacking, so far as the authors of this report are aware, to determine whether the water ever flows toward the lake, and, if so, to what extent and for how much of the time.

7.—POLLUTION FROM BOATS AND DREDGINGS.

The possible pollution from boats would seem within the range of the authorities to control by suitable ordinances, vigilant inspections and the exclusion of shipping from the water areas in the neighborhood of the intake cribs, and yet it is by no means certain how reliable such protection can be made. The danger from this kind of pollution may be very great.

Dredged material has in former years been dumped in various areas in Lake Michigan, designated and authorized by the Secretary of War; but, under an Act of Congress, approved June 23, 1910, dumping is forbidden in the lake nearer than eight miles from the shore, unless placed behind bulkheads where the material cannot run into the lake. Although the eight-mile limit is none too great, if this requirement was complied with, it is probable that there would be little cause for complaint. It is hard

to believe that the material dredged from "Bubbly Creek" and other excessively polluted places, could fail to produce evil consequences if discharged within reach of the intakes.

According to the United States Census reports, over 14,000,000 persons take passage on lake vessels each year and the investigations of the International Joint Commission show that practically all discharge their excrement to the water through which they pass. Through the efforts of Health Commissioner Young of Chicago the worst of this pollution, that from passenger and excursion steamers, has been practically eliminated at Chicago, but it is impossible to wholly stop it. Six thousand vessels enter and leave Chicago yearly.

Another evil practice attributed to lake vessels is the taking of water ballast in polluted harbors and its subsequent discharge, frequently within a short distance of some water works intake. The emptying of a shipload of water, as unfit to drink as that of the Chicago River, at one of the intake cribs might lead to results of the most serious character. The infectious material which was discharged from a boat might be relatively fresh and virulent and enter the water supply with little opportunity for destruction and dilution.

8.—POLLUTION BY OTHER MUNICIPALITIES.

The possibility that the Chicago water supplies may become polluted by the sewage of other municipalities is a danger which is not only real, but one which is understood to exist at the present time. The southernmost crib is at times affected by the drainage of the large and increasing settlements to the south in the States of Illinois and Indiana. Thus far it has been impossible wholly to avoid this danger, and although extensive works are projected by the Sanitary District to divert the sewage of the Calumet to the Illinois River, as has been done with the sewage of Chicago, it is by no means clear that works of their kind can give this intake the protection which the circumstances require. The Chicago drainage area

is much smaller than that of the Calumet, and it was much easier to divert the flow of the Chicago River to the Illinois than it would be to reverse the larger body of water in the Calumet. The problems presented by the two watersheds are similar, but the scale is so different that the solution which has been found for the smaller cannot be applied to the other.

9.—THE LAKE MICHIGAN WATER COMMISSION'S FINDINGS.

In 1908 Chicago undertook to bring about concerted action among the cities and states along the shore of Lake Michigan with the object of investigating the conditions of water supply and sewage disposal in that region.

An association was formed, consisting of official delegates from the various governmental interests concerned. The name of this body was the Lake Michigan Water Commission. There were representatives of the United States Public Health Service, the United States Army, the States of Wisconsin, Illinois, Indiana and Michigan and of the most important cities on the lake shore. Reports were printed in 1909 and 1911.* The Commission is still in existence, but it has been inactive for some years.

The Lake Michigan Water Commission found that in Wisconsin there were twenty-six cities and towns, with an aggregate population of 500,000, which were located on the shore of the lake or on the territory immediately tributary to it. In that part of Illinois which drains into Lake Michigan there were, beside Chicago, a number of cities and towns which discharged to the lake a total of 7,000,000 gallons of sewage per day. In the State of Michigan eighteen municipalities discharged into the lake the sewage of an aggregate population of 200,000. From the State of Indiana there was emptied into the lake the sewage of about 100,000.

A large and rapidly growing population discharged its sewage into the Calumet River, and this stream, which

*First Report of the Lake Michigan Water Commission, Urbana, Ill., 1909.

flows into Lake Michigan immediately south of Chicago, was described as "unspeakably vile and putrescent." Added to the sewage was a large amount of waste from glucose factories, steel mills, oil refineries and other works. The sewage of that part of Chicago which lies south of Eighty-seventh Street emptied into the lake through the Calumet.

The commission found evidence of the pollution of the lake water in analysis and in the vital statistics of the municipalities which took their drinking water from the lake. Excessively high typhoid rates existed in many of these places and the water of those which took their supplies from the lake were generally contaminated.

Study showed that there were no regular currents in Lake Michigan; the water might flow in any direction, according to the wind, and might attain a velocity of three miles per hour, or more. The delegate who stated these facts was Major W. V. Judson, Corps of Engineers, United States Army, and his paper is published in the First Report, pp. 65-66.

The report says:

> "We are thus led to the conclusion that the all important agency in producing currents is the wind.
>
> In general, although there are many exceptions to the rule, it may be said that all winds produce surface currents, and these currents move with the wind. It is believed that the travel of the surface currents is something like 5 per cent of the wind travel. The depth of the surface current is something like 30 to 40 feet. As great velocities as 1.6 miles per hour have been accurately measured, and it is probable that these currents travel as rapidly as 3 miles per hour during storms.
>
> Surface currents cause counter currents in deep water which are not necessarily exactly opposite in direction to the surface currents."

As a result of its investigations, the commission expressed the opinion that localities even twenty or thirty miles from the point of entrance of large quantities of sewage were "not safe places from which to derive water for domestic use."

In the autumn of 1909 an investigation was made

of the lake water to the north of Chicago. The investigators were Langdon Pearse, of the Sanitary District of Chicago, F. O. Tonner and Dr. Edward Bartow, Director of the State Water Survey of Illinois. Samples of the lake water from Chicago to Waukegan, a distance along the shore of 23 miles, were analyzed chemically and bacterially, distances out into the lake up to five miles being included.

Over a dozen villages and towns lie along the shore in this territory. The chemical results confirmed the bacterial data and both were in general agreement with what might be inferred from an inspection of the conditions of drainage.

The authors concluded that the lake was not a safe source of drinking water supply in the region covered by their study. The examinations showed that the water was decidedly polluted, and with winds from certain quarters, fecal pollution might reach out three or four miles.

The condition of that part of the lake which borders Indiana and adjoins Illinois was investigated by H. E. Barnard, Chemist of the State Laboratory of Hygiene, and J. H. Brewster, Water Chemist.

The Indiana cities extend around the whole southern end of the lake and run from Michigan City to Chicago, a distance of about 35 miles. The chief sources of pollution were the Calumet River, which was described as a trunk sewer, the discharge of local sewers into the lake, including the effluents from numerous manufactories, shore and bottom wash due to winds and currents, the dumping of dredged material, and accidental pollution by shipping.

The chemical and bacteriological data collected convinced the investigators that the water around the southern end of the lake was grossly polluted, and unfit for use as a source of water supply for drinking and domestic purposes. The discharge of the Calumet River materially affected the potability of the water of Lake Michigan for a distance from its mouth of over ten miles in every direction, depending on the wind and the currents in the

lake. The water supply of Chicago felt the effect of the pollution. The distance from the river to the intake of the Sixty-eighth Street Crib, measuring around the end of the Government breakwater, was about four and one-half miles.

10.—THE LAKE WATER AT CHICAGO.

The lake was examined along nearly the whole water front of Chicago, in the late summer of 1908, by Dr. J. F. Biehm, Director of Laboratories, Chicago Department of Health, and the results will be found in the First Report of the Lake Michigan Water Commission, p. 109.

Within one mile of shore there was no point where B. coli was not found, in samples of 1 c. c. The area of occasional pollution extended out about three miles. The Carter H. Harrison and Two Mile Cribs were constantly surrounded by a zone in which B. coli were found in over 60 per cent. of the samples.

The purest water was found at points twelve to fifteen miles out. These contained 10 to 37 bacteria per c. c. cultivated in agar and counted after 96 hours. The most polluted samples at Chicago contained 60,000 bacteria and were collected south of the Chicago River and within the harbor limits. At the mouth of the Chicago River the count was 280 to 3,000. The numbers gradually rose as the river was ascended, until just below the junction of the North and South Branches the number was 8,000,000.

The quality of Chicago's water supplies is watched by the Chicago Department of Health, and through the courtesy of the Commissioner, Dr. G. B. Young, the detailed records of the analyses for 1914, and summaries of the analyses for 1913, have been placed at the disposal of the Board of Experts. In the year 1914 the number of samples analyzed was 1900. The samples were collected throughout the year so as to show the condition of the water taken in all the cities and principal pumping stations. The examinations included determinations of the numbers of bacteria which develop at 20 degrees C. in

gelatin and in agar, and at 37 degrees in agar. To those who are not familiar with water analysis, it may be explained that the 20 degrees count is chiefly useful in indicating the relative amount of organic matter present and the number developed at 37 degrees (body temperature) is nearly specific for intestinal organisms. B. coli, which are fecal bacteria, are determined in 1 c. c., and 10 c. c.

The turbidity is usually determined twice each month. Turbidities of about 10 in the scale recommended by the Committee on Standard Methods of Water Analysis of the American Public Health Association occur frequently, and of 60 to 70 at long intervals. The water from the three cribs nearest the mouth of the Chicago River had a turbidity of 10 or more in 90 out of 142 tests. Nearly all the months were represented.

In interpreting the results of the bacterial analyses, the Board of Experts has followed the criteria employed by the experts of the International Joint Commission* which examined over 19,000 samples of water from the Great Lakes, and whose experience entitles them to be regarded as authorities in connection with this subject. The investigations showed "that the colon bacillus is practically never normally present in the unpolluted waters of the lakes and that the normal total bacterial count in nutrient agar (+10) of the Great Lakes waters is below 10 per c. c." According to the Joint Commission's experts, the line which separates a satisfactory degree of purity from a state of "considerable pollution," requiring careful purification, is where the B. coli number from 10 to 20 per 100 c.c.; that is, are sufficiently numerous to appear in 10 c. c. of the water. Under such circumstances, the number of bacteria which develop in agar (+10) at 37 degrees C. is usually 25 to 50. Twice this is "serious pollution" and should be avoided, if possible, even when the water is to be purified. Still more is gross pollution. Purification is not enough for this water;

*Progress Report of the International Joint Commission on The Pollution of Boundary Waters, including the Report of the Sanitary Experts, dated January 16, 1914, p. 20.

the "sources of pollution should be eliminated or nullified." Water which is so impure as to contain B. coli in 1 c. c., which is 1,000 per 100 c. c., is dangerous in the extreme.

In using these criteria, it should be explained that the lines separating the different classes of water are not positive and inflexible, and that the standard is applied here because it appears to be a reasonable and suitable one under the circumstances. Judged by this standard, Chicago's water supplies are at times seriously polluted and unsafe for drinking purposes. The pollution is occasional, but unquestionable, and, at times, intense.

For a large part of the time the supply is of exceptional purity for a surface water, the number of bacteria which can be cultivated at 20 degrees C. being well below 100, the 37 degrees count below 5 and no coli being found in samples as large as 10 c. c. At other times, the water is polluted according to every test that can be applied to it. Criteria which are less exacting than that which the experts of the Joint Commission have found to be suitable for the water of the Great Lakes would condemn it. The 20 degrees counts and 37 degrees counts run into the hundreds and even thousands, and B. coli are found in 10 c. c., 1 c. c., and, on rare occasions, .1 c. c. of the water.

The onset of the dangerous periods is sudden and they disappear gradually. They are of all degrees of severity. The water of some intakes is much worse than the water of others. Under the circumstances, it is difficult to resist the temptation to strike averages in the hope of arriving at an opinion as to the condition of the water most of the time. This proceeding is, however, certain to lead to a misconception of the facts.

The records for 1914 show that the Lake View Crib, the Two Mile Crib and the Sixty-eighth Street Crib supply the worst water. In 1914 there were 214 samples taken of the water at the Lake View Crib, representing 86 days. In these samples B. coli were found 44 times in 10 c. c., and 9 times in 1 c. c. There were 12 times when the bacterial count exceeded 25 per c. c., when developed

in agar at 37 degrees C. and 6 times when this count exceeded 50. Among the four pumping stations handling this supply somewhat better water was found at the Norwood Park and Jefferson Park pumps and worse at the Lake View works.

The Two Mile Crib water was examined 252 times. B. coli was found 67 times in 10 c. c. samples and 15 times in samples of 1 c. c. The 37 degree counts exceeded 25 on 25 occasions, and 50 a dozen times. The water examined at the Twenty-second Street Pumping Station was a little better, but that at the Chicago Avenue Station was much the worst water recorded for any crib or station in the whole year. Of 271 samples, B. coli were found 126 times in 10 c. c. and 28 times in 1 c. c. In nearly half of these cases the water was not fit to drink, according to the International Joint Commission's standard.

The water from the Sixty-eighth Street Crib was next to the worst. Out of 185 samples representing 70 days, 34 contained B. coli in 10 c.c. and 9 in 1 c.c. There were 25 or more bacteria developed per c.c. in 37 deg. counts on 22 occasions, and 50 or more on 11 occasions. The results for the Sixty-eight Street Pumping Station, which is the only one connected with this supply, were in agreement with the foregoing results.

11.—NECESSITY FOR PURIFYING THE WATER.

Disinfection has been used at Chicago to some extent, as a means of meeting the occasional pollution of a dangerous character. This idea has simplicity and economy to recommend it. Sterilization is not, however, capable of improving the appearance of the water and removing the visible effects of the shore pollution. There is the further objection to this treatment that it is likely to be regarded only as an emergency measure and may be out of operation when most needed. At best, chemical disinfection is an expedient which should be resorted to only in those cases where better and more continuously efficient results cannot be secured.

If the problem was simply one of bacterial purity, the

proper remedy would doubtless be disinfection, because of its economy. But it is more than that. At times of storm, the water becomes decidedly turbid. According to the analyses of the Chicago Department of Health, the maximum degree of turbidity, or cloudiness, at different times during the course of the year, is usually between 60 and 70. This is twice the turbidity which generally causes remark and complaint among persons who use water for domestic purposes, and ten times that which is considered permissible for the best water supplies.

The turbidity varies greatly, being contingent on whether or not the violent storms which occur displace much material from the shores. In the Fall of 1913, a storm of unusual severity sent the turbidity up to 300, near which point it remained ten days at least. Some idea of this degree of muddiness can be had from the fact that an ordinary pin could not be seen beneath two inches of this water in strong daylight.

There are, in general, two ways of clarifying turbid waters: by sedimentation in large basins and by filtration. Of these, filtration is alone suitable for Chicago, by reason of the lack of space which is required for basins and the high degree of purification demanded. Filtration is entirely feasible and that type of filter in which a coagulant is used and the rate of purification is very rapid, is likely to prove the most suitable. Good mechanical filters, if connected with the present pumping stations, would be capable of removing the turbidity and affording, with proper care of the lake, all the protection which the water supply will require.

There is no doubt in the minds of the authors of this report that the City of Chicago must sooner or later adopt filtration for its entire public water supply. It can be installed upon a reasonably small scale, and where most needed, and subsequently extended as the requirements demand. The process is neither experimental nor novel. It is based upon principles which have been carefully studied and practiced for many years. From the observations and information gathered by the authors of this re-

port while in Chicago, it appears feasible to find suitable locations for the works at various points along the Lake Shore front. The works would in no sense destroy the attractiveness of the locality.

12.—QUANTITY OF WATER AVAILABLE AND REQUIRED

The quantity of water available for domestic consumption is unlimited, for no matter how small may be the supply of diluting water for the Drainage Canal allowed by the United States Government, it is inconceivable that any restriction will be placed upon the requirements for domestic consumption.

It is perhaps largely due to the inexhaustible supply of lake water at hand, and which is to be had merely for the pumping, that Chicago's consumption is so great. The rate for 1913 of 218 gallons per head per day is excessive even for American cities, whose generous use of water appears to European engineers to be lavish and inexplicable Many cities in Europe get along tolerably well with one-tenth of this allowance.

In an interesting paper read May 19, 1913, before The Western Society of Engineers, John Ericson, City Engineer of Chicago, described the water works and called special attention to the large per capita consumption.* In the course of his remarks Mr. Ericson said:

> "The total quantity of the pumpage during last year would fill a lake averaging ten miles in length and four miles in width to an average depth of nearly 30 feet. It is equivalent to 203 gallons, or a barrel 3 feet in diameter and 4 feet high full of water, for every man, woman and child in the city every day in the year, if equally distributed. Of course, in these figures is included all the water used by the stock yards, manufacturing, and other great water-consuming establishments. And yet we hear a constant cry for more water—more water. To satisfy this enormous thirst of our citizens, the city administrations, which are changed every two or four years, under prevailing conditions, must go on adding one system after another, at the cost of millions upon millions of dollars."

*Journal Western Society of Engineers, Oct., 1913, pp. 763-796.

Careful investigation by the Water Survey Division of the Bureau of Engineering showed that the water actually delivered into the mains is distributed about as follows:

(1) 40 gallons per day per capita go to frontage consumers.
(2) 47 gallons per day per capita go to meter consumers.
(3) 10 gallons per day per capita go to free service.
(4) 5 gallons per day per capita slip through meters unregistered.
(5) 40 gallons per day per capita are lost through leaky plumbing fixtures.
(6) 61 gallons per day per capita are lost through wilful wastage and underground leakage in mains and service pipes, etc.

A further analysis of what becomes of the water supply and a discussion of the utility of meters in restricting the waste, together with a large amount of other valuable information relating to the Chicago water works, are contained in a report by Mr. Ericson, which was transmitted to the Mayor and Council on November 20, 1911, by the Commissioner of Public Works.* The purpose of the report was to present a statement of the condition and needs of Chicago's water supply system with recommendations for immediate improvements, and an orderly plan of development for a term of years.

In other cities, the allowance of water per head varies greatly according to their industrial or residence character and the cost of the water. Railroads and manufacturing establishments and high class hotels and residence apartments are large consumers. The quantity ranges in most American cities from 20 gallons to over three times this amount for purely domestic purposes.

According to the report of a Committee of the New England Water Works Association, the total consumption of water in 67 Massachusetts cities and towns in 1910 averaged 63 gallons per head per day.† The consumption of water per head per day in some of the largest American

*Journal of the Proceedings of the City Council of the City of Chicago, Nov. 20, 1911, pp. 1650-1670.

†Journal of the New England Water Works Association, March, 1913.

cities in 1913 was as follows: New York, 96 gallons; Philadelphia, 178 gallons; Boston, 108 gallons; St. Louis, 117 gallons; Cincinnati, 126 gallons; Cleveland, 107 gallons; Milwaukee, 112 gallons.

The tendency in most cities is for the rate of consumption to increase. An increase of five gallons per head per day every ten years was considered reasonable to expect by the Milwaukee Sewage Disposal Commission in 1910. Chicago's rate increased from 203 to 218 in 1913.

Many cities have sought to decrease their consumption by the introduction of meters and most of them have been signally successful. But meters do not of themselves check waste: it is the intelligent use of the data which they supply which is capable of accomplishing the desired results. There must be a public opinion favorable to a saving in water consumption in order for restrictive measures to be effective.

How large an allowance should be made for Chicago's consumption of water in the future depends largely upon the attitude which the public will hold toward the curtailment of unnecessary waste and the requiring of consumers to pay for what they take. Three hundred gallons per head per day seems to be an excessively large figure, and yet it has been used by some in estimates intended to show how great would be the cost of treating Chicago's sewage. At this rate, the water supply in 1940, assuming the estimates of population by the Chief Engineer of the Sanitary District to be correct, would be 1,230,000,000 gallons per day.

Part IV

SEWAGE DISPOSAL

1.—THE FIRST ATTEMPTS AT SEWERAGE.

The earliest attempts at drainage were based upon principles which were later found to be incorrect. The ground was low and flat and the inexperience of the day suggested that the streets be dug down and an attempt made to carry off the surface water in sluices. Next, an attempt was made to lay pavements and sewers upon the natural surface of the ground and allow the sewage to run off in the gutters.

By 1850, when the population was about 28,000, many of the populous localities were described as noisome quagmires, the gutters running with filth or clogged up, forming stagnant pools of indescribable liquid. The trouble was aggravated by the fact that many of the streets were planked, so that some of the drainage collected and fermented beyond the reach of water, broom or disinfectant. Cholera was at times prevalent and it was believed that want of proper drainage was in part responsible for it. Between 1849 and 1854 the death rate was 48-50 per 1,000. The stockyards were started in 1848.

By act of Legislature, in 1852, a board of sewerage commissioners was provided. In two years, this body expended $100,000 in building sewers and ditches and otherwise improving the low land. The population was growing rapidly; in 1853 it was 60,000, and in 1855 80,000. By 1854 four and one-half miles of sewers had been put down, at a depth of five to eight feet below the surface of the principal streets in the business part of the city, emptying into the Chicago River. The results obtained by these early efforts were regarded as measurably satisfactory;

but the drainage scheme was but little more than experimental and the sewers of a temporary character.

2.—ORIGIN OF THE PLANS FOR THE PRESENT SEWERAGE SYSTEM.

A bill was passed by the Legislature on February 4, 1855, creating a board of sewer commissioners to be appointed by the city council. This board proceeded to select the most competent engineer of the time who was available for the position of chief engineer: E. S. Chesbrough, for five years City Engineer of Boston. A year was spent in making plans and investigations. In order that no pains should be spared to make the system perfect, Mr. Chesbrough went to Europe to study at first hand the latest and best developments in the art. It is safe to say that the results of his work, however they may fit the requirements of the present day, represented the best which was obtainable sixty years ago.

The scope of the work to be done by the sewer commissioners was indicated in the instructions which they received from the Legislature. A systematic plan and policy of construction was provided for. The Act says:

> "It shall be the duty of the commissioners, before entering upon the construction of any sewer, to fix upon a plan or system of sewerage of such nature that all subsequent sewers may be executed upon that plan."

At this time such systematic sewerage was unknown in the United States and it is now far less common than it should be.

3.—NATURAL DIFFICULTIES OVERCOME.

The ground was unfavorable for sewerage. In the vicinity of the North and South branches of the Chicago River, the surface was only three or four feet above the level of the lake, and to the westward, near the mouth of the river, it was not more than ten or twelve feet above it. To a considerable extent it was necessary to raise the grade of the streets to keep the sewers underground.

After much discussion, it was decided to raise the

grade of the city to a height of ten feet above the lake on the streets adjacent to the river and so permit of the construction of cellars seven or eight feet deep for the houses. A higher grade was recommended, but it was argued that there would be too much difficulty in finding the necessary earth. For some years after construction, some of the sewers were entirely above ground.

According to the Chesbrough plan, the sewage was to be delivered mainly into the river, which, the chief engineer thought, would deliver it well out into the lake. There were to be mains three to six feet in diameter running along the alternate streets to the river. These were to receive the sewage from the houses on the streets through which they passed, and from sewers two feet in diameter, placed in the streets which ran at right angles to the mains. The sewers were built on the combined plan: that is, they were to receive both house and storm water, in accordance with the best English practice of the day.

At the present time, there are 19 sewers discharging into the Chicago River between the lake and the junction of the two Branches; 36 into the North Branch; 51 into the South Branch from the junction to the beginning of the Drainage Canal at Bridgeport; 10 into the South Branch, beyond Bridgeport, and the Ogden Ditch; 16 into the South Fork; 4 into the east arm and 2 into the west arm of the South Fork; 3 into the Drainage Channel and 13 from Chicago into the Calumet River.

The sewers of Chicago are constructed on the combined plan and were intended to have a capacity sufficient to care for a rainfall of an inch an hour. They lie close to the surface of the ground. Part of the system, as originally built, is too small for the present conditions and must be reconstructed. Owing to the unexpected growth of the city, it is, and long will be, necessary to build relief sewers all over the city. Important work of reconstruction is required in the Loop District, or most important business section of the city, by reason of insufficient size, damages caused in the construction of buildings and other

structures, and foulness and difficulty of cleaning the present sewers. As a rule, the sewers are half filled with dirt and sewage even in dry weather. An interesting and important report on the reconstruction of the sewers in the Loop District was made by C. D. Hill, Superintendent of Sewers, March 27, 1911.*

Mr. Hill's report recommends that the new sewers be built on the separate system in the Loop and that no domestic sewage be discharged into the main river lest it be flushed into the lake by occasional reversals of current. The author recommends that some form of apparatus be installed at the outlet of each sewer that would, to some extent, purify the sewage and thereby decrease the pollution of the river, and he looks forward to a still further exclusion of the sewage from the river in this part of the city. Mr. Hill says, p. 562:

> "In the designing and building of these sewers, it is advisable to anticipate the future construction of an intercepting sewer that will convey all of the sewage of this district to some convenient place for purification, as the population of the city of Chicago will undoubtedly increase to such an extent that the mere dilution of the sewage will not be sufficient. It will be necessary to purify, at least partially, the sewage before it it discharged into the Sanitary District Channel."

4.—THE FOUR METHODS OF DISPOSAL ORIGINALLY CONSIDERED.

Four alternatives for the disposal of the sewage were considered by the Chesbrough Commission:

1. Directly into the river and thence into the lake.
2. Directly into the lake.
3. Into artificial reservoirs to be pumped and used as fertilizer, and
4. Into the river and thence by a steamboat canal to the Illinois river.

The first plan was adopted because it seemed to involve fewest uncertainties and took the best and most economical advantage of the opportunities of the site. To

*The Sewerage System of Chicago, by C. D. Hill, Journal of the Western Society of Engineers, Vol. XVI, No. 7, Sept., 1911 pp. 545-564.

drain directly into the lake would require greater length of sewers and more cost and might lead to trouble in protecting the outlets against wave action at times of storm and ice. It was supposed that the sewage might affect the water supply, if any of the outlets should be near the pumping station.

The river was at this time in a seriously polluted condition. Its sluggish nature had early caused trouble. Ordinances were passed to restrict the pollution in 1833-4 and subsequently, but in spite of these legal precautions, the river became more and more polluted. By 1845 its condition was described as "terribly offensive."

When, in 1855, Mr. Chesbrough proposed to discharge the sewage into the river, he took pains to explain that the solid materials which would thus be emptied into the stream were relatively light and would be flushed out. If deposits occurred, they would be swept into the lake at seasons of freshet.

An attempt to utilize the sewage for fertilizing purposes, Mr. Chesbrough thought, might not prove successful and the storage of the sewage in reservoirs might lead to foul odors which would seriously threaten the health of the inhabitants. The discharge of the sewage into the proposed steamboat canal, which was regarded by Chesbrough, in 1856, as a proposition "too remote for present purposes," was carried out, 1892-1900.

With reference to the use of the canal for sending the sewage to the Illinois River, Mr. Chesbrough said:

> "Should the proposed steamboat canal ever be made for commercial purposes, the plan now recommended would be about as well adapted to such a state of things as it is to the present, making it necessary to abandon only the proposed method of supplying the South Branch with fresh water from the lake and to pump up from the new canal, or draw from the Desplaines directly, flushing water from the west district, instead of obtaining it from the present canal at Bridgeport as herein recommended."

In order clearly to understand the foregoing quotation, which shows the intention of the designer of the present sewerage works of Chicago, it is necessary to explain

that the plan contemplated a flow of flushing water through the Chicago River which would be maintained in part by means of canals from the lake to the North and South Branches. The mention of Bridgeport refers to the location of the pumping station by which some of the water of the Chicago River was fed to the Illinois and Michigan Canal.

The new sewerage works, together with the wastes discharged by the packing houses and other industrial establishments, soon led to offensive conditions in the river. In 1836, an erysipelas epidemic occurred in the neighborhood of the South Branch and was attributed to the decomposition of the blood and other wastes which were discharged from the slaughter houses. The vicinity became known as the "Valley of Death." The Board of Health was established in this year.

5.—FIRST USE OF THE ILLINOIS AND MICHIGAN CANAL FOR DISPOSING OF THE SEWAGE.

It is said that the possibility of an all-water route for commerce from Lake Michigan to the Mississippi was a controlling factor in determining the site of Chicago. At seasons of heavy rainfall, it was possible to take a boat through the Chicago River to and into the Desplaines, which then overflowed its ordinary channel, and pass thence down the Illinois and Mississippi. The State of Illinois early recognized the value of a water route, and in 1836 adopted plans for the construction of the Illinois and Michigan Canal.

The Canal was opened in 1848. It ran, with a water surface width of sixty feet and a depth of six feet, from the South Branch of the Chicago River in a southwesterly direction, across the divide separating the drainage areas of Lake Michigan and the Illinois River, to La Salle, a distance of 96 miles. Originally intended for navigation, the canal was fed partly from the Desplaines and the Calumet Rivers, which lie to the west and south of Chicago, and partly from the South Branch of the Chicago River by a

lift wheel at Bridgeport, the head of the canal, five and one-half miles from Lake Michigan.

The canal was soon found to be serviceable in disposing of some of Chicago's sewage. Little water could be supplied to the canal by the Desplaines and Calumet Rivers in the summer, and, in consequence of this fact, practically all the flow in the summit level of 26.5 miles was obtained from the Chicago River by means of the Bridgeport pumps. This carried away considerable quantities of the sewage which was making the river foul.

6.—ENLARGEMENT OF THE ILLINOIS AND MICHIGAN CANAL SO AS TO TAKE MORE SEWAGE.

The original project for the Illinois and Michigan Canal provided for a flow to be secured entirely by gravity, and in 1865 the State authorized the completion of the canal in accordance with that plan. The intention was to take in more water at the head and thus secure a thorough cleansing and purification of the Chicago River. The work of enlarging was done by the City of Chicago between 1866 and 1871 and it appears that about $3,000,000 was expended in this undertaking.

Meanwhile, the city grew rapidly and the volume of sewage increased beyond expectation. In 1870, the population was three times what it had been ten years before; that is, about 330,000. At the stockyards, over one million head of cattle, sheep and hogs were slaughtered yearly. The industry was located in a swampy district to the south of the city and its drainage was discharged into an arm of the South Branch of the Chicago River, a sluggish ditch, utterly inadequate to receive it.

The increased flow of the canal was insufficient to accomplish the desired object and the Chicago River became more notoriously foul than before. Only the South Branch and main river were improved: the water of the North Branch remained no better than it had been. By 1874, the condition of the North Branch was deplorable. In the language of one who had occasion frequently to

pass near this stream, "No words can describe the potency of that smell."

In 1880 there was carried out a project for the improvement of the North Branch, called the Fullerton Avenue Conduit. This conduit was a brick tunnel, 12 feet in diameter and 11,898 feet long, connecting the North Branch with Lake Michigan. The water was moved by means of two screws, like those of a propeller, placed in the center line of a boat-shaped iron chamber. The tested capacity of the works was 24,000 cubic feet per minute, but they were generally operated at about one-half of that rate. The water could be made to flow in either direction. It was found much more effective to pump the water of the North Branch into the lake than to operate in the opposite direction and this course was usually followed.

7.—CONSTRUCTION OF PUMPS TO FORCE MORE SEWAGE THROUGH THE ILLINOIS AND MICHIGAN CANAL.

In 1881, the State Legislature granted permission to the city to augment the flow of the Illinois and Michigan Canal by pumping. The population was then about half a million. Over six million animals were being slaughtered at the stockyards annually, mostly in the winter season. After graphically describing the insanitary conditions which existed in the canal and valley, the Legislature set forth in a joint resolution that "if said city should proceed without delay to cause a flow into the canal from the Chicago River sufficient to dilute and purify the waters and thus remedy the evils complained of, said flow to be not less than 60,000 cubic feet per minute—or so much thereof as said canal can carry," Chicago might continue to use the canal for sewage disposal purposes.

The pumps were erected at Bridgeport in 1886. They had a tested capacity of 60,000 cubic feet per minute, and were usually operated by the city at 60 to 80 per cent of this limit, until the Main Drainage Channel was operated in 1900. Notwithstanding the increased flow secured by the pumps, the effect upon the Chicago River was far from satisfactory. The canal could not dispose of the sewage

of the population which, in the 90's, exceeded one and a half million, and the drainage of the stockyards which, in 1895, slaughtered an average of 30,000 animals per day.

8.—INCEPTION OF THE PROJECT FOR A SANITARY AND SHIP CANAL.

Private citizens took an active part in promoting the construction of the Sanitary and Ship Canal, and it was due to their efforts that the technical board known as the Water Supply and Drainage Commission was appointed in 1886, upon whose recommendation the project was finally carried out. In fact, it appears that the conclusion of the Water Supply and Drainage Commission as to the best means of disposing of the sewage was foreshadowed in considerable detail seven years before the Commission's report was made.

In a report of the Main Drainage Committee of the Citizens' Association, rendered in 1880, it was stated that the Chicago River might be regarded as a great ditch, six miles long, averaging about 150 feet in width and 10 to 15 feet in depth, into which flowed the greater part of the sewage of Chicago, together with the offal of the immense slaughter houses, the refuse of manufacturing establishments, great and small, and, to a great extent, that of the distilleries and their neighboring cattle pens. All efforts to cleanse the river had failed. The committee proposed, as a measure of relief suitable for all time to come, a new cut or canal of dimensions comparable with those of a river, to carry the drainage of the city and neighboring settlements over the divide to the west.

In order to make the plan complete, all the sewage would have to be discharged into the river or its branches. The Fullerton Avenue Conduit could remain as it was originally, or it could be utilized for an additional water supply. The forks and branches of the river at the south end would purify themselves as the currents would gravitate toward the current created by the outflow of the "New River," as the proposed channel was to be called. The water of the Chicago River would be renewed every

24 hours, with one million cubic feet over the "whole body of it within the city limits would, by this operation, become as clear as the water of the lake."

9.—DEMAND FOR THE DRAINAGE CHANNEL IN 1885.

The Committee on Main Drainage and Water Supply of the Citizens' Association made another report on August 27, 1885, following an unprecedented flood in the Desplaines River which overflowed to the Chicago River and carried a great black mass of accumulated filth from the latter into the lake and so to the public water supply. In this report, the proposition of 1880 was amplified and urged as a public necessity which should receive the attention of a commission of experts to be created for the purpose of devising a comprehensive system for disposing of the sewage of the city and putting a stop for all time to the insanitary conditions which then existed. The South Fork was declared to be "in an abominable condition of filth beyond the power of pen to describe," the drinking water as obviously and undeniably polluted by the occasional discharges of the river and of the Fullerton Avenue Conduit into the lake, and the city in serious danger of floods from the Desplaines. Chicago then had reached a population of nearly 700,000, and the report said:

> "That the city should have attained this growth without an adequate official plan for a permanent system of main drainage would be startling in this day of sanitary science, were it evident that the conditions of the problem had ever been properly apprehended."

The project proposed by the committee was for a new channel between the Chicago River and the Desplaines, which would "take care of the natural flow of 260 square miles of territory and the sewage, properly diluted, of its population." This waterway could easily be developed into a ship canal to unite the Great Lakes and the Mississippi and could, moreover, with due regard to the interests of navigation, be made to develop over 100,000 horsepower.

As to other methods of disposing of the sewage, the committee reported that—

> "Experience has not yet developed any artificial treatment of sewage that does not involve large first cost and continual expenditure. The best of these, by the method of intermittent downward filtration, is not feasible for Chicago, on account of the great distance to proper land."

The proper disposal of the sewage was declared to be unquestionably down the valley of the Illinois. It must be diluted to the point which will speedily produce a complete oxidation, or the growing population along the river will not permanently tolerate so insufferable a nuisance" and "the contents of all channelways into which sewage is discharged should be changed so rapidly that no sewage will remain within the city limits over 24 hours."

10.—APPOINTMENT OF THE WATER SUPPLY AND DRAINAGE COMMISSION OF 1886-7.

Support for the Sanitary and Ship Canal project was afforded by the report of the Water Supply and Drainage Commission, which was appointed by the Mayor of Chicago in 1886.

Instructions were given by the City Council for an investigation and report which would give the city a definite plan and policy for the development of "a system of water supply and drainage adequate to meet the requirements not only of the present, but of years to come." Pure water and scientific drainage were declared to be necessities of Chicago, and it was expressly stated that the people demanded a comprehensive and carefully worked out system; "no temporary expedient or makeshift would satisfy them," and that the existing methods of drainage and sewerage were inadequate.

The commission was not only to report upon all engineering and sanitary matters connected with the subject, but was 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."

The commission was instructed to "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 first cost and annual requirements for the maintenance of the system proposed," not later than January, 1887. The sum of $50,000 was made available for the uses of the commission.

The commission was to be composed 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 body so created was called the Water Supply and Drainage Commission. Rudolph Hering was chosen Chief Engineer, and served ten months, Benezette Williams served four months, and Samuel Artingstall served about one month up to the time that the report was submitted.

The report was made in January, 1887, as required by the City Council in its resolution authorizing the appointment of the Commission. The intention of the Commissioners in making this report was to indicate the character of the legislation which might be required in order to carry out any project determined upon and leave to a later date the presentation of the detailed features of the scheme and other minor results of the inquiry. No other report was made.

11.—CONDITIONS OF WATER SUPPLY AND SEWAGE DISPOSAL IN CHICAGO IN 1887.

It is desirable at this point to review, briefly, the conditions which the Commission had to consider, for it will be necessary to examine their conclusions closely.

At the time of the investigation, most of the sewage of the North and West Sides, and part of the South Side, was discharged directly into the Chicago River. From Evanston, which adjoins Chicago on the north, the sewage was discharged into the lake. From a part of the South Side it was emptied into the lake through three outlets, situated at Twelfth, Twenty-second and Thirty-fifth

streets. To the south, the sewage of Pullman was disposed of on land. The town of Lake, including the stock yards district, drained into the South Fork of the South Branch of the Chicago River.

At times, the city suffered greatly from the offensive condition of the river and from the contamination of the water supply brought about by the discharge of the polluted contents of the river into the lake.

The intake for the water supply was located in Lake Michigan about two miles from shore, opposite the foot of Chicago Avenue. The water was brought to shore through two circular, brick tunnels, five and seven feet in diameter, lying fifty feet apart and eighty feet below the level of low water in the lake.

At the shore end of the tunnels, the water was pumped directly into the mains for distribution. The maximum capacity of the tunnels was about 150,000,000 gallons per day, and this was nearly reached at times of greater consumption. A new intake was being built 1,500 feet from shore to connect with the others, to provide against accident and to insure an adequate supply for the near future.

The capacity of the water works, as to intakes, pumping machinery and distribution was described by the Commission as inadequate and the report declared that an increased supply was imperatively needed. The business section and the southern part of the city were suffering from a want of water; there were parts of the district where it was impossible to get water in the second story of the houses.

The investigators considered that the solution of the problem submitted to them demanded the attainment of two objects: The protection of the water supply and the removal of the river nuisance. Inasmuch as the water must be taken from the lake, it was concluded that both its pollution and the objectionable condition of the river should be prevented by a better disposition of the sewage. The latter question constituted the main object of the investigation.

The confidence with which the investigators considered that they had solved the sewage disposal half of their problem is shown by the recommendations which they made for the other half: the development of the water supply. New tunnels, inlets, buildings and machinery were required, and the city was urged to decide upon the location of the new works as soon as possible. Two pumping stations were recommended for the southern part of the city: One between Harrison and Twelfth streets and the other somewhere east of the Union Stock Yards. Other pumping stations would be required as the population increased.

With regard to the quality of the water to be obtained, the report says:

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

12.—THE THREE METHODS OF SEWAGE DISPOSAL CONSIDERED BY THE WATER SUPPLY AND DRAINAGE COMMISSION.

Among the possible methods of getting rid of the sewage there were three that were thought worthy of consideration by the commission: Discharge into Lake Michigan; disposal on land, and discharge into the Desplaines River and thus to the Illinois and Mississippi. The work of the commission had reference to these three possibilities and was classed as hydrographic, topographic and miscellaneous.

At the time the commission was created, the topographical work was already under way under Mr. Artingstall, who was the City Engineer. It consisted of surveys which were apparently intended chiefly to determine the feasibility of diverting the sewage to the Desplaines. The hydrographic work was put in charge of Mr. Lyman E. Cooley, and consisted largely in determining the flow of the Desplaines and the probable effect of discharging the

sewage of Chicago into it when diluted by a large and constant stream of water from the lake. There were also studied under this head the currents and levels of the lake and the question of deposits in the river and in the lake in front of the city to determine the effects of the sewage as then discharged.

Among the other branches of the investigation mentioned by the Commissioners in their report were studies as to the feasibility of purifying the sewage by filtration on land and the probable growth and distribution of the population of Chicago and its environs.

No reference is made in the report as to the probable effect of the sewage on the health and comfort of the people in the Desplaines and Illinois River Valleys, nor to the possible pollution of the water supply of the City of St. Louis and other cities on the Mississippi. Nothing is said as to the possibility of purifying the water supply of Chicago, although the efficacy of slow sand filtration was recognized at the time. Such filters had been in use in England for the treatment of a part of the London water supplies since 1839, in Berlin since 1856, and in Poughkeepsie and Hudson, N. Y., from the early 70's.

If the Commission undertook to determine the great question as to the interests which the State of Illinois and the United States had in the disposal of the sewage by way of the Illinois River in accordance with their instructions, there is no mention of the fact in their report. This is greatly to be regretted in view of the long continued dispute and present litigation between the Sanitary District and the United States Government over the diversion of water from Lake Michigan for the use of the Canal.

Of the three methods of disposing of the sewage, only the discharge of the wastes into the Desplaines met the approval of the Water and Drainage Commission.

13.—THE COMMISSION'S OBJECTIONS TO DISPOSAL INTO THE LAKE AND ON LAND.

The report stated that if the sewage was discharged into the lake, it would have to be emptied at one end of

the city, while the water supply should be obtained as far away from that point as practicable; a conclusion which has been acted upon by some other large lake cities. It might be practicable, the authors thought, to allow the sewage to enter the lake for many years under these circumstances; but the necessity would arise later for clarifying it, at least partially, previous to discharge. The dry weather flow and a considerable quantity of storm water would have to be intercepted and carried through many miles of conduits and pumped to the outlet. The water supply would have to be brought a long distance and distributed by pumping stations scattered through the city. Nor would the removal of the dry weather flow of sewage entirely prevent the pollution of the Chicago River.

The plan contemplated for the disposal of the sewage on land was by intermittent filtration. To carry out this scheme, the Commission stated that there would be required: A sufficient area of land, a comprehensive system of intercepting sewers to carry the sewage to the works; pumping plans to handle the sewage and a certain amount of storm water; a thorough preparation of the land, including leveling, underdraining, and a distributing system; means for removing the purified water from the beds, and, finally, buildings, roads, a complete farming outfit and an organization for carrying on the farming operations and disposing of the crops.

The land disposal scheme was worked out on the basis of 2,000,000 people, with an average dry weather sewage discharge of 150 gallons per head per day. The allowance for storm water was equivelent 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 system of sewers. The surplus water was to be allowed to discharge into the rivers and lakes. The dry weather flow of sewage would 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. The land required would be 10,000 to 15,000 acres.

The only available territory in the vicinity of Chicago

suitable for sewage disposal, the Commission said, consisted of two sandy ridges in the town of Thornton, extending across the state line into Indiana, and a sandy ridge crossing the town of Niles. The Commission said that an enormous cost would be 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. With regard to the alternative of disposing of the sewage on land, the commissioners stated: "We therefore consider such a project impracticable."

14.—THE DRAINAGE CANAL RECOMMENDED.

The third solution was the one which was recommended. The sewage should be carried across the low divide which separated the city of Chicago from the Desplaines River Valley, "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." For this purpose, the current of the Chicago River should be reversed by connecting the South Branch with the Desplaines River, the means of connection being a canal of such size as to be capable of carrying off the storm waters of the Chicago River after some of the flow of the head waters had been diverted. Flood flows of the river had been known to reach a maximum of 10,000 cubic feet per second, and this was an important element in fixing the size of the Drainage Canal.

The diversion of the sewage was to be complete. The report said that with the sewage kept out of the lake, there would be no need of locating the waterworks intake farther than two miles from shore.

How and where the sewage was to be discharged into the Chicago River was not stated. No precautions were suggested for the avoidance of deposits, or dead ends, or unsightly or malodorous conditions, except that the sewage was to be diluted to a specified extent with lake water. Nothing was said about trade wastes in the report.

15.—AMOUNT OF DILUTION RECOMMENDED.

The sanitary requirements demanded a flow of water sufficiently great to dilute the sewage so that it would be inoffensive along the river at all times and to carry away the storm water from the drainage area so that there would be no back flow of polluted water from the river to the lake. In short, the natural currents of the Chicago River were to be completely, and at all times, reversed, so that instead of flowing to the lake, the water of the river with its sewage was to be carried by the canal to the Desplaines.

With regard to the dilution required, the Commission reported as follows:

> "The proper degree of pollution of 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."

It was stated that the information which would definitely decide the extent of the dilution would be given in another report, as the data had not all been collected; but no other report was submitted. For the purpose of estimating the cost, it was assumed that the channel would have a cross section of 3,600 square feet and a velocity for the water of 3 feet per second, or two miles per hour. This gave a discharge of about 600,000 cubic feet per minute, or a dilution of 24,000 cubic feet of water per minute for each 100,000 persons contributing sewage. This was believed to be sufficient to meet the maximum requirements of a population of 2,500,000 persons.

It was recognized that difficulty would be experienced in securing such a flow of water through the various branches of the river that there should be no discharge to the lake at times when the level of the latter suddenly fell as a result of wind and barometric conditions.

Marked fluctuations often occurred at intervals of a few minutes. In one case, August 16, 1886, the lake level fell 2 feet 10 inches in fifteen minutes. On such occasions, the foul water of the river had been traced flowing into the lake for more than a mile in the direction of the water works intake. To overcome the tendency of the river to discharge into the lake, the Commission proposed that the upper Desplaines and the North Branch be diverted to the lake and that a lock be constructed in the North Branch.

16.—COST OF THE DRAINAGE CANAL.

The Water and Drainage Commission estimated that to discharge the sewage directly into the lake and take the water supply from a point sufficiently distant to insure freedom from pollution would cost at least $37,000,000, with an annual expense for interest and operation of at least $2,400,000. To dispose of the sewage of the district by filtration on land would require an investment of about $58,000,000 and an annual expense of over $3,000,000. The total cost of the Drainage Canal project would be between $23,000,000 and $27,950,000, and the annual cost, including interest, etc., about $1,300,000.

Beside the economical advantages of the Desplaines scheme over other possible methods of disposal, its superiority was urged by the Commission on other grounds. The proposed canal would, 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 would further establish a water power of great commercial value to the state and, by lowering the level of a section of the river, would have the same effect as raising the level of the low-lying prairie in that vicinity.

The construction of the main drainage and disposal works, with their intercepting sewers, waterways and pumping stations, should be executed under one management. As to the limits for the future city, the investiga-

tion showed that the topographical conditions clearly defined two distinct districts. The main district extended from Eighty-seventh street north to Evanston and from the lake to the Desplaines River on the west. Its sewage should be collected into one channel and discharged into the Desplaines Valley at Summit about three miles west of the lake. The other district should extend over the natural drainage area of the Calumet River and Lake south of Eighty-seventh street and have, as the outfall of its sewage, a channel to run from Blue Island to Sag.

17.—CREATION OF THE SANITARY DISTRICT.

Action in accordance with the findings of the Water Supply and Drainage Commission was sought at once, but was delayed by the Legislature. An Act was finally passed and approved May 29, 1889.

The Act provided, among other things, for the creation of a Sanitary District, which should be a quasi-municipal corporation, to construct a channel and necessary adjuncts to convey the drainage and sewage of the municipalities, with diluting water from Lake Michigan, to the Desplaines and Illinois Rivers. The channel was to have sufficient capacity to produce a continuous flow of not less than 20,000 cubic feet per minute for each 100,000 inhabitants. Provision was intended to be made for a population of 3,000,000.

It appears that the requirements of the State law that not less than 20,000 cubic feet per minute must be diverted into the Drainage Channel for every 100,000 inhabitants was not based upon a definite knowledge of the amount of diluting water required, but largely upon considerations of expediency. The report of the Drainage and Water Supply Commission refers to a dilution of 24,000 cubic feet as ample for the dilution of the sewage of 2,500,000 persons.

> "The capacity of the channel was fixed at 600,000 feet as the quantity required to remove the flood waters from some 420 square miles of territory (after the diversion of the Upper Desplaines 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 considerations had been given to the question of dilution; the chief force of the investigation had been applied to the investigation of other alternative solutions."

It appears from the foregoing that however thorough the hydrographic and engineering work of the Commission may have been, there were some vital questions connected with the construction of the Canal which had not been settled or perhaps even studied. The Commission is itself authority for the statement that it intended to make a second and more complete report. Had the Commission been able to deal with the questions submitted to it in accordance with the instructions which it received and in a manner consistent with the high sense of responsibility which was characteristic of its members, it is certain that some serious and expensive errors would have been avoided.

18.—CONSTRUCTION OF THE SANITARY AND SHIP CANAL.

The construction of the Chicago Sanitary and Ship Canal was a great engineering feat which became justly celebrated in all parts of the world. Water was turned into the Canal, in accordance with a permit from the Governor of the State of Illinois, on January 17, 1900. The Canal was not, and still is not, completed to its full capacity as designed, except in certain sections which are built in the rock. When finished, it was to have a capacity of 10,000 cubic feet per second when flowing at a velocity of less than two miles per hour. It has been found since the canal was opened that the actual capacity toward the lower end is 40 per cent greater than had been expected.

Th canal is 28.05 miles long. It is 22 feet deep and has a width which varies in different places between 110 and 201 feet at bottom, with sides either vertical or inclined one on two. The canal is approximately parallel

to the old Illinois and Michigan Canal and near it. Beginning at Robey street, near the head of the I. & M. Canal, it extends to Lockport, where the level, and consequently the flow, are regulated by a moveable dam and sluice gates. The water is discharged into the Desplaines River between Lockport and Joliet.

In order to pass the desired amount of water through the Chicago River without creating currents of excessive velocity, improvements in the river were begun in 1901. By these a width of 200 feet and a central depth of 26 feet were to be attained.

19.—THE DIVERSION OF SEWAGE FROM THE LAKE.

Two systems of intercepting sewers have been built by the city to collect sewage which formerly discharged into the lake and carry it to arms of the Chicago River.

One of these systems, which was practically completed in 1908, is on the North Side and consists of two parts. One branch runs from a point north of Howard avenue, southerly to Lawrence avenue, and the other begins at Diversey boulevard and runs northerly to Lawrence avenue, where it joins the first. The two branches are united in a 16-foot conduit through which the sewage is pumped to the North Branch of the Chicago River, at Lawrence avenue. This pumping station also takes water from the lake and discharges it with the sewage into the river. The capacity of the pumps is 40,000 cubic feet per minute.

The southern intercepting sewer system was practically completed in 1906. It extends from 37th street to 39th street, where the sewage is picked up by pumps and forced, with a considerable amount of lake water, through a conduit 20 feet in diameter, in a westerly direction to the east arm of the South Fork of the South Branch of the Chicago River, commonly known as "Bubbly Creek." The capacity of the pumps is 120,000 cubic feet per minute.

Other sewers north of 31st street, which formerly discharged into the lake have been diverted directly into the

Chicago River. The intention has been that no sewage shall be discharged into Lake Michigan from the northern limits of the Sanitary District to the mouth of the Calumet River, a distance of over thirty miles, and this object has been accomplished.

As a means of diverting sewage from the lake and supplying diluting water for its purification, a channel was built from the village of Wilmette, north of Evanston, to the North Branch of the Chicago River, a little north of Lawrence avenue. This is the North Shore Channel, which was completed in 1911, at a cost of $1,600,000 for construction, and $1,170,000 for the right of way, a pumping station and engineering and other expenses, making the total cost about $2,770,000, according to the Sanitary District's figures.

The North Shore Channel is 8⅛ miles long, 75 feet wide at the surface and 13½ feet deep. It is navigable by boats bound between the North Branch and the lake. The pumps are built after the plan of those which were installed in connection with the Fullerton Avenue Conduit, and have a designed capacity of 15,000 cubic feet per minute.

20.—REVIEW OF THE DEVELOPMENT OF CHICAGO'S SCHEME OF SEWAGE DISPOSAL.

The history of sewage disposal in Chicago shows that the method now followed is the outcome of a practice which was begun more than seventy-five years ago, when the city was a small place and the volume of its sewage was relatively insignificant.

The disposal of the sewage was recognized as a serious problem as soon as the city had any sewage to dispose of. The question of water supply, apart from that of sewage disposal, seems never to have been considered difficult; it has always been considered that water in unlimited volume and of acceptable quality could be obtained from the lake, if only the sewage could be kept out of it.

For many years the necessity of keeping the sewage away from the drinking water was not recognized. This

lesson was learned at the cost of much suffering and death. The sewerage system, representing the best thought of the time, was designed to discharge into the river with full knowledge that it would flow thence to the lake. Nobody supposed that it would injure the drinking water. It was many years before Chicago found that it was poisoning its water supply.

The idea of sending all the sewage to the Illinois River instead of allowing it to flow to the lake, arose from the fact that the Chicago River had little current and the Illinois and Michigan Canal, as originally built, was seen to be carrying a good deal of the filth away. Later, the intolerable stench which arose from the Chicago River and the fear of disease which was aroused by the foul conditions, caused the authorities to call upon the canal for more and more relief, and its capacity was increased on two occasions. The canal afforded a ready outlet, only it was not big enough.

Once embarked upon the policy of cleansing the Chicago River by causing its sewage and water mixture to flow toward the Mississippi, the development of the disposal system into what it is today was perfectly logical and consistent. The scheme is the same in principle as it has always been. There are no works of purification. The sewage is all dumped in crude condition and by the most convenient route directly into the river to be disposed of by the beneficent forces of nature in such places and at such times as those forces are able to operate. Beyond supplying all the water possible, no attempt is made to aid or control these forces; they and their manner of working are not understood. In order that there shall not be too great a nuisance in the city, and to prevent the poisoning of the drinking water, the river is led off to the Illinois Valley. Chicago's way of getting rid of her sewage has been well described by a prominent engineer, long connected with the Drainage Channel proposition, as "disposal through the back lots."

Part V

WHAT BECOMES OF THE SEWAGE

1.—PRESENT CONDITION OF THE CHICAGO RIVER AND SANITARY AND SHIP CANAL.

The condition of the Chicago River was inspected by the Board of Experts of the Chicago Real Estate Board at various times during the last two weeks in April, 1914. By invitation of the Sanitary District, a trip was taken from Lake Michigan through the Chicago River and Drainage Channel to Lockport. Three more days were spent along the Desplaines and Illinois Rivers, many points being visited between Joliet and Henry, about 125 miles from Lake Michigan.

At the time of the inspections, the water of Lake Michigan, as it entered the Chicago River, was soapy in appearance and of a light, olive color; it looked not unlike sewage, except for the absence of characteristic solid ingredients. The turbidity was probably somewhat in excess of 100. There was no way of knowing the amount of impurities present; but it may be assumed that there was nothing about the water as it entered the river from the lake which rendered it less suitable than usual for the dilution and purification of the sewage. The turbidity, which was above the average, owing to recent storms, aided disposal, since it caused the sewage solids to disappear more quickly than was common.

Proceeding from the lake through the river toward the Drainage Channel, the first large sewer outfall noticed was at the foot of Michigan avenue, near the mouth of the river. The discharge discolored the water for a distance of about 200 feet. All the principal outfalls discolored the water. Little attempt had been made to hide the

mouths of the sewers. The river was frankly an open sewer and a commercial canal. No effort had been made to render it attractive, and it was not so in any sense.

Apparently nearly all the sewers discharged at the bulkhead line and at, or near, the surface of the stream. Some sewage solids were usually seen near the points of discharge, and there were eddies where considerable masses accumulated. The river was carrying along most of its great load of sewage beneath the surface, to a considerable extent hidden from casual notice by the turbid lake water. On looking carefully into the water, bits of paper, excrement and other solid matter could be seen in some quantity.

Where the currents are not sufficiently rapid to keep the solids moving, deposits take place and these ferment, giving off gases which rise in bubbles to the surface. In disengaging themselves from the material in which they are formed, the bubbles cause eruptions in the deposits, with the result that the black sewage mud is raised and becomes diffused through the overlying water. The evolution of gas, and consequent blackening and production of offensive odors, vary greatly. In the least noticeable cases, the bubbling is scarcely perceptible; in the worse, the eruptions are several feet in diameter and the air smells badly for a distance of several hundred feet. Where fermentation is proceding actively, the water is in a state of ebulition, the surface looking much as it does at times of rain. The water is then black throughout. In some of the most stagnant places, a scum forms upon the surface of a thickness and consistency which is sufficient to permit small domestic animals to walk upon it. All stages and degrees of fermentation exist in Chicago's waterways.

At the end of April, a small amount of effervescence was noticeable at the junction of the North and South Branches, in many of the long slips and other quiet parts of the main channel from the lake to the Drainage Canal; considerably more was noticed in the turning basins.

In the North, South and West Branches, all the evidences of excessive pollution were apparent. It was sur-

prising to note how great was the area and extent of these nuisances and the indifference with which they were regarded. For years the west arm of the South Fork has been described as a "seething mass of septic sewage" without there ever having been any serious attempt to improve it. This is "Bubbly Creek," the "Valley of Death," a stagnant and malodorous ditch, than which there is probably no greater evidence of sanitary neglect in any city. Other festering pools, but of less extent, have long existed.

Once the water and sewage mixture leaves the main channel of the Chicago River and enters the Drainage Channel, there is little visible change in the appearance of the stream, until it approaches the works at Lockport, where the flow is regulated. At the time of the inspections noted in this report, the water was of the same soapy, olive, turbid hue which had been noted at the lake, only it was darker. In the Drainage Canal there was a notable absence of sewage solids at the surface, but there were some deposits at the bottom.

There was some discoloration along the sides of the Canal. The light, limestone rock and gravel shores were in places conspicuously marked by brown and black, showing that variations of several feet had occurred in the level.

Some samples of the water and sewage mixture were analyzed for dissolved oxygen, and found to contain 7.2 parts per million. Had the water contained its normal amount, there would have been 11.3 parts. The oxygen had, therefore, been about one-third depleted. In a bottle, the water had a distinctly foul odor. Odors from the canal were noticeable on the upper deck of the boat, whenever there was a lull in the strong cool wind which was blowing.

Extensive deposits occur in the Drainage Channel for about two miles above the controlling works at Lockport. These ferment and give off large quantities of gas. At the time of the inspections, there were 2.6 parts per million of dissolved oxygen in the water as it flowed over

the weir which regulates the flow through the Drainage Channel. The oxygen had been reduced to less than ¼ of its normal amount in passing from the lake to the end of the Canal. Some white paint which had been put upon one of the buildings had been turned black by the foul gases.

2.—CONDITION OF THE DESPLAINES AND ILLINOIS RIVERS.

By sending the filth which formerly stagnated in the Chicago River down the Desplaines and Illinois Rivers, this nuisance-producing material has been transferred from one place to another, but it has not been disposed of in the sanitary sense.

The Chicago River has been improved, but in place of the foulness which once existed in it, there flows, for one hundred miles, through the Illinois Valley a discolored, unwholesome and offensive stream. The valley is naturally beautiful, fertile and populous. Prosperous cities and well ordered villages are located in it. But the chief advantage which their situation near the stream affords apparently lies in the water power which is here and there available.

For over one hundred miles from Chicago, the inhabitants of the valley seem to have relinquished the most valuable rights of riparian owners. The water is not fit to drink, nor to wash in, nor to water stock in, nor for the many other domestic and industrial uses of a normal river. Fish die in it; the thought of swimming in it is repugnant to the senses; boating, far from being a pleasant and healthful diversion, can be enjoyed only by the hardy. The stream flows with the majestic sweep of all great rivers and the banks are overhung with rich, luxurious foliage; but the water is discolored, malodorous, poisonous. Fine black organic sewage mud covers the bottom and deposits on the shores when the river overflows its banks.

Thousands of tons of organic matter, most of it in an offensive state of decomposition, are thrown into the Chi-

cago River every twenty-four hours. Every conceivable kind of filthy thing that can be flushed away by water from the streets, houses and persons of the sick and well in a population of 2,500,000 inhabitants, not to mention the excrement of a hundred thousand hogs and head of cattle and horses and mules, is cast down into the valley every day.

The precise amount or quality of these foul wastes has not been determined, but it is not necessary that it should be in order to form some idea of the burden of pollution which is put upon these waters. It can be estimated in various ways. According to the researches of the Metropolitan Sewerage Commission of New York, which made careful studies of the digestion of sewage in New York Harbor, the sewage solids are derived from feces, toilet paper and newspaper, soap and washings, street wastes (consisting largely of feces and urine and an infinite number of comminuted solid matters), amounting to about 45 tons per 1,000 inhabitants per year, these materials being reckoned as existing in a dry state. Assuming that 90 per cent of the inhabitants of Chicago are connected with the sewers, it appears that nearly 100,000 tons of this material are discharged into the Chicago waterways every year.

The weight of feces and urine discharged each day by that part of the population of Chicago which was connected with the sewers immediately preceding the opening of the Drainage Channel, was estimated by Professor A. W. Palmer, of the University of Illinois, to be 127 tons, reckoned as existing in the dry state. Of this, 104.8 tons was organic matter, containing 20.5 tons of nitrogen.* The population contributing this material was 1,310,700. According to Mr. G. M. Wisner,† the population draining to the Desplaines and Illinois from the Sanitary District was 2,167,903 in 1910. On Prof. Palmer's basis there must

*The Pollution and Self-Purification of the Water of the Illinois River, Chemical Survey of the Waters of Illinois River, Report for the years 1897-1902, Appendix, p. x.

†Report on Sewage Disposal, 1911, p. 16.

now be over 35 tons of nitrogen cast into the valley every day.

The condition of the stream from Chicago down through the Canal and Desplaines and Illinois River Valleys, to and beyond Ottawa, has been described by Mr. Paul Hansen, Engineer, Illinois State Water Survey, in a paper read before the American Public Health Association in September, 1913.*

> "The conditions in the drainage canal proper are not especially foul, nor is the odor in the vicinity of the canal marked, owing to the fact that most of the organic matter is still in a fresh and undecomposed condition. An exception to this occurs in hot weather when ebulition takes place in the sludge deposits in the bottom of the canal and causes large quantities of this foul sludge to rise to the surface. These comparatively unobjectionable conditions persist until Lockport is reached, thirty-five miles below the mouth of the Chicago river at Chicago. Upon entering the Lower Desplaines river, the water and sewage from the canal are joined by the somewhat highly polluted water of the Upper Desplaines. A change in the character of the water then takes place, due to the onset of putrefactive conditions. The liquid grows darker and disagreeable odors are more pronounced. The putrefactive processes continue and reach their culmination at some point between Morris, 62 miles below the mouth of the Chicago river, and the Marseilles dam, 80 miles below. The point of worst condition varies with the stream flow and the season of the year, generally being farthest up stream in the winter and farthest down in the summer. Within this distance, the water of the river is likely to have a characteristic grayish color and is totally devoid of all life except those organisms which flourish under putrefactive conditions. Most prominent among these are *sphaerotilus natans* and *carchesium lachmanni*. Below the Marseilles dam the water of the stream begins to recover from its sick condition and this recovery is, no doubt, given an impetus by the marked aeration that occurs as a result of the flow over the dam. A normal appearance, however, does not occur in the summer time until Hennepin is reached, 116 miles below the mouth of the Chicago river. Here the grayish color has disappeared and is replaced in the summer time, at any rate, by a characteristic greenish hue indicative of the presence of chlorophyl-bearing organisms."

*Amer. Journal of Public Health, Vol. IV, No. 10, pp. 35-6.

The state of the Desplaines and Illinois Rivers with respect to pollution produced a strong impression on the Sanitary Experts of the Real Estate Board. On the days when the inspections were made, the water was offensively polluted with sewage as far as Ottawa—eighty-five miles from Lake Michigan. Wherever bridges crossed the stream, it was possible to see unmistakable evidences of the sewage. Odors were noticeable, grease lay upon the surface of the river, dead fish were numerous, and large quantities of sewage fungus were observable in the water. Disagreeable odors were noticeable at a distance of nearly one-quarter of a mile from the Marseilles dam. Above this point animal and vegetable forms which are natural to a normal river are absent. Through the whole course of the stream from Chicago to and below Ottawa, gulls were seen feeding on the solid refuse which the sewage brought down.

3.—INVESTIGATIONS OF THE STATE BOARD OF HEALTH.

The attitude of the State Board of Health of Illinois toward the discharge of Chicago's sewage into the Illinois valley must be carefully taken into consideration if a proper understanding is to be reached of Chicago's great sanitary problem. To many persons unfamiliar with the history of the city's efforts to protect its water supply and dispose of its sewage, it appears that the State has done little to protect the dwellers in the valley from a colossal nuisance. This is a mistake. The State Board of Health has taken an active interest in the disposal of the sewage, and there is no reason to suppose that it has ever been indifferent to the welfare of the valley.

At first the attitude of the State may have been one of indifference, but soon after the establishment of the State Board of Health, there seems to have been an anxious concern manifested for improvement. The first time that the State Board made a recommendation to the city of Chicago in relation to its sanitary affairs was in regard to the disposal of the sewage; this occurred in the

second annual report, 1879. Dr. John H. Rauch, formerly Sanitary Superintendent of the City of Chicago, was then secretary. The city was urged to improve the conditions then existing by enlarging the capacity of the Illinois and Michigan Canal by means of pumps, this course appearing to the Board, on the best advice obtainable, to be a remedy which was immediately available, one which would afford all the improvement needed and the solution which would cost the least sum of money. The pumps were expected not only to carry off the sewage of the city and so remove the nuisance and danger of epidemic disease, but a secure such a flow of fresh, diluting water from Lake Michigan as would dilute and oxidize the organic matters so that no further trouble would be experienced from them in the canal or river system into which they emptied. Great confidence was expressed in the capacity of the water to assimilate the offensive materials which the sewage and industrial refuse contained.

The confidence which the Board of Health felt in the purifying capacity of water was not held by all the sanitary experts of the day. Some held the opinion that the digestive capacity of water for sewage was not great and that what appeared to be purification was only sedimentation. Specific instances were cited wherein too much reliance had been placed by other cities upon the beneficent forces of nature to bring about the self-purification of streams. For example, in England, a commission had reported in 1865, after eight years of study, that:

> "The right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided."

In 1886, the Board of Health of Illinois engaged Prof. John H. Long of the Department of Chemistry of Northwestern University, Chicago, and formerly Chemist of the City Department of Health, to make an investigation of the manner and extent to which the sewage disappeared. Dr. Long's studies were carried on from 1866 to 1889, most of the work being done between May, 1888, and March, 1889. About 700 samples were taken from points along

the Illinois and Mississippi rivers. A preliminary report was printed in 1889. A full report, which was made later, appears to have been lost without ever having been published or a copy preserved.

After the opening of the Drainage and Ship Canal in 1900, it was considered desirable to make additional investigations, particularly with the object of determining the effect of the new waterway on the Illinois and Mississippi, and many of the results of Prof. Long's earlier studies were published, with the reports of others, by the State Board of Health* and elsewhere. An effort was doubtless made to give the work a broad scope and to conduct it in an unprejudiced manner, but it must be noted that the point of view in the later investigations was to afford information which would show that the sewage of Chicago was not polluting the water supply of St. Louis, which was drawn from the Mississippi. The effect of Chicago's sewage on the health and comfort of the inhabitants of the Illinois Valley was not, apparently, regarded as calling for special consideration and the State Department of Health seems not to have investigated it at this time.

Prof. Long's report does not afford data from which a strict comparison of the conditions in the valley before and after the Drainage Canal was opened can be made, irregularities in the operation of the Drainage Canal and Illinois and Michigan Canal, differences in weather conditions and other factors interfering seriously with the results. Nevertheless, the report is of considerable service in affording information as to the self-purification of the Illinois River and the possible effects of the sewage of Chicago on the waters of the Mississippi.

4.—RESULTS OF PROF. LONG'S INVESTIGATIONS OF THE ILLINOIS RIVER.

Among the most important pieces of information brought out by Dr. Long's work were the following:

There was a marked improvement in the quality of

*Report of the Sanitary Investigation of the Illinois River and its Tributaries; Illinois State Board of Health, 1901.

the water from the Illinois as it flowed toward the Mississippi, apart from the changes which occurred through sedimentation and dilution. The improvement was largely dependent on temperature, the winter rate being much slower than the summer rate. But little purification took place between Bridgeport and Joliet, 33 miles below. In fact, the figures for albuminoid ammonia and free ammonia and oxygen consumed increased slightly. Beginning at Joliet, there was a rapid reduction in the chemical evidences of pollution to Morris, 58 miles below Bridgeport, and Ottawa, 81 miles below Bridgeport, where the ammonias were reduced to one-third or one-quarter of their original amount. From Ottawa through Henry, 125 miles from Bridgeport, to Peoria, 159 miles from Bridgeport, there was a slower, but no less certain, improvement. At Peoria, the river was again heavily contaminated by the discharge of wastes from cattle and distilleries.

Peoria cattle shed filth and not Chicago sewage was the main factor in the animal pollution of the lower river. The Illinois River at its mouth was in better organic condition than were most of its tributaries. At Grafton, where the Illinois joins the Mississippi, little more than harmless salt remained to tell of the enormous pollution, 320 miles above. The physical appearance of the stream and the extent of the fishing industry, aside from the analytical results of the investigation, pointed clearly to the improvement accomplished.

As to the manner in which the self-purification of the water took place, it is interesting to observe that the views held by Prof. Long in 1901 were, so far as they went, not far different from the accepted theories of today. He plainly recognized sedimentation and fermentation as important; the first in securing temporary, the second permanent, improvement, and he was evidently of opinion that the chief element in causing the sewage matters to disappear was oxidization.

With regard to the disappearance of the organic matter, Prof. Long says:*

> "The main results stated in my preliminary report are confirmed and strengthened by the work subsequently done. It has been shown that in the stretch of the canal and river between Chicago and Peoria a remarkable destruction of organic matter is constantly taking place, not by sedimentation, as former critics of the Board were anxious to believe, but by organic oxidation."

5.—INVESTIGATIONS BY THE STATE WATER SURVEY.

In 1897 the Illinois Legislature passed an Act to establish a Chemical Survey of the waters of the State, and in 1902, a report was made upon the work which had been accomplished to that year. Five-sixths of the volume of 243 pages were devoted to the chemical condition of the Illinois River before and after the opening of the Drainage Channel, the author being Arthur W. Palmer, Professor of Chemistry in the University of Illinois.† A large number of analyses were made and tabulated.

Prof. Palmer's results and opinions agreed with those of Prof. Long, already referred to. The principal conclusions were that in spite of the sewage which was discharged into it, the Illinois River purified itself so that at its junction with the Mississippi, its waters were more suitable for drinking than were the waters of the Mississippi itself. There was less actual weight of organic matter discharged into the Mississippi by the Illinois after the Drainage Canal was opened than there had been before. There were two main sources of pollution of the Illinois: Chicago and the Peoria-Pekin region. So far as the self-purification of the Upper Illinois was concerned, there was a great deal of improvement in the neighborhood of Morris, but the water did not resume its natural state until it reached the vicinity of Averyville, 98 miles below Bridgeport. That this improvement was not the result of mere dilution was shown by calculations based on the

*Illionis State Board of Health Report, 1901, p. 76.

†The Pollution and Self-Purification of the Waters of the Illinois River, Chemical Survey of the Waters of Illinois, 1897-1902, pp. 62-240.

chlorine and the nitrogenous organic matter, free ammonia and nitrates. Between Averyville and La Salle, a distance of 60 miles, probably the last of the organic matter was destroyed. Large quantities of plankton were to be found in this stretch of the river.

Prof. Palmer reported the average result of 141 determinations of the dissolved oxygen which he found, but as he failed to state at what points in the river they were taken, they are useless in the present inquiry.

Data on the dissolved oxygen in the water of the Illinois River in midsummer and later winter were obtained by the State Water Survey in 1911 and 1912.* The analyses were not numerous and refer to a long stretch of the river.

In July and August, 1911, the dissolved oxygen fell rapidly from the head of the Illinois River to Morris, where it was about 1.5 parts per million. Proceeding down the river, there was a further decline to the Marseilles Dam, where there was only .5 part per million, followed by a gradual rise to Starved Rock and Chillicothe, where there were 4.2 parts.

In February, 1912, the lowest point reached was above the Marseilles Dam, where there were 6.3 and 8.8 parts per million. In March, 1912, there was a gradual rise in the dissolved oxygen from the outlet of the Drainage Canal to Morris, where it was about 10, followed by a slow decline to Peoria.

These analyses, so far as they go, show that the sewage and water mixture is assimilated much more slowly in winter than in summer, in consequence of which the point where the river resumes a wholesome condition is not always the same.

In 1913 the composition of the sludge in the Drainage Canal and the Upper Illinois River was analyzed by the Illinois State Water Survey† and found to resemble sew-

*Effect of Chicago Sewage on the Illinois River, Illinois State Water Survey, Bulletin 10, June 2, 1913, pp. 30-39.

†The Composition of Sludge and Bottom Deposits of the Illinois River, Report of the Chemical and Biological Survey of the Waters of Illinois, 1913, p. 155.

age sludge. Marked improvement occurred between Marseilles and Henry; below Peoria, the sediment seemed to be that of a normal and relatively unpolluted stream. The samples were collected between March 18th and April 5th, 1913. Samples collected at various points as far as Chillicothe were described as having a disagreeable, fecal odor.

The composition of the gases arising from the Illinois River in the summer of 1911 was determined by R. H. Jesse as a part of an interesting research for the State Water Survey.* Samples were taken at Morris and above the dam at Marseilles.

The bulk of the gas was carbon dioxide, methane and oxygen. In one case the nitrogen amounted to 25.24 per cent., but this was far above the average. This large amount of nitrogen occurred at Henry. The carbon dioxide usually ranged between about 12 and 24 per cent, and the methane between 73 and 83 per cent. Sometimes a fraction of one per cent of oxygen was found, and, with a single exception, there was a small amount of an unknown gas absorbed by cuprous chloride in all the samples:

Commenting on the results of his analyses of the Illinois River gases, Jesse says (p. 54):

> "In order to compare these gases with those from stagnant pools, which are not polluted with sewage, there is given an analysis of a gas sample collected from Mazon creek, which enters the Illinois river near Morris. The difference between this gas and those from the Illinois river is as striking as is the similarity between the latter and the gases from septic tanks."

6.—INVESTIGATIONS OF THE STATE LABORATORY OF NATURAL HISTORY.

Exhaustive biological investigations of the Illinois, begun in 1877, have been made by the State Laboratory of Natural History and valuable monographs have appeared on the subject by Dr. Stephen A. Forbes, Director, Dr. C. A. Kofoid and others, on the forms of life which exist in

*Insoluble Gases Formed by the Decomposition of Organic Matters, Report of the Chemical and Biological Survey of the Waters of Illinois, 1911, pp. 47-61.

the water at different points between Lockport and the Mississippi. Of special value are Dr. Kofoid's two volumes on his quantitative investigations and general results and the constituent organisms and their seasonal distribution, brought out in 1903 and 1908, respectively. In a recent Bulletin* of the Laboratory, Dr. Forbes and Mr. R. E. Richardson have thrown such an interesting light on the self-purification of the Illinois as it exists today that it seems desirable to mention some of their more important facts here. These observations were made chiefly in 1911 and 1912.

A large part of the work related to the minute animal and plant life of the stream—the so-called plankton—which forms a considerable part of the food of many kinds of fishes and nearly all the food of the young of almost every kind. Distinction was easily made between the organisms which found their most congenial habitat in (1) septic, (2) polluted, (3) contaminated, and (4) clean water conditions.

The Drainage Canal was described as visibly polluted with sewage solids and of a sewage odor, not particularly offensive, in fall weather. The dissolved oxygen was nearly, but not entirely, depleted. Many fishes, evidently from Lake Michigan, were dead along the banks. The minute forms of life were such as belonged in a septic and polluted environment.

The Desplaines River at Lockport was more offensively polluted than the Drainage Canal itself. The water had a grayish look and a filthy smell which was described as a mixture of fishy and privy odors. Septic forms of life existed and no fish were found except in cold weather, when the conditions were less offensive.

The Desplaines at Dresden Heights, about 50 miles below Chicago, near the junction with the Kankakee, in summer supported only typically septic forms of life. The water had a grayish, sloppy appearance with a mingled fish and privy odor. Sticks and stones were festooned

*Bulletin of the Illinois State Laboratory of Natural History, Urbana, Illinois, U. S. A., Vol. IX, June, 1913 Article X.

with tufts of organisms of putrefaction which, in order to avoid scientific terms, may be called sewage fungi. No fishes were found, but many shells of dead molluscs were seen. Only at the edges was there enough oxygen to supply the needs of any of the forms of life originally natural to the stream.

The Kankakee was found to be supersaturated with oxygen, even in summer, and its biological conditions were those of clean streams—no blue-green algae, no fixed forms of protozoa, and no septic fungus. Green algae, many river mussels and several kinds of water snails were among the clean water forms.

At Morris, about 60 miles from Chicago, and below Morris, the decomposition of the organic matter reached its height. The water was grayish and continuously foul, with a distinct privy smell in the hottest weather. Bubbles of gas were continuously breaking at the surface. On the warmest days, putrescent masses of soft, grayish-black, mucky matter, from the diameter of a walnut to that of a milkpan, were floating on the surface. In midsummer, the oxygen in midstream was .27 part per million, corresponding to 3.1 per cent. of saturation. The animals and plants were of the kind which reguire septic and contaminated habitats. Every stick and grass blade along the edge of the main stream was tufted with the sewage fungus. No fishes were seen or heard of in the summer, except in the tributaries. The bottom sludge was characterized by a virtual absence of oxygen, a large amount of carbon dioxide, and a predominance of marsh gas. Sludge worms were abundant.

The autumn conditions were better at Morris and in winter the odors were those of undecayed human feces in place of the ranker smell noticeable in the warmer weather. Decomposition being much slower in winter than in summer, the dissolved oxygen figure was higher.

In the midsummer of 1911, the water above the Marseilles Dam, which is about 75 miles from Chicago, had a grayish look and a disagreeable odor, but held much less material in suspension than at Morris. Active decomposi-

tion was prevailing. The biological collections were like those at Morris, except that there was less sewage fungus and some forms of insect larvae, crawfishes, mollusks, and other clean water animals near the shores. No trace of fishes were found above the Marseilles Dam in the summer of 1911 and but few in the winter and the stomachs of those which were caught were empty.

The effect on the water in passing over the Marseilles Dam and rapids below was to cause the water to absorb oxygen and to pulverize a great deal of the organic matter, and the still water above the dam afforded an opportunity for much of the suspended matter to settle out. The microplankton was about 20 per cent. less abundant below than a mile or so above the dam and chiefly of the same kinds. Mollusks were not only living but breeding below the dam and crustaceans were taken. In the summer of 1911, the ratio of dissolved oxygen was three times as high below the dam as above it.

In the summer of 1912, the water at Ottawa, about 81 miles from Chicago, had a distinct sewage odor somewhat less noticeable than that at Marseilles. The river sludge did not differ materially from that above the dam, either in sensible character or in the organisms which it contained. The characteristic foul-water fungi were less abundant than at Marseilles. The same blue-green algae, characteristic of polluted water, were found. There were no sponges, hydroids, or planarians, such as are found in clean water. The lessening of contaminate forms was shown by the occurrence of small numbers of various insect larvae, including dragon-flies, May-flies and sand-flies. No mussels could be discovered. Fishes were found to some extent, including carp, bullheads, minnows and shiners.

The odor at Starved Rock, about 90 miles from Chicago, in August, 1911, and September and October, 1912, was still disagreeable, but there were no bubbles of gas, as at Marseilles, and less suspended matter. The beneficial effect of the Fox River, which enters here, was noticeable in the higher dissolved oxygen figures of this

stream. But few specimens of sewage organisms were found. Apparently a considerable variety of fishes existed, but the numbers were never large. The sludge was full of slime worms. Blue-green algae were not nearly as plentiful as were the clean green kinds. Living sponges and crawfishes were found. The fishes included carp, redhorse, bullheads and minnows.

At Peru, 100 miles from Chicago, the water still had a grayish look, was full of minute gray particles and had a slight sewage odor in August, 1911. The dissolved oxygen varied between 3.17 and 3.51 parts per million, which is 35.8 to 39.6 per cent. of saturation. Mussels were found in considerable variety, but many were dead. The first river shrimps were found at Depue, about 112 miles below Chicago, and at this place were also taken many varieties of insect larvae, and naiids, planarians, etc. Here also were the first commercial fisheries, carp, sunfish and crappies being plentiful.

At Hennepin, about 115 miles from Chicago, the water became, to all appearances, practically normal in the midsummer of 1911, being odorless, greenish, free from clusters of fine water organisms and sewage debris. The mud had no offensive odor and only a few slime worms. Commercial fishing was in progress, mostly, however, in the adjacent lakes. There were but 2 septic organisms to the cubic centimeter here as compared with 16 at Starved Rock and 80 at Morris, and 6 pollutional forms as compared with 71 at Starved Rock, 134 at Marseilles and 142 at Morris.

Between Henry and Chillicothe, about 140 miles below Chicago, the process of renovation was simply carried a little farther than above. Only in winter, apparently, are the sediments offensive as far as Chillicothe. Commercial fishing was carried on in the Henry-Chillicothe section on a large scale in good seasons, but much complaint had lately been made all along this part of the river that fishing was not so good as in former years. Many species of fishes, most of them bottom fishes, including large cat-fishes, the red-horse, the buffalo, and the

sheepshead, were formerly common in the upper part of the Illinois River but are now wanting, rare or greatly reduced in numbers.

The chemical data indicated the existence of four phases in the river conditions, corresponding to the four seasons. The midsummer phase was characterized by a concentrated pollution and an early and rapid decomposition and deoxygenating process with the lowest oxygen readings at Morris and above the dam at Marseilles, followed by a sudden rise in oxygen below the dam and a gradual rise down the stream to its mouth. The winter phase was characterized by a delay in decomposition, such that the oxygen ratio was high at Marseilles and declined slowly to the middle of the river's course (Havana) and then gradually rose to its mouth. The spring and fall phases were intermediate between these two.

7.—ANALYSES BY THE SANITARY DISTRICT OF CHICAGO.

Two trips through the Illinois River for the purpose of making oxygen analyses were made by the Sanitary District, one on July 19 and 20, and the other on August 31 to September 5, 1911.* Starting with a practical exhaustion of the oxygen at the mouth of the Drainage Canal, the low figures until the Marseilles Dam was reached were 1½ parts in one case, and 5½ parts per million in the other case above the dam.

The effect of passing over the dam and through the rapids below was to add about 2 parts per million of oxygen to the water, after which there were from 4 to 7 parts per million present to Dam Henry. At Peoria, there were from 6 to 9 parts per million present. The higher figures for each part here given refer to the July trip, when the river was at a high stage and the lower figures refer to the August-September trip, when the water was low. At the time the trips were made, there were about 9 parts per million of oxygen in the Lake Michigan water at

*Report on Sewage Disposal, George M. Wisner, Chief Engineer, Sanitary District, Oct. 12, 1911, Fig. 1, p. 4.

Chicago. There was no oxygen whatever in the water and sewage mixture which passed the power house at the end of the Drainage Canal at Lockport. The samples taken 500 feet below, after passing the power house, contained 4.1 to 5.1 parts per million.

Mr. Wisner's report gives the results of analyses of 39 samples of the contents of the Drainage Canal at Lockport for the six months from March 21st to September 21st, 1911, and from these it is possible to form some idea of the material which is discharged into the Illinois Valley. About one-half the samples were taken near the top and the other half near the bottom of the stream. After the first of June, there was generally a complete absence of dissolved oxygen and no oxygen in the form of nitrites or nitrates, showing the stream to be in a putrid condition.

The chlorine usually ran steadily below 20 with extremes of 15 and 21 parts per million. The suspended matter varied markedly between 12 and 74. The total organic nitrogen fell off as summer advanced, with an average of 1.17 and extremes of 1.80 and 0.65; the nitrogen as albuminoid ammonia averaged 5.7 and ranged between .40 and 1.03; the nitrogen as free ammonia averaged 1.22 and ranged between 0.46 and 2.6, and the oxygen consumed averaged with limits of 2.7 and 17.1. The extremes of alkalinity were 126 and 148 expressed in terms of calcium carbonate. These results are all expressed in parts, by weight, of the substance named in every million parts of the water and sewage mixture.

At the time these analyses were made, the flow of the Drainage Channel averaged 421,000 cubic feet per minute and varied between 323,000 and 488,000 cubic feet per minute. The temperature of the water was about 70 deg. Fahr.

8.—OPINIONS OF THE EARLY PROMOTERS OF CHICAGO'S SEWAGE DISPOSAL SCHEME.

The investigations of Prof. Long and his colleagues have been widely quoted and have done much to fix the

opinions of scientific men as to the measure of success which has attended Chicago's plan of disposing of its sewage. But the results had no effect in preventing St. Louis from bringing the threatened suit in 1900 against Chicago for polluting her water supply.

It is often supposed that Prof. Long's investigations were the first to throw light upon the manner in which the forces of nature operated in disposing of the sewage, but this is not the fact. That the sewage was finally disposed of by oxidation, that agitation facilitated the oxidizing process and that temperature had an important effect upon the rate of oxidation were known at Chicago more than twenty years before Prof. Long's report of 1889 was made.

An investigation of the best means available for improving the water supply of the City of Chicago was among the earliest efforts of the State Board of Health of Illinois, and in a preliminary report to the Board in 1869 rendered by Dr. John H. Rauch and Dr. Frank W. Reilly on "The Water Supplies of Illinois and the Pollution of Its Streams," it is stated "That the oxidation of organic matter is promoted by the process of pumping will be seen by comparing the analyses of specimens," which the investigators had collected before and after the water of the river had passed through the Bridgeport works. In the next paragraph, it is stated that "the agency of the pumps in promoting oxidation will be more needed in winter than in summer, because, among other things, the stirring of the water of the canal by the passage of boats promotes oxidation, in some degree at least, but, more importantly, because low temperature retards oxidation."*

The object of the report of Dr. Rauch, which has just been quoted, was to secure the construction of the pumping works at Bridgeport, and in this he was successful.

Dr. Rauch had confidence in the self-purifying capacity of the canal and thought the only difficulty lay in

*Pollution of the Illinois River, James A. Egan, State Board of Health of Illinois, 1901.

increasing its flow sufficiently. He held the opinion that a large dilution of the sewage would render it offensive to the people in the Illinois River Valley and he was so certain that this would be accomplished that he concluded his report with the following words (p. XIII):

> "There is another view of the case to which the attention of the municipal authorities of Chicago should be called, which is that the city has no right to unnecessarily injure the material and sanitary interests of any other part of the state. The community of interests which exists between the citizens of Chicago and the inhabitants of the country lying along the canal and river, forbids the injury of either by the other."

9.—ORIGINAL ESTIMATES OF QUANTITY OF DILUTION WATER REQUIRED.

It was not certain to Dr. Rauch how much water was required to effect the desired purpose. He said (p. XIV):

> "If 60,000 cubic feet of water per minute at the head of the canal will not create the necessary current to effect this purpose, I have only to remark that the amount may be increased up to 100,000 cubic feet, which, according to Mr. Thomas, is the present capacity of the canal."

In a note appended to his report, the author gave further estimates of the amount of water which, in his judgment, would be needed to flush away, without nuisance, the sewage of the city. He argued strenuously for at least 60,000 cubic feet per minute and this he thought would be sufficient for the population of that day; at the same time he clearly foresaw that the growing city would eventually require more. Dr. Rauch was then Secretary of the State Board of Health and his arguments had the intended effect. The Report of the State Board of Health from which the above abstracts are taken says (p. XVI):

> "It might well be stated here that owing to the persistent recommendations of Dr. Rauch, fortified by the opinions of competent observers, that the only remedy for the conditions existing lay in an increased flow of water into the canal—and strengthened also by the protests of cities receiving the sewage of Chicago, and a tentative proposition to compel the city to dispose of its sewage in another manner than by discharging it into the canal—steps were taken in 1881 to cause

an increased flow of water from the Chicago river into the canal."

After the pumping works advocated by Dr. Rauch were constructed, the water which they supplied kept the Chicago River from extremely offensive conditions for about two years, after which it resumed the state which existed prior to the construction of the works. What changes, if any, were produced in the condition of the Desplaines and Illinois Rivers, were not indicated. The state of those streams, as they appeared to the senses, was not recorded.

10.—INSANITARY CONDITIONS ATTENDING THE SELF-PURIFICATION OF THE RIVERS.

It is perfectly evident that the forces of nature eventually purify the Illinois River and make the water fit to drink. This fact was established by the early investigations of the State Board of Health for their time and it has been confirmed for subsequent times by the elaborate investigations of the Water Survey and the State Laboratory of History as well as by the experiments and tests which were made in order to defend Chicago against the charge that it was polluting the water supply of the city of St. Louis. There is no doubt but that the harmful properties of the sewage eventually disappear.

The catch of fish in the lower Illinois has been increased in recent years, although a large part of the increase seems to be due to the introduction of European carp, and many excellent species which were formerly abundant have disappeared from the upper reaches.

It is evident that sedimentation, fermentation and oxidation play important parts in causing the sewage matter to disappear, but how these processes operate is far from being understood. Evidently they act variously at different seasons of the year and it is certain that they are not under control.

It might be supposed that the highly polluted river would occasion a good deal of sickness, but this does not seem to be the case. The pollution of the Illinois is not a

question of health as much as one of decency. Chicago's sewage does not produce epidemics in the Illinois Valley or elsewhere. Contrary to old belief, it never did so in Chicago, except where the drinking water supplies were directly or immediately concerned, or the infectious matter was carried to food by flies or other physical means. The people of the Desplaines and Upper Illinois know that the water is poisonous and do not drink it. Long continued experience has given them a degree of care which has been sufficient to avoid the danger. It is possible that some share of immunity has been acquired against the ordinary infections which might be expected. How the hundred miles of sewage would act as a distributor of disease in case Chicago was visited by cholera, or other malignant epidemic disease, can only be conjectured.

11.—ROLE OF THE CHICAGO DRAINAGE CANAL IN DISPOSING OF THE SEWAGE BY DILUTION.

In spite of the large amount of analytical and other study which has been given to the condition of the Desplaines and Illinois Rivers, it is not known how much of Chicago's sewage could be carried off with a given volume of diluting water from Lake Michigan without creating offensive conditions at some point, before the stream purifies itself. From the evidence considered by the Sanitary Experts of the Real Estate Board, it appears that no such estimate is possible.

It needs no analysis to show that the minimum ratio of dilution which is required by the State law has only a theoretical basis and that the avoidance of insanitary conditions in the Desplaines and Illinois Rivers was the object really aimed at in specifying the least amount of water which should be employed.

Many conditions other than dilution enter into the question of how the sewage disappears. The composition and state of the sewage with reference to putrefaction is an important consideration, as are the condition of the

diluting water with reference to temperature, oxygen content, velocity of flow, area of surface as compared with depth, agitation, etc. It makes a great deal of difference whether the sewage is allowed to become entirely, or somewhat, putrid, before it is discharged, and whether fermentable deposits exist. The composition and amount of trade wastes may entirely upset all other calculations. All these conditions play important parts in the disposal of the sewage into the Chicago River and its subsequent removal and digestion through the Canal and river system.

The early investigators believed that the sewage materials must finally be oxidized before they could be destroyed and no advance in scientific thought has changed that belief. Messrs. Rauch, Reilly and Long were right in supposing that the diluting water could bring a large initial supply of oxygen and that further demands must be furnished chiefly by the atmosphere. The investigators had an incomparable opportunity to study the oxygen requirements of the sewage and the phenomena attending its discharge into the Illinois and Michigan Canal; but their methods were not such as would be used today and they had few data on the amount of dissolved oxygen present or required. There is reason to suppose that the Drainage and Water Supply Commission of 1886-7 had access to all the analytical data which had been collected for the preceding fifteen years, beside other information concerning the filth produced and its behavior, but they were uncertain as to the amount of dilution required, and their recommendation in respect to this matter was provisional.

All the calculations which have been made, recently or in former times, as to the dilution accomplished or required at Chicago appear to have been based on the assumption that the sewage was discharged as sewage into the diluting water and that this water and sewage mixture then flowed away in a definite and constant proportion. Nothing could be farther from the fact. The mixing is not completed in the Chicago River and prob-

ably not in the Drainage Canal until the sewage and water have flowed for a considerable distance.

It has never been possible to say with any degree of accuracy how much sewage was being carried away, and how much was being left behind. Some was always depositing and some disappearing by fermentation attended by the liberation of gas. All the arms of the Chicago River have received large volumes of sewage and there has been nothing like regularity in the thoroughness with which they have been flushed out. Winds, movements of vessels, changes in the lake levels and rainfall have all had their influence, and although the great bulk of polluting material may now find a fairly prompt outlet through the Drainage Canal, the amount which deposits and putrefies and cannot be reached and promptly removed by flushing is considerable.

From analyses of the mixture of sewage and water and the volumes passing Lockport, contained in Mr. Wisner's report on sewage disposal, it is possible to calculate approximately how much nitrogen is being discharged into the Desplaines and Illinois valleys. The data used relate to the period between June 1st and September 28th, 1911.*

The volume of water averaged for the four months, 4,210,000 cubic feet per minute, or 18.9 million tons per day. The nitrogen as total organic nitrogen, averaged 1.17 parts per million, or 21.1 tons per day. The nitrogen as free ammonia was 1.22 parts per million, or 22.1 tons per day. Nitrites and nitrates were absent. The total, 43.2 tons, represents the nitrogen which was discharged on an average day in the summer of 1911 from the Drainage Canal at Lockport into the Desplaines and Illionis Valleys.

There is a marked difference between the 43.2 tons of nitrogen calculated from the known condition and quantity of the water, and the 35 tons estimated on the basis of the feces and urine excreted by the tributary popula-

*Report on Sewage Disposal by George M. Wisner, Chief Engineer of the Sanitary District of Chicago, October 12, 1911, Plates 7A and 7C.

tion. This suggests that the feces and urine are not the only important source of the nitrogen, a supposition which appears reasonable in view of the large numbers of animals in Chicago and the manifold uses to which the water is put in cleaning the persons, homes, business places and streets of the city. And when the amount and character of the trade wastes are taken into consideration, it is probable that the whole weight of nitrogen is not represented even by the 43.2 tons. A considerable amount must escape from the over-polluted parts of the waterways in the form of gas.

Aside from its pre-eminently useful office as a means of carrying the sewage away from Chicago, the function of the Drainage Canal is to mix, dilute and partly digest the sewage, before it is discharged into the Desplaines River. It is most active as a digestive agent in summer when the temperature is most favorable to the chemical and biological changes which take place.

12.—SELF-PURIFICATION AS SHOWN IN THE ST. LOUIS SUIT.

Some of the most useful information available concerning the behavior of the water and sewage mixture in purifying itself is contained in the results of analyses and experiments made with the object of obtaining evidence with which to defend the suit which was brought by St. Louis to stop the discharge of Chicago's sewage into the Drainage Canal.

The bill of complaint alleged, among other things, that the water supply of St. Louis, which is taken from the Mississippi about 43 miles below the junction of that river and the Illinois, and 363 miles from Chicago and the supplies of other towns in Missouri, would be poisoned by the contents of the Drainage Canal which carried about 15,000 tons of filth daily, and that the Mississippi water would be rendered unfit for use, the conditions of pollution amounting to a direct and continuing nuisance. The pollution would endanger health and irreparably injure

business and had already caused sickness along the banks of the Mississippi.

The complainant was the State of Missouri, in which the city of St. Louis is situated, the use of the name of the State being necessary in the case for the reason that it is impossible, according to the laws of the country, for one city to sue another. The suit was brought January 17, 1900; it was decided February 19, 1906.

The defendant undertook to prove through facts and opinions introduced by experts, that the water of the Mississippi was not poisoned or its adaptability for domestic use destroyed. On the contrary, an attempt was made to show that the sewage-laden water contributed by the Drainage Channel greatly improved the water of the Mississippi. It was claimed for Chicago, "That by natural laws governing running water in large bodies, the sewage was deprived of all its deleterious qualities by processes of vaporization, attrition and chemical conversion."

The expert testimony covers over 8,000 printed pages, and represents the state of knowledge of the day on chemical, bacteriological and epidemiological subjects more or less germane to the case. There is an excellent summary by Leighton.*

The decision of the court was rendered six years after the beginning of the suit. The Court stated that the actual facts had required for their establishment delicate experiments and the most subtle speculations of modern science. But the bill of complaint was dismissed on the ground that the evidence fell far below the allegations.

The testimony concerned the self-purification of the Illinois as regarded from the drinking water standpoint. There is comparatively little evidence to show how the river recovered its purity, so far as nuisance is concerned. That the Illinois River was able to assimilate the enormous amount of filth which was thrown into it was, nevertheless, evident.

*Pollution of the Illinois and Missisippi Rivers by Chicago Sewage, by Marshall O. Leighton, Water Supply and Irrigation Paper No. 194, United States Geological Survey, 1907.

The chemical and bacteriological evidence indicates that the Illinois purifies itself twice on its journey from Chicago to the Mississippi: once after receiving the sewage of Chicago and again after the sewage of Peoria and Pekin are poured into it. In each case the pollution is excessive. The sewage of Chicago constitutes what is probably the heaviest load of polluting material which is discharged at one point into any river in the world. The pollution from Peoria and Pekin consists largely of the excrement of cattle. This material was described as sometimes forming floating islands so large and compact that they had to be broken up before they could pass the bridges which span the river.

The evidence shows that after receiving its burdens of filth, the Illinois River passes through periods of sickness from which it emerges as clear and wholesome as other rivers in the same region which have not been contaminated beyond the common. Curiously enough, the distance traveled before the purified condition is resumed, appears from the testimony to be about the same in each case: 125 to 130 miles.

The process of self-purification is assisted by the addition of river water which the tributaries of the Illinois receive on their way toward the Mississippi. This dilution is evident in the decrease in chlorine which takes place in the water between Lockport and La Salle, 70 miles below. The reductions which occur in the free and albuminoid ammonias and in the numbers of bacteria are still more marked.

During its course as a highly polluted stream, the unsuitability of the water for drinking and other domestic purposes is recognized by those who live upon the shores of the river. No public water supplies are drawn from it. Comparison of the death rates among the cities and towns by the river side, with the rates in other parts of the country, do not show that any harmful effects are produced upon health.

13.—DATA ON THE DISAPPEARANCE OF THE DISEASE GERMS.

The evidence presented in the St. Louis suit concerning the disappearance of typhoid bacilli and other intestinal bacteria are among the most interesting parts of the testimony. Apparently the harmful bacteria do not live long in the water and sewage mixture, but their length of life and the manner of death cannot be said to have been demonstrated. It was impossible to study the germs in their natural environment or to imitate that environment with sufficient exactness to establish these facts. The evidence on this point was of a suggestive, rather than of a convincing, character, and was of principal value when taken into consideration with other data of a related nature.

Typhoid statistics in the region concerned, the records of epidemics in different parts of the world, the usual behavior of saprophytic organisms, the known requirements of the typhoid bacillus as to food and temperature, and the time required for the sewage bacteria to pass from one point to another along the waterways, all had cumulative force in favor of the opinion that any germs of typhoid which might be discharged into the sewers of Chicago could not survive until they entered with the drinking water into the houses of St. Louis. Dr. E. O. Jordan, Professor of Bacteriology in the University of Chicago, under whose supervision a large part of the analytical work was done, expressed the opinion that typhoid bacilli would not live, under the conditions which existed, for more than four to six days. Assuming that they moved at the average rate of about two miles per hour, they could only travel from 50 to 75 miles from Chicago toward St. Louis before they perished.

The effect of irregularities in the discharge of the sewage and in the flow of the river before the harmful properties of the sewage were destroyed, was considered, and opinions were expressed on both sides of the question whether the deposits which formed at some seasons might

be flushed down the river at others, without yielding proof of one contention or the other.

The effect of sedimentation was said by some to be on the side of purification, since it removed bacteria from the water. This contention was disputed by others, who claimed that sedimentation only stores impurities which may later be raised up and carried on by swifter currents.

The effect of dilution was a contested point, some expressing the opinion that it was a purifying influence, since it lessened the chance of drinking harmful germs in a given volume of water, while others thought this was of little moment since the germs were not actually destroyed.

Similarly, the effects of sunlight, of algae, of agitation and of other influences were asserted, challenged, and argued without bringing out information which is useful in the present inquiry.

14.—TESTIMONY AS TO THE EFFECT OF VARIOUS RATIOS OF DILUTION.

Theories were advanced, examples were cited and authorities were quoted to show how water would, and would not, purify itself. Tables were put in evidence to show what ratios of sewage to water would produce a nuisance, those which would remove all risk of nuisance and what degrees of dilution would prove doubtful. Mr. Rudolph Hering, Consulting Engineer, who introduced this testimony, said that in his opinion the mixture would prove offensive if the amount of flowing water was less than 2 cubic feet per second per 1,000 persons sewering into the stream. This dilution would represent 1,292 gallons per capita per day. If the dilution was equal to, or more than, 8 cubic feet, it would not be offensive. Between these wide limits there might, or might not be, nuisance. It was the duty of the engineer to select between these limits that dilution which conformed best to the local conditions.

In connection with the Chicago Drainage Canal, Mr. Hering testified that while a member of the Water and Drainage Commission in 1886-7, he had recommended a

dilution of 4 cubic feet per second per thousand persons, because in the state of his knowledge at that time he did not feel justified in recommending a less dilution. Subsequently, the allowance was reduced to 3.33 cubic feet, and on that basis the canal was built.

There was introduced in the testimony in the St. Louis suit, a table, based on the population tributary to, and the amount of water flowing through, the Drainage Channel. This showed the approximate dilutions which had existed in the Drainage Channel since it was opened in 1900. From these figures, it appears that in 1900 the population whose sewage was discharged into the canal was 1,443,780; the average dilution, as determined by weekly averages, was 2.70 cubic feet per second per thousand of population. In the year 1902 the tributary population was 1,545,300 and the average dilution was 3.18.

15.—THE ANALYTICAL EVIDENCE IN THE ST. LOUIS SUIT.

The analytical evidence which was offered in the St. Louis case was presented in the form of tables and diagrams in great variety. Every analytical study of the Illinois before and after the opening of the Drainage Canal was brought forward, and in some cases, experts were especially employed to interpret the results. Emphasis was naturally placed on the bacteriological data, but the chemical results received nearly an equal share of attention. The analyses which Professors Long and Palmer made of the waters before and after the opening of the Canal were considered of more than ordinary importance from the chemical standpoint.

The data presented by Prof. Long related to the period between the years 1886 and 1902, and showed the condition of the old Illinois and Michigan Canal, the Desplaines, the Illinois and the Mississippi Rivers at various points and at various seasons. After the opening of the Drainage Channel, the composition of the water and sewage mixture of the Channel was, in parts per million, as follows: Albuminoid ammonia, 1.13; free ammonia, 3.9;

oxygen consumed, 7.46; chlorine, 23.5. At Morris, 58 miles from the head of the Drainage Channel, the following average data represented the conditions from May to October, 1900: Albuminoid ammonia, 0.63; free ammonia, 2.84; oxygen consumed, 6.40; chlorine, 17.8.

Of special interest in connection with the chemical work, was the testimony of Prof. Palmer to the effect that there was always enough dissolved oxygen in the waters of the Illinois to saturate the water. At times the water was supersaturated with oxygen, a condition which was attributed to the action of chlorophyl-bearing organisms.

16.—THE ILLINOIS BEFORE AND AFTER THE OPENING OF THE DRAINAGE CHANNEL.

So far as the chemical evidence which was introduced in the St. Louis case is concerned, the data indicate that the condition of the Illinois was better after the opening of the Drainage Channel than it had been before. If the Channel had brought more sewage into the valley, it had also brought more diluting water, the net result being that the river was in better condition than when the Illinois and Michigan Canal had alone to carry the sewage of Chicago to the Illinois.

Dr. Leonard P. Kinnicutt, Professor of Sanitary Chemistry in the Worcester (Mass.) Polytechnic Institute, basing his opinion on the data submitted by Profs. Long, Jordan and Palmer, testified that about 20 per cent. of the organic matter which was discharged into the Drainage Channel disappeared before the water and sewage mixture reached Lockport. In his judgment, the Drainage Channel was a useful instrument in furthering the purification of the sewage, serving somewhat in the capacity of a septic tank.

17.—THEORIES AS TO SELF-PURIFICATION.

Various experts expressed the opinion that water did not purify itself more rapidly when running than when standing still. It was time, rather than distance traveled, that was the all-important factor in the self-purification of

streams. Prof. Sedgwick emphasized this point, and called attention to the large number of fatal mistakes made by cities which, relying too much upon the self-purifying power of running water, had built public water works which had brought great epidemics of typhoid fever upon them.

Among the theories which were advanced to account for the self-purification of Chicago's sewage was that of Prof. Long, who pointed out that, inasmuch as the banks of the Illinois are very low, one of the effects of floods was to spread the water over an area of many hundreds of thousands of acres, providing for the sedimentation and oxidation of matters carried by the waters at these periods.

The overflow disposed in this manner of a vast amount of organic matter which, in a stream with high banks, would have to be carried forward. Inasmuch as by far the largest part of the water at flood times left the river's natural bed and was distributed over the land, the original sewage or its remnants must, in like manner, be distributed, and thus made accessible to the purifying processes of sedimentation and oxidation. The lakes and dams across the Illinois likewise afforded large basins for oxidation.

18.—RECOGNITION OF THE IMPORTANCE OF OXIDATION.

The useful part played by oxidation in disposing of the sewage was clearly recognized in the suit, but the conditions which were necessary in order that the process of oxidation might be carried on to the best advantages were not defined. It was found that in some way the Drainage Channel and the Illinois and Michigan Canal were useful in disposing of the sewage and it was suggested that they might be acting in the capacity of septic tanks, but this was a mere guess.

It seems not to have been suspected, except by Prof. Palmer, that all of the sewage which was produced in Chicago and turned into the Chicago River did not get

into the Drainage Channel, but remained in the form of deposits which fermented and sent off to the atmosphere the products of their decomposition. Yet this process was, and still is, going on.

The amount of organic matter and the other constituents of the sewage were not accurately determined. It could not, of course, be shown by analyses of the water of the Chicago River or of the Drainage Canal.

Since the analyses of Prof. Long and his associates, a change has occurred in the significance which sanitary experts attach to determinations of the nitrogen compounds in water, so that no such importance would be attached to the great mass of chemical results which were submitted in the testimony in the St. Louis case today as was given to them at the time when they were presented. At the present time, there is a distinct tendency to set aside the elaborate and complicated analyses of albuminoid ammonia, free ammonia, nitrites and nitrates for more simple and direct tests of the extent of fouling, such as determinations of the putrescibility of the water and sewage mixture and the amount of dissolved oxygen present. There were, apparently, no putrescibility tests submitted in the St. Louis case and the dissolved oxygen determinations were exceedingly few.

The bacteriological work was of the sort which the best present usage calls for, except, perhaps, that more importance would now be attached to determinations of B. coli and greater accuracy would be possible in stating the numbers of this intestinal organism than the standard methods of a dozen years ago permitted.

As a whole, the analyses hung together well, and it is worthy of remark that no considerable part of the more important analytical work has ever been challenged. Only the inferences which were drawn from the data, and which were necessarily more or less arbitrary, are open to dispute.

Part VI

THE CALUMET PROBLEM AND THE LAKE LEVELS CONTROVERSY

1.—RELATION BETWEEN THE CALUMET PROBLEM AND THE LAKE LEVELS CONTROVERSY.

In its narrowest sense,the Calumet problem consists in determining how best to dispose of the sewage which is produced in the State of Illinois to the south of the original Sanitary District of Chicago in order to protect the water supply of Chicago against pollution from the Calumet. In a broader sense, the problem appears to be the disposal of the sewage in the whole Calumet River drainage area, a large part of which lies in the State of Indiana.

The lake levels controversy is a dispute between the Sanitary District and the United States Government as to the amount of water which Chicago has a right, or may be permitted, to divert from Lake Michigan to the Desplaines and Illinois Rivers.*

The Calumet sewage problem and the lake levels controversy are related in that the Calumet-Sag Canal calls for 2,000 cubic feet of lake water to begin with, and twice that amount ultimately. Application by the Sanitary District for permission to take 2,000 cubic feet in addition to the 10,000 cubic feet per second already allowed for the Chicago Drainage Channel precipitated objections from the United States to the diversion of so much water at the southern end of Lake Michigan. The ground of these objections lay in the danger that the removal of 14,000 cubic feet of water per second would lower the levels of

*For a brief on the facts and issues on behalf of the Sanitary District, see The Diversion of the Waters of the Great Lakes by Way of the Sanitary and Ship Canal of Chicago, by Lyman E. Cooley, Chicago, February, 1913.

the Great Lakes, thus reducing the depth of water in the harbors. A material reduction in depth would entail expense upon the United States for dredging and other improvements.

At the present time, the Sanitary District is proceeding to construct the Calumet-Sag Channel as though it was certain to obtain the diluting water required, notwithstanding the fact that the application made by the District for permission to divert 4,000 cubic feet per second for the purpose of reversing the flow of the Calumet River and causing the water of that river to pass through the Canal was denied by the United States Secretary of War in an opinion in which he repeated a suggestion already made that this was a question of capital and national importance and should be submitted to the Congress of the United States.

At the present time the United States is endeavoring to prevent the diversion of more water from the lake than the 4,167 cubic feet which has been allowed for the Chicago Drainage Channel and is suing the Sanitary District in two cases, the two being tried simultaneously, by mutual agreement.

The bill of complaint in the first suit was filed on March 23, 1908. It seeks to enjoin the defendant from building any channel to connect the Little Calumet River with the Sanitary District's main channel so as to reverse the flow of the Calumet and the Little Calumet Rivers or to divert any water from Lake Michigan, except through the Chicago River. The second bill of complaint was filed October 6, 1913, and seeks to enjoin the Sanitary District from diverting or abstracting water from Lake Michigan in excess of the 4,167 cubic feet per second already allowed.

It is inappropriate and unnecessary here to discuss the lake levels controversy, beyond indicating its bearing upon the whole question of how the sewage of Chicago shall in future be disposed of. Through a large number of expert witnesses, Chicago has sought to show that there is no other way of protecting its water supplies and dis-

posing of its sewage than by the discharge of the sewage into the Illinois valley except at prohibitive expense, and it contends that the lake levels are in no danger of being lowered through the abstraction of the water which is required for the purpose of diluting its sewage and flushing it to the Illinois.

2.—DRAINAGE AREA AND POPULATION IN THE CALUMET DISTRICT.

The Calumet River enters Lake Michigan about 11 miles south of the mouth of the Chicago River and immediately south of the original Sanitary District boundary, The drainage area of the Calumet is 825 square miles, of which 485 square miles lie in the State of Indiana, and 340 square miles are in the State of Illinois. Under ordinary circumstances, the flow is very small (700 cubic feet per second plus sewage 525 cubic feet per second) but at times of heavy rain, it has been found to have a flow of 13,000 cubic feet per second, and it is believed that the discharge may reach a maximum of 15,000 cubic feet per second. The drainage area includes large swampy regions and lakes which prolong the flood periods. The Calumet River has been improved by the United States Government for a width of 200 feet and a depth of 20 feet up to the Forks or outlet of Calumet Lake, a distance of 5 or 6 miles, and it is expected that further improvements on the same lines will be made up to Stony Creek, about 7 or 8 miles further. The Calumet is formed about 7 miles from its mouth by the junction of the Grand Calumet, and Little Calumet, the latter, in spite of its name, being by far the more important branch. Lake Calumet, with an area of about four square miles, lies about half way between the mouth of the Calumet River and the entrance to the proposed Sag Channel.

The Calumet River is of increasing importance as a harbor. At the mouth are immense manufacturing establishments, and the future industrial development of this region promises to rival that of the Chicago River itself.

3.—PRESENT CONDITIONS OF SEWAGE DISPOSAL IN THE CALUMET.

The Calumet River is in a highly polluted condition. When visited by the Board of Experts of the Chicago Real Estate Board in April, 1914, the water was seen to be black and giving off quantities of gas, doubtless the product of the fermentatons which were proceeding at the bottom.

Great volumes of sewage and manufacturing wastes are discharged into the river, particularly by the towns of Gary, Indiana Harbor, East Chicago, Whitney and that part of Hammond known as Robertsdale, as well as the sewage from that part of Chicago which lies south of 87th Street.

In May, 1910, the Committee on Engineering of the Sanitary District of Chicago recommended the immediate construction of the Calumet-Sag Channel for the disposal of that part of the sewage which it could be made to carry off, and accompanied the report in which this recommendation was made with a number of letters, from one of which, written by Dr. Arthur Lederer, Chemist and Bacteriologist of the Sanitary District, the following statement is quoted.*

> "At times of flood the current will run out of the Calumet river at a rate of 5 or 6 miles an hour for days at a time, contaminating the water supply of Indiana Harbor, East Chicago, Whitney and Hammond. Even the water supply of the southern portion of Chicago is affected for when off-shore winds prevail, streams of muddy water can be seen in the lake for several miles out, tending to the west as far as the Hyde Park crib of the Chicago water works."

4.—THE CALUMET-SAG CHANNEL.

The possibility of reversing the flow of the Calumet River, after the manner in which the current of the Chicago River has been reversed, and of discharging both of these two rivers to the Illinois Valley was considered by

*Calumet-Sag Channel a Vital Necessity; Report of the Committee on Engineering of the Sanitary District of Chicago, adopted May 25, 1910. Letters submitted with the Report, p. 12.

the Drainage and Water Commission of 1886-7. That Board appears to have contemplated the diversion of the greater part of the storm water of the entire Metropolitan district as a practicable proposition after "a glance at the map and an examination of the ground." Their idea of how the diversion could be accomplished is stated in the following quotation from their report, p. 24:*

> "Both branches of the Calumet river can be diverted west of the Indiana state line into Wolf lake and thence into Lake Michigan. The Desplaines river can have its flood waters diverted into the North Branch near the north line of the town of Jefferson, and the contained waters can be led from Bowmanville directly into the lake. Salt Creek, a branch of the Desplaines river, can readily be turned southwardly near Weston Springs, through a watercourse known as Flag Creek, at one time evidently the old bed, discharging into the Desplaines opposite Sag, and thus reducing the necessary storm water capacity in the new channel between Sag and Summit."

The Channel from the Calumet to Sag was estimated to cost between $2,500,000 and $3,000,000 and the diversion of the flood waters of the Calumet would cost between $350,000 and $400,000.

A circumstance which greatly favored the construction of the Calumet-Sag Channel and was a prominent factor in determining its size, was the fact that the lower end of the Chicago Drainage Channel proved in practice to have a capacity 4,000 cubic feet per second greater than the 10,000 cubic feet capacity which had been expected.

The upper end of the Drainage Canal could not flow 14,000 cubic feet, but it would be entirely practicable to add 4,000 cubic feet from the Calumet to the lower end and thus utilize the capacity to the fullest extent.

Preparation for the construction of the Calumet-Sag Channel was made when, in 1903, the original area of the Sanitary District was increased by the addition of a rectangle of 94.5 square miles of territory to the south. The new territory, generally called the Calumet District, included the Calumet River from its mouth, a short way up

*Report of the International Waterways Commission, January 4, 1907, Appendix A, p. 24.

the Grand Calumet, and a long way up the Little Calumet, the total distance by way of the winding streams being not much short of 25 miles.

The annexed region contains the Calumet Lake and a part of Wolf Lake, the other part of the latter lying in the State of Indiana.

There has been a great deal of argument over the Calumet, both in and out of Chicago, some persons thinking that the enlargement of the original territory of the Sanitary District by the Calumet annexation, and a nearly equal area to the far north which was made at the same time, was neither necessary nor justified as a part of the question of disposing of the sewage from the central and densely settled section of Chicago. Others have held the view that the metropolitan region should be dealt with as a single aggregate and that no provision for disposing of the sewage of part should be made without reference to the needs of the whole region.

A number of notable reports have been made on the disposal of the sewage of the Calumet District and the diversion of the Calumet River to the Illinois and these will be considered here, after briefly describing the canal which is being built.

The Calumet-Sag Channel is being constructed from Stony Creek on the North Calumet River, east of the town of Blue Island, to the Chicago Drainage Canal, at a place called Sag about 13 miles above the lower end of the Chicago Drainage Canal. Its length is about 18 miles, its width is to be from 36 to 60 feet and its depth 20 feet.

The Canal is to have regulating works at its eastern end to control the water which flows through it and the arrangements as to bridges, etc., are such as to provide for navigation.

The capacity of the canal is at first to be 2,000 cubic feet per second, provision being made for enlarging it so as to pass 4,000 cubic feet at a later period, if desired. Under the Sanitary District law, the original flow of 2,000 cubic feet per second is supposed to provide for the disposal by dilution of the sewage of a population of 600,000.

According to official figures, given by the Chief Engineer of the Sanitary District in January, 1914, the estimated cost of the Calumet-Sag Channel for a capacity of 2,000 cubic feet per second is $14,290,100.53. This includes the construction of the channel, controlling works, intercepting sewers to convey the sewage to the channel from the principal centers of population and for the sterilization of certain storm water overflows, land, engineering and emergencies. The capitalized operating cost of the channel, sewers, etc., as of 1920, is $5,159,370. Total capitalized and construction cost, $19,449,470.

When developed to its full capacity of 4,000 cubic feet per second, the construction cost would be $19,925,100, the capitalized operating cost $6,229,500, and the total capitalized and construction cost $25,729,640. These figures are as of 1930.

5.—THE INTERNATIONAL WATERWAYS REPORT.

On January 4, 1907, the International Waterways Commission, consisting of official delegates from the United States and Canada, presented to their respective governments a report* upon the Chicago Drainage Canal in which the question of diverting lake water for the Chicago Drainage Canal and Calumet-Sag Channel was considered, together with other means of disposing of the sewage. The Commission recommended "that the government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal." So far as the availability of other means of disposal for the sewage was concerned, the Commission stated, p. 16 of its report:

> "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 then be tributary to that river, and that the amount named will, therefore, suffice for the sanitary purposes of the city for all times."

*Report of the International Waterways Commission to the Honorable Secretary of War of the United States and the Honorable Secretary of Public Works of Canada, January 4, 1907.

By "areas now sparsely occupied" the Commission meant to include the Calumet.

The opinion of the International Waterways Commission as to the practicability of disposing of the sewage by other means than by flushing it through the Calumet-Sag Channel was largely based upon the conclusions stated after an investigation had been made into the situation by the firm of Rudolph Hering and George W. Fuller, Consulting Engineers. The instructions to these experts are stated on p. 12 of the Commission's report as follows:

> "To examine the sanitary situation at Chicago, so far as it is affected by sewage disposal, and to report whether it 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 waters 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 is alone 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."

In their report, which was presented to the International Waterways Commission in 1906,* Messrs. Hering and Fuller stated that the extension of Chicago's dilution

*Report of the International Waterways Commission, January 4, 1907, Appendix F. Report on the Disposal of Sewage of Chicago and Vicinity, by Rudolph Hering and George W. Fuller, December 18, 1906, pp. 42-54.

scheme was not the only way to dispose of the Calumet sewage and that "For the Calumet River, 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."

At the time this report was made the population in the Sanitary District of Chicago draining to the Calumet exceeded 100,000. The population had nearly doubled within six years and was expected to reach a million within a comparatively short period. The population in the area tributary to the Chicago River drainage area would eventually exceed the 4,200,000 estimate for which the utmost capacity of the Chicago Drainage Canal had been provided. The "dilution method would certainly not alone for all time take care of the crude sewage of this region."

The Calumet-Sag Channel would not be nearly as effective in reversing the flow of the Calumet River as the Chicago Drainage Canal had been in reversing the flow of the Chicago River and the protection of the lake water supplies would be less. The Calumet-Sag could not keep all sewage out of Lake Michigan at times of heavy rainfall.

The solution of the Calumet problem which was suggested was not the construction of the Calumet-Sag Channel, but the purification of the sewage in accordance with modern scientific methods, together with the filtration of that part of the water supply which was within the range of pollution from the Calumet River. For treatment, the sewage should be collected by means of intercepting sewers and pumping stations. The report says, pp. 47-48:

> "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 clean and non-

putrescible, 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 filtrating it according to water filtration 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 clean and non-putrescible."

The sewage would be screened, passed through septic tanks and then applied to intermittent sand filters, contact filters or sprinkling filters. The estimates were based on a population of 1,200,000 at 130 gallons per head and an allowance of 1,000 gallons per square mile per day, the total volume being 340,000,000. The estimates for construction and operation (the latter capitalized at 5 per cent.) were for intermittent sand filters, $28,383,000; for contact filters, $22,807,500, and for sprinkling filters, $17,637,500. The present population for the Calumet area of the Sanitary District being less than 200,000 would require but a part of the work to be done and the cost would be correspondingly small.

Three sites for the works which were available and suitable were: 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 Lake Calumet and Lake Wolf.

6.—MR. HERING'S REPORT IN FAVOR OF THE CALUMET-SAG CHANNEL.

On October 15, 1907, Mr. Hering made a report to the Sanitary District of Chicago in which he advocated the construction of the Calumet-Sag Channel as affording a more economical solution of the Calumet sewage problem than the purification of the sewage by sprinkling filters and for "other advantages of more or less weight." Among these advantages were the practicability of using the channel for purposes of navigation, and for the supply of water for the development of power at the electric works of the Sanitary District at Lockport.

The report was intended to express the author's opinion as to the most desirable method of disposing of the sewage "without causing a nuisance or pollution of the lake water, irrespective of previous recommendations or legal restrictions." Two alternatives were discussed—treatment by sprinkling filters and disposal through dilution by means of the Calumet-Sag Channel.

Disposal by dilution was advocated for the reason, among others, that "the dilution method of sewage purification being the prevailing one and the oldest one in use, is thoroughly known as to what it can do and what it cannot do." There was some uncertainty about sprinkling filters, especially in northern climates. "A final disposition of sewage by diluting it with a sufficient quantity of running water had the advantage of simplicity in operation and required less care and labor than treatment works."

The estimates of cost of sprinkling filters and disposal by dilution through the Calumet-Sag Channel for a population of 1,200,000, as given in the report to the International Waterways Commission were reported in the report to the Sanitary District and supplemented by estimates for a population of 300,000. Those estimates were then compared with the cost of the Calumet-Sag Channel on the basis of a flow of 2,000 cubic feet per second, which, at the legal rate of dilution, was expected to be able to dispose of the sewage of 300,000 population.

The sprinkling filter proposition was estimated to cost $4,761,000 for a population of 300,000 and $9,257,500 for a population of 1,200,000. The channel proposition was estimated to cost $15,533,000 for a population of 300,000 and $15,705,500 for a population of 1,200,000. The operating costs were, for the sprinkling filters plan $360,240 and $900,300, respectively. In estimating the annual cost of the channel scheme the cost of electric power which was to be developed at Lockport was regarded as a proper credit, and with this deduction, an annual cost was arrived at of $128,800 for a population of 300,000 and an annual cost of $230,600 for a population of 1,200,000.

The expenses of the two projects were then estimated as on a total annual cost basis—that is, made up of operating expenses and fixed charges for interest, allowance being made for the revenue to be derived from the sale of power in the channel scheme and no return credited to the treatment works. For the populations given, the two projects were then compared as follows: For a population of 300,000, sprinkling filters would cost $360,240 and the channel would cost $384,000. For a population of 1,200,000, sprinkling filters would cost $900,300 and the canal $490,900.

Power could be derived from the water and sewage mixture discharged by the channel not only at Lockport, but at Joliet, and if this was wholly utilized and the product credited, the cost of the channel would be still further reduced.

A large part of the report is devoted to considerations favorable to the Calumet-Sag Channel and to arrangements intended to meet criticism which had been brought against it, notable among which were the objections of the International Joint Commission.

7.—INEFFECTIVENESS OF THE CALUMET-SAG SOLUTION.

The objects which it was intended should be accomplished by the construction of the Chicago Drainage Canal were the protection of the lake against sewage, the prevention of nuisance in the Chicago River and the final disposal of the sewage. These objects were to be accomplished at one stroke by the building of a canal between the Chicago and Illinois Rivers of such size as to be capable of reversing the flow of the Chicago River at all times so that instead of discharging into Lake Michigan, it would flow in the opposite direction, drawing pure water from the lake to mix with and purify the sewage. For this project to be successful the original promoters thought that the flood of waters should be diverted and toward this end expected that the North Branch of the Chicago River and the Desplaines, which sometimes overflowed

into the South Branch of the Chicago River, should be cut off and sent directly to the lake, well to the north of the City. With this diversion the Drainage Channel was to have the capacity of 10,000 cubic feet per second which it has now.

The Calumet-Sag proposition is in no sense a duplicate of the Chicago solution. The drainage area is greater and the Canal smaller. The size and distribution of the population to be served is not comparable in the two cases and the hydrographic conditions are dissimilar. The flood discharge of the Calumet is supposed to be about 15,000 feet or over seven times the capacity of the channel as it is intended to be built at first. It is doubtless possible to cut off a large part of the flood flow from the upper arms of the Calumet, but this is not a part of the Sanitary District's plan so far as the reports and estimates of cost indicate.

If the flood waters are not diverted, the lake will not be protected against pollution, for there will be discharges of the river into the lake at times of storm which are certain to carry accumulations of filth into it, not to mention the washings of the streets and premises of the residence and manufacturing establishments in the region.

At ordinary stages of the Calumet River the reversal of flow of the current will be very slow and quite insufficient either to keep deposits from forming or to keep the river looking clean and wholesome. The rate of flow in a channel 200 feet wide and 20 feet deep caused by a discharge of 2,000 cubic feet per second is less than ½ foot per second, or less than 1-3 mile per hour. At this rate, it would take lake water 36 hours to get to the channel if it proceeded in the most direct and expeditious manner possible.

If the flood waters are diverted, it is by no means apparent that the Sag Channel will prove to be a valuable means of purifying the sewage which is discharged into it. The diluting water will not have the same capacity for purifying the sewage as unpolluted lake water possesses, for it will not be so clean. The distance from

the lake to the entrance of the Chicago Drainage Channel is about 5 miles; from the lake to the head of the Sag Channel is more than three times that distance. There are, at most, three possible sources for the water to come from, besides Lake Michigan: The South Calumet, the Grand Calumet and Lake Calumet. The particular source which would be effective at any time would probably depend largely upon the wind and rainfall.

If the water came directly from Lake Michigan, it would unquestionably be polluted to some extent by the drainage of the industrial establishments and if it was derived from any of the other sources it would have a load of organic matter from the swamps and alluvial deposits for the dissolved oxygen to deal with.

There are a number of towns in the Calumet watershed which are in the State of Indiana and unless this sewage is disposed of in a satisfactory manner, no works which the Sanitary District of Chicago can build will wholly solve the Calumet problem. This has been recognized by the Sanitary District and negotiations were carried on for some time looking to the disposal of this sewage through the Calumet Canal, but the proposition was voted down by the Indiana residents.

The ultimate population to be expected in the Calumet District is far in excess of the 1,200,000 which the largest capacity of the Sag Channel which has been estimated is intended to provide for. Sewage treatment tanks will therefore be needed eventually whether the channel is built or not.

In case the suit brought by the United States to restrict the diversion of Lake Michigan water results in an allowance of 10,000 cubic feet or less, any water which the Calumet-Sag Channel takes will be at the expense of Chicago, which certainly needs all the dilution which it can get for its sewage.

The Calumet-Sag Channel will add materially to the total weight of organic matter which is discharged into the Illinois Valley and from what appears to be the probable condition of the water which will be available for this

channel, the dilution will not compensate for this added load. The damages obtained by the inhabitants of the Illinois Valley against the Sanitary District for flooding, which already amount to a large figure, are certain to be increased by reason of the greater volume of water sent down.

There is apparently no evidence in any of the reports which deal with the Calumet-Sag Channel project that the rights and sanitary welfare of the people of the Illinois Valley have been investigated or considered.

Part VII

AVAILABLE PROCESSES FOR TREATING THE SEWAGE

It is probable that all who have an unbiased technical knowledge of the subject, apprehend that the time has come when Chicago's sewage will have to be purified to some extent. Whether the treatment is to be restricted to the removal of suspended solids from the sewage, or beyond that stage, it is impossible to say with certainty at the present time. The most careful consideration will be required to determine how much or how little purification is essential in order to maintain reasonably clean water in the Drainage Canal and the rivers into which it flows and where it is feasible and desirable to construct treatment plants.

A description of all the methods of sewage disposal which are now employed in different parts of the world is too wide a subject to discuss properly within the space of this report; nevertheless, it may be of some value to call attention to several of the more important methods, bearing in mind that in dealing with the proposition of how best to treat the sewage of Chicago, it would obviously be useless to dwell upon processes which are not applicable to large cities.

Methods for the disposal of sewage may be divided into two great classes: those whose object it is to remove the solid matters and those which are intended to deal more particularly with the liquids. For the removal of the solids, the most common devices are grit chambers, screens and sedimentation basins. For the treatment of the liquid portion, various types of oxidizing filters are employed or the sewage is applied to land. Complete

treatment usually means a combination of some process for the removal of the solids and some means for the oxidation of the liquids. The liquids cannot well be treated until the solids have first been removed.

The solids which are removed form grit, screenings or sludge, according to their consistency and method of removal. The product of oxidizing filters is nearly all liquid and flows off in the treated sewage. The oxygen is obtained automatically from the atmosphere and is made to combine with the organic matter of the sewage by means of bacteria which grow naturally on the surface of the particles of filtering material.

In exceptional cases, sewage is disinfected, the means of disinfection usually being chlorinated lime or some other chemical germicide. The treatment of sewage rarely proceeds to the point of rendering the sewage pure like drinking water, the cost and care required to accomplish this purpose generally being beyond what the situation calls for. The usual object in building sewage works is to prepare the sewage for discharge into some water course which would become offensive to the senses if the sewage was discharged into it in crude form. All sewage must be discharged, whether purified or not, into some river or lake or arm of the sea, for there is no other way to get rid of the water of which it is so largely composed. No less than 998 parts of sewage in 1,000 are water, the rest being made up of an endless variety of mineral and organic substances.

There is no one best method of sewage disposal any more certainly than there is one best way to build a bridge or a railroad or a public water supply. The best design is the one which is best adapted to the local circumstances and accomplishes the desired end in the most economical manner.

1.—REMOVAL OF THE SUSPENDED MATTER.

Generally speaking, the amount of impurity in sewage due to suspended matter exceeds one-half of the total impurity. Proportions vary, of course, in different local-

ities, but the desirability of eliminating as much of the suspended matter as possible within reasonable limits of expense is obvious. So general and so emphatic is this view becoming amongst experts that few would even suggest the discharge of crude sewage into the sea until after the most careful consideration of all the circumstances relating to health and sense of decency.

In discussing available methods of treating the sewage, it should be assumed that the elimination of solids in suspension is an essential feature, and preliminary to every other method which has so far been established on a firm basis.

How far the removal of the solids would go toward the solving of the sewage problem it is not possible to say, but that it might be all that would be required for the greater part of the sewage, at least for a long period of years, is quite probable. The necessary works could be so built that if, at a later date, it became necessary to employ some method of further purification, this could be done with little loss or change of the constructed works.

There are two general ways in which the works which would be necessary for the elimination of the solids could be employed: they might be constructed near the ends of the present main sewers, with outlets discharging well below the surface of the existing waterways or the sewage could be collected into intercepting sewers which would lead to points where the necessary works would be located. It is not necessary or desirable to collect all the sewage to one point for treatment, and the cost of doing so would be enormous. It will be far better to deal with the sewage of different parts of the city at different places and probably in different ways, according to the local requirements and opportunities. Apparently there should be one large station located well to the west of the city and several smaller ones elsewhere.

The precise nature and location of the works which will be required it is impossible to forecast until exhaustive investigations into all the circumstances have been

made, and it is with this salient feature of the case always in mind that suggestions are here offered.

2.—SCREENS.

On all large works it is found advisable to have widely spaced bar gratings between the outfall sewer and the grit chamber. Such a grid is necessary for the purpose of retaining pieces of wood, cloths, scrubbing brushes, old boots, etc., which otherwise would interfere with any machinery used for removing the grit from the pit.

Sometimes fine screens are employed at this stage of the process to keep back organic, as well as inorganic, matter. The advisability of this course is open to question, and must remain open until the engineer has had ample opportunity of considering his design as a whole in its relation to details, but it may be helpful to direct attention to a phase of the question which is frequently lost sight of, viz., the increased foulness of the liquid after it passes through fine and even medium screens. This may not be of vital importance at Dresden, where the Riensch Disc Screen is in operation, but it has been found to be of great importance where complaints of malodor have occurred, as, for example, at Birmingham, where Smith Revolving Screens were once in operation. The revolving brush employed to remove fecal matter from the screen tended to close up the perforations through which the sewage had to pass, thus imparting foulness and increasing the strength of the sewage and rendering it less amenable to rapid oxidation.

Another obvious disadvantage in passing the whole of the sewage through screens before it is allowed to settle in grit chambers or settling basins, is the enormous increase in the amount of work which the screens are called upon to do, seeing that but for the interposition of the screens, the solid matter would settle readily in the basin to be removed in bulk at intervals of days or weeks, as might be found convenient, instead of having to be taken from the face of the screen as it arrives at all times of the day and night.

3.—GRIT CHAMBERS.

An essential part of all treatment works is the grit chamber, or detritus pit, as it is sometimes called, the chief function of which is to arrest heavy road grit and lighter solids which become entangled with it, thus saving the pumps, etc., which would otherwise suffer if an undue proportion of gritty matter were allowed to pass through them.

It is difficult to lay down hard and fast rules as to the capacity of grit chambers in any scheme without knowing definitely the size and gradient of the outfall sewers, as well as other equally pertinent data, but it may be taken as a general principle that the capacity should be about 1,500 cubic feet per million gallons, that the rate of flow (about 3 inches per second) through one tank should proximate the needs of the maximum dry weather flow of any ordinary day, and that an additional grit chamber should be built to correspond with every dry weather flow volume which it is deemed advisable to treat.

For example, six grit chambers would be built if it were found desirable to treat up to six times the dry weather flow. In the case of Chicago, this volume would be considerably in excess of what is necessary. There should, however, be not fewer than three grit chambers in a large installation, in order to provide opportunity for emptying and effecting repairs to the dredging machinery used in cleaning, without interfering with the regular process of treatment.

To illustrate the need of obtaining exact information before adopting a specific scheme, it should be stated that there may be a disadvantage in attempting to eliminate all the particles of road grit, if the subsequent treatment of the sludge is to include pressing. The inorganic matter present in sludge tends to incorporate with it the finer organic particles and so establish a better drainage of the water from the pressed sludge than would be possible if the sludge were composed only of very fine particles.

4.—SEDIMENTATION TANKS.

The removal of suspended matter should be regarded as a physical and economic necessity in every scheme. Since it is cheaper to remove solids from a tank or screen than from any other part of a purification plant, they should be so removed. The fresher the sewage, and, consequently, the nearer the treatment works to the origin of the sewage, the better are the results from screening and sedimentation. Again, the more suspended solids (especially inorganic matter) in the sewage, the higher is the percentage of sludge obtained in tanks from the volume of sewage treated.

Sedimentation tanks should be designed with a view to securing the maximum amount of clarification and the highest speed of sludge removal. There are many types, but for large works located in an isolated place, where it is unnecessary to think of roofing them over, it will probably be found that the horizontal flat bottomed type is the most efficient. They should be designed to facilitate rapid emptying and cleaning, and should have capacity equal to a resting period of about three to four hours for the average dry weather flow. Continuous flow versus quiescent settlement should also be the subject of careful local study, although the experience of other cities should not be lost sight of.

Whether the tanks should be used in parallel or in series requires knowledge of the particular sewage and other local conditions. On a large installation it is generally found that the work can be done best on the continuous flow method, and by working the tanks in parallel, provided the subdividing walls are sufficiently numerous and sufficiently governed by sluice valves or penstocks to enable the work of cleansing to be carried on without undue interruption of the continuity of the process.

To obtain a really good tank effluent—and by that is meant sedimentation equal to the elimination of about 70 per cent of the suspended solids—it will be necessary to adopt the principle of providing a certain number of spare

tanks, in order to cope with sudden increases of flow. The best results are obtained from tanks which are cleaned frequently, say every fortnight in cold weather, and every week when the temperature in the shade exceeds 70 deg. Fahr.

The question of odor or aerial nuisance should not be ignored, and the scheme should be consistent in its details. There should be no carelessness which will permit the sewage to septicise on its way to the treatment works, and then, too late, anxiety to keep down septic action. Contrariwise, there should be irritating by-laws to insure good house drainage, and no lavish expenditures of public money to obtain self-cleansing velocities, or a good alignment of sewers with smooth surfaces, if the sewage is to be septicised the moment it reaches the treatment works.

Consistency in design should be paramount, if the design is to be built on a sound foundation. Improvements in detail will, no doubt, suggest themselves from time to time, and these should be taken advantage of as far as practicable.

5.—CHEMICAL PRECIPITATION.

Sedimentation tanks are readily converted into chemical precipitation tanks by the addition to the sewage of, say, milk of lime, or any of the many chemicals now used; but whether the additional cost which this entails is warranted is another question. This process is capable of removing 85 per cent or more of the suspended matter. That the use of chemicals produces a very large addition to the amount of sludge is apparent. When a ton of dry lime is added to sewage, it has to be taken out as ten tons of sludge, and the finer the particles of lime the more is the amount of moisture taken up by them. A small difference in the percentage in its weight, as may be understood from the fact that one ton of sludge with 80 per cent of water corresponds with two tons with 90 per cent of water and four tons with 95 per cent of water so far as the actual

amount of dry solid matter (about 40 pounds) contained in each, are concerned.

If the merits of tank treatment were calculated on the cost of removing a ton of liquid sludge, chemical precipitation would appear at first sight to possess a great advantage, but the addition of so much solid matter in the shape of dry powder merely to be taken out again in the form of sludge goes far to neutralize the apparent gain. If the calculation is made on the basis of million gallons treated, the consumption of water unduly influences the calculation. In any case the volume of sewage is due primarily to the water supply, which varies between wide limits in different cities, being 30 gallons per head in London and 213 in Chicago, and secondarily, to the infiltration of ground water into the sewers and to trade wastes. Volume of sludge, however, bears no relation to water supply, but has a direct relationship to the number of persons contributing to the sewerage district.

Much detailed information is required before one is justified in determining the type of the tanks which should be employed, and, consequently, the cost to be incurred.

Under certain circumstances, the adoption of chemicals is fully justified, tending, as it generally does, to accelerate clarification, to relieve the oxidation process and, where basic phosphates, etc., are used, to enrich the sludge so that it may be used as a fertilizer. But the tendency of the times is to abandon the use of chemicals.

6.—SLUDGE DIGESTION TANKS.

The single story septic tank is usually unsuitable as a constituent of a plant which depends to any extent upon the oxidation of the sewage by means of dilution. Fermentation and sedimentation are usually in conflict, and the engineer must select and adhere strictly to that process which in his judgment will harmonize best with his designs. If he aims at, and has the means of obtaining, complete septicization, it may be possible to render organic sludge inert and to pass over the outlet weir septic liquor

without drawing off at the same time large pieces of sludge in an active state of fermentation; but this has never been done anywhere on a large scale, and it is not recommended for Chicago.

The Emscher, Imhoff (or two story tank) is in a different category as it is capable of facilitating the conduct of two processes at one time. It is a sedimentation tank and a septic tank in one structure, and if well designed is capable of efficient work. The Imhoff tank is better than its prototype, the Travis tank, and well worth the additional cost.

The initial cost of the two story tank is its greatest drawback, and this very fact creates a temptation to limit the area and capacity of the upper story which, if made sufficiently large, should serve the same purpose as the best designed sedimentation tank. The temptation to economize on this structure creates another difficulty, namely, inclination to provide inadequately for excess flow due to rainfall. An Emscher tank, when called upon to do no more than it is designed for, namely, an unvarying flow is, barring cost, all that can be desired in this form of plant.

7.—SEDIMENTATION AND DIGESTION.

At Birmingham, the processes of sedimentation and sludge digestion are carried on in two distinct tanks—the sedimentation tank and the sludge-digestion tank side by side rather than one on the top of the other. By this means, the process is well under control, the cost of construction is less, and the results are not dissimilar.

There are advantages and disadvantages in both methods and the engineer must appraise them in determining what design is most suited to his special circumstances. Operating costs of the Imhoff tank are less than in the Birmingham method, but the latter has the advantage of lower initial cost. The separate tank system is better when an antiseptic like gas tar arrives at the treatment works; it can be at once isolated instead of being retained automatically in the under story of the Emscher

tank, where it would tend to inhibit the action of the anaerobic organisms.

At Birmingham, the sludge digestion tanks are formed of a combination of excavation and embankment built without lining of any kind. This construction is sufficient so far as ability to retain the sludge is concerned, but it is not convenient for thorough and complete cleansing. Supply and draw-off pipes, with appurtenant valves, etc., form the chief cost of this installation of tanks. Frequent pumping of sludge from the sedimentation tanks keeps them in a condition best suited to yield a tank effluent free of suspended solids, and as the sludge thus removed is distributed over a number of digestion tanks, the burden upon each is limited.

In the process of working it is found to be desirable to pump into the same delivery pipe a quantity of the ripest sludge from a digestion tank along with the fresh sludge above referred to in order to inoculate the fresh sludge with the fermentation organism at the earliest possible moment. In winter, too, steam is used to heat the sludge as it passes along the delivery pipe on its way to the digestion tanks. These tanks are so completely under observation and control that there is no excuse for pumping to the drying area—which is more than four miles distant—any but the "ripest" of sludge. Notwithstanding the large item for pumping, the whole operation from beginning to end—which is to deposit the dry briquettes into a great heap on low lying ground—costs only three cents per person, or 11.4 cents per ton, against London's 11.2 cents per ton and Manchester's 13.8 cents per ton for dumping it into the sea.

Apart from the hygienic question of disposing of sludge without nuisance, there is an economic question which is still unsettled, and may be expressed by the question: What value, if any, has sludge in dried form? Even although the fermentation process militates against the retention of the nitrogen found in the fresh sludge, there is so much nitrogen left in the dry septicised sludge that

it can be made profitable in some instances by converting it into sulphate of ammonia.

In winter it is difficult to dry septic sludge, but at Birmingham the drying area, which is 50 acres in extent, is gradually filled up during winter as the sludge ripens in the tanks. Still the cost of providing additional capacity to tide over this season has to be taken into account, and for this reason the denser the sludge obtained the less storage is needed, and in this respect the deeper the digestion tank (within limits, of course) the better.

8.—FINAL DISPOSAL OF SLUDGE.

The problem of how to get rid of fresh unsepticised sludge without creating a nuisance is not easy, and it is not less expensive as a rule where the quantity to be disposed of is large. Where the city is small and surrounded by arable land, the sludge may be got rid of in its semi-dry state by selling it or giving it to farmers, but on large works it is found that sludge accumulates to such an extent when the season is unsuitable for farmers to lift it that they refuse to remove it unless well paid for so doing.

Artificial and generally proprietory processes have succeeded in overcoming this to some extent by drying the sludge to a powder and storing it in bags until the farmer either has need for it or time to cart it away.

Other methods of getting rid of sludge may be enumerated as follows:

1. Spreading it on land, and digging it in as soon as it becomes spadeable;
2. Trenching it, or running it into long trenches about 3 feet wide and 1 foot deep;
3. Lagooning, or simply filling up depressions, and allowing it to remain until it becomes, by thorough fermentation, an inert mass;
4. Filter pressing;
5. Manufacturing into manure.

Spreading sludge over land.—Where this has been done, the sludge has generally not been over 9 inches in depth. When allowed to remain until it has become suf-

ficiently dry to be dug into the ground as a gardener digs in manure, its depth has been reduced to about 4 or 4½ inches, and in this state it has quickly become incorporated with the soil, rendering it friable. Where the land has been made up of stiff clay, the sludge has converted it into a good arable soil.

Trenching.—The trenching process resembles the foregoing, but it has the great merit of being more under control during hot weather, for if it is necessary that the sludge should lie for a short time before it is dry enough to bear the weight of an earth covering, it is easily protected from the sun's rays by coarse grass, or other material of that kind. In this way nuisance is obviated.

If trenching is contemplated, a word of caution should be given against making the trench deeper than for 12 inches of liquid sludge, otherwise the nitirifying organisms act upon it but slowly, if at all.

From a quarter to half an acre of good land will take one thousand tons of sludge. Half to one acre of medium land will take the same quantity, and probably one to two acres of bad land will be needed to deal with one thoussand tons of liquid sludge per annum. These average figures will not work out so favorably in exceptionally wet seasons.

Lagooning.—This process is only possible where there are suitable depressions of comparatively waste land available for the purpose. It should always be borne in mind that the sludge which is run into these lagoons becomes an emulsified mass impossible of complete solidification. Unless the process is very carefully watched, it is liable to become a nuisance, and, unless in exceptional cases, should be avoided. Indeed it can only be regarded as a temporary expedient at the best.

Filter Pressing.—A filter pressing plant is capable of converting five tons of sloppy matter into four tons of very strong sewage and one ton of fairly dry cake, the latter then being in a form in which it is easily manipulated.

The modern press consists of moveable rectangular cast iron plates. The surface of each plate is covered with

jute cloth. When the plates are brought together, a space for the sludge is formed between them, the liquor in the sludge is forced through the cloth, the sludge being retained. The sludge is usually conveyed from the sludge well to the presses by means of compressed air, the power which is also used to actuate the presses. The cost of pressing varies. The Royal Commission on Sewage Disposal, of England, give the cost in large towns at from 50 to 62 cents per ton of pressed cake (55 per cent water), and in the case of small towns, with a population under 30,000, the price is given as from 93 cents to $1.43 per ton of pressed cake (55 per cent water). In a few cases the farmers pay as much as 20 to 25 cents per ton for this cake, but in most parts of England from 8 to 12 cents per ton is the usual price.

9.—UTILIZATION OF SLUDGE.

Within recent years there has been a distinct tendency to utilize sludge as a fertilizer, and when it is remembered that each adult excretes yearly about 12 pounds of nitrogen, 7 pounds of phosphoric acid, and 5 pounds of potash, worth together about $2.62,* it is seen how important it is to utilize excremental sludge where possible. The sewage of Chicago undoubtedly contains manurial substances to the value of several millions of dollars per annum. Of course it is obvious that all of this valuable product cannot be utilized, for a large part of the manurial ingredients are present in solution, and for the rest, dry conservancy methods are unpleasant, insanitary, costly, and repulsive to a civilized community, but it does not follow that because the water carriage system is in vogue, no part of this manure can be recovered. Sewage sludge, as it is taken from the settling tanks, contains from 90 to 95 per cent water, so that for every ton of solid matter that is taken away, about twelve tons of water must be conveyed with it. It must, therefore, be dried before it can

*Hall, Fertilizers and Manures, 1909, p. 224.

become useful as a fertilizer, or at least made sufficiently dry to allow of its being carted on to the land.

In a few cases sludge has been dried to a much greater extent. For example, at Glasgow, where the product is sold as "Globe Fertilizer," and at Kingston-on-Thames, where it is sold as "Native Guano." At Bradford, the sludge is heated and pressed for the recovery of grease, and the resultant cake is sent to France as a fertilizer. At Oldham, the grease is extracted from the sludge by distillation with superheated steam and the dry residue sold as a fertilizer. The same remark applies to Huddersfield.

The Royal Commission on Sewage Disposal carried out certain experiments with sewage sludges, the results of which are given in their Fifth Report, Appendices viii (1908) and iv (1910). Seven different sludges were used, all in a dried form, containing 12 to 37 per cent water. They concluded that sludge does not appear well adapted for root crops, but should prove useful for grass land. They also concluded that $2.50 per ton on the farm is an outside figure for the value of the sludge.

Practical experience on a large scale shows that many farmers and market gardeners in the neighborhood of large towns can show the marked effect which the use of sludge has upon their crops, and one cannot but note the great sale for dried sludge at Bradford. This is sent to France, although the carriage costs $4.00 per ton, and some of the same sludge has been sold to the Argentine and to the United States.

In the opinion of Dr. Maclean Wilson, of the West Riding of Yorkshire Rivers Board—who has given this question a good deal of study—it may be confidently assumed that in a very short time sludge which is now wasted or given away will be disposed of at a price which will pay for its preparation, and at the same time make it profitable for the agriculturist, and in a recent report, one of the Board of Experts, Mr. Watson, speaks well of the Dublin process, which includes fortifying the organic matter with potash and phosphates. Wherever the sludge contains over 2½ per cent of nitrogen, the engineer should

consider carefully whether he is justified in throwing it away.

According to the Metropolitan Sewerage Commission of New York, which made a thorough study of the possibilities of utilizing sludge under favorable conditions as to transportation, a sludge containing 50 per cent moisture, whose dried material contains 3 per cent of ammonia and less than 10 per cent of grease, may be further dried, ground and sold as a filler for fertilizer with some slight profit in the case of large works.

Centrifugal machines have recently come into use, especially in Germany, for drying sludge. They have the advantage of occupying less space and requiring less auxiliary machinery than presses and do not require lime or heat as to presses. By their use it is practicable to reduce the moisture in sludge to 60 to 70 per cent. Centrifugal sludge drying machines are in successful use at Frankfort, Hanover and other places in Germany.

Some sewage contains a great deal of grease and methods have been invented for recovering it, the works at Bradford, England, and Charlottenburg, Germany, affording examples of how this result can be accomplished. Finally it remains to state that sludge has been converted into gas and burnt. These processes, however, are exceptional and their employment is usually justified only by peculiar local conditions.

10.—SEWAGE FARMS.

The Craigentenny meadows near Edinburgh are generally quoted as one of the oldest examples of land treatment, seeing that they came into use about the end of the eighteenth century. But the object of the promoters of that scheme seems to have been to raise crops of grass rather than to purify sewage, inasmuch as there was no attempt to induce percolation through the soil—as a fact the excess flow was shed off the surface direct into the sea.

The efficiency of soil, particularly garden loam, as a purifier of sewage is so well known and so highly thought

of that in England irrigation is perhaps the favorite method of purifying sewage where land in large quantities is available. Some soils are more suitable than others, and some—like clay and peat—are of comparatively little service as purifiers of sewage.

At Berlin, where the largest sewage irrigation fields in the world are to be found, the soil—which is of a light sandy nature—is reasonably good, as is the land used for a similar purpose in the neighborhood of Paris.

The largest sewage farm in England was, until 1906, at Birmingham, where the available soil was not good, consisting of clay, red and yellow marl, gravel and sand in various proportions characteristic of the Keuper beds and alluvial deposits. Because the quality of land was poor, and the area inadequate, Birmingham has ceased to depend upon land irrigation to purify her sewage.

Where a large area of land is required for irrigation, as would be necessary if that method of purification were adopted at Chicago, it would hardly be possible to obtain it of uniform quality. Close examination of the soil and subsoil would have to be made before an estimate could be formed of the amount of sewage which an acre of land would be capable of purifying. But it may be assumed that where the land is well prepared, and the drainage system complete, it is possible to purify efficiently as much as 35,000 gallons per acre per day, but an accurate estimate of the purifying power of soil generally is much more likely to be from one-third to one-half of this.

That land may be usefully and profitably employed to raise crops and feed cattle, whilst it is, at the same time, effecting the purification of foul liquid, there can be little doubt; but it should be borne in mind that the two objects are, to a large extent, incompatible; large volumes of sewage cannot be treated at the same time that good crops are raised. If the latter is the chief desideratum, land should not be expected to purify more than 5,000 gallons per acre per day, as an average, for the whole year. In order to have a paying sewage farm, the average available must be sufficiently large to allow the farmer to irrigate only when

he finds that the sewage will not injure his crops. It is this incompatibility of purpose which has brought about that condition of inefficiency so frequently quoted by advocates of proprietary purification systems.

11.—SANITARY ASPECTS OF IRRIGATION.

From the hygienist's point of view there are various questions to consider in connection with irrigation, one of which is the likelihood of creating a nuisance in the valley in which the irrigation land is located. The advocates of sewage farming cannot deny that where the area is too small, a certain amount of smell is produced, in some states of the atmosphere, and as the area employed is so enormous in the case of large cities—it would probably be not less than 50 square miles at Chicago—the whole district at times becomes permeated with a distinct odor characteristic of sodden land. That sewage farming gives rise to sickness or disease there is no proof; indeed, the absence of sickness or disease, such as diphtheria or typhoid fever, has been the subject of remark on many occasions.

At a meeting of the British Medical Association held in Glasgow in 1888, Dr. Alfred Carpenter stated "that in no single instance out of nearly 100 cases in which sewage had been utilized by broad irrigation had any fact been proved to establish the allegations of insanitariness which are sometimes raised against them."

The sewage farm has become unpopular in England, not because it is unable to perform the functions of a purifier, but because of the difficulty of obtaining suitable land. Under ideal conditions it satisfies the wishes of its staunchest supporters, but these conditions rarely obtain. Wind and rainstorm during darkness render the work of distributing the sewage exceedingly difficult and, unless the land has been made perfectly level, the cost of contouring and constructing the small earthen embankments which are necessary, is great. If the embankments are on sloping ground, the effect of a rainstorm may be to break them and overload the level ground below, and the sewage

may reach the river without having undergone the purification required. Serious though this is, still more serious drawbacks exist in countries where there are long periods of frost or where there are protracted periods of wet weather. Countries subject to long spells of drought afford conditions the most favorable and probably the most profitable of any.

Where conditions are entirely favorable, the sewage farm is entitled to rank as one of the best methods of sewage disposal. Diverse opinions may be held as to what are favorable conditions, but it may be assumed that where there is one acre of suitable land per 5,000 gallons, as in Berlin and several other important cities, the efficient or good sewage farm, when judged solely by the effluent produced, is still in the front rank. Effluents from such farms are remarkable for their few microorganisms, their low albuminoid ammonia and their uniform character.

12.—INTERMITTENT SAND FILTRATION.

Like broad irrigation, this method of purifying sew age is no longer popular, but it is nevertheless efficient, and when carefully worked, capable of producing excellent results. Excepting that intermittent sand filtration does not require so large an area of land to produce a good filtrate as broad irrigation, and that it costs more for maintenance, it has nearly all the merits and demerits pertaining to that method. When suitable land of reasonable cost and extent can be obtained, as in parts of Massachusetts, this system of purification may be considered, and may even be cheap, if an exceptionally good effluent must be obtained. When the effluent is ultimately to flow into a great stream which is not required for potable purposes, intermittent sand filtration does not appear to be called for.

13.—CONTACT BEDS.

A well known method of purifying sewage lies in its application to what are called contact beds, which may be said to be tanks constructed of brick or concrete, filled

with stone, clinker, coke, etc. The sewage enters one of the tanks, and is allowed to rest and come in contact with innumerable microorganisms for a short time before it is run off. As the sewage is withdrawn from the bacteria bed, atmospheric air flows into it, causing the bed to recuperate preparatory to receiving another dose of sewage.

It has been found in practice that while one contact is sufficient for an exceptionally weak sewage, it is by no means enough for the average English sewage. With several notable exceptions, contact beds in England are built in duplicate, so that the filtrate which is drawn from the first can pass through the second before it is regarded as sufficiently oxidized to enter a stream. For the more dilute sewage of Chicago, a single contact would probably be found sufficient.

Fifteen years ago the contact bed was almost invariably employed in connection with the septic tank, and experience has generally associated the one with the other. There are many cases, however, where contact beds have successfully dealt with unsepticised sewage. so that the intimate relationship which has existed in the past need not now be regarded as indispensable.

The septic tank and the percolating filter have been, for several years, closely allied, and they, too, are dissolving partnership for the reason that objectionable smell almost invariably accompanies the spraying of septicised liquor over an oxidizing bed. Neither contact filters nor septic tanks seem particularly well adapted to Chicago conditions except in dealing with trade wastes.

14.—PERCOLATING FILTERS.

The merits of the contact bed when compared with the percolating filter are not conspicuous; at the same time they have some advantages. They are likely to produce less odor. Professor Frankland recently preferred them at Oldbury, England (where the trade wastes have a large proportion of sulpho cyanides in them), and that, too, after experiments on three contact beds and three percolating filters. Both experiments were made on the

basis of applying the effluent of the first to the second and that of the second to the third.

The gradual loss of capacity of contact beds is a serious drawbacks; the effluents from them are not so well aerated as those from percolating filters, nor are they so uniform in character.

Percolating or sprinkling filters are generally capable of treating about twice as much tank liquor on the same capacity of filtering medium constructed as contact beds, and they are more easily adjusted to take a larger volume, if a storm should suddenly increase the volume of sewage arriving at the works.

The preference of the Board of Experts for percolating filters rests on these and other reasons, not the least being that, as the oxidizing process is dependent upon the free admission of air into the heart of a bed, this is more readily done when the medium is built as a percolating filter.

That the present well known form of oxidizing bed upon which the sewage is sprayed over, say, 6 feet of ½ to 2½ inch stones, is the best possible form, no one will venture to assert, but it follows nature so closely that it is improbable that it will be greatly improved.

15.—AERATION.

The question of oxidizing organic matter by the oxygen of the atmosphere has been studied for about thirty years, but no work has yet been done of sufficient importance to warrant this process being referred to as on a par with the other oxidizing methods here spoken of.

Mr. Harry Clark, in his Lawrence experiments, and Messrs. Black and Phelps in their report on their proposed treatment of New York sewage, have all made valuable contributions to the study of this question, and more recently Dr. Gilbert J. Fowler has made a distinct advance by blowing air through sewage in contact with what he calls activated sludge. But it is necessary to await the establishment of a plant on a large and practical scale in order to illustrate the efficiency and the cost of the process

before being warranted in characterizing this as an available oxidation method.

16.—MISCELLANEOUS PROCESSES.

Electrolytic treatment, ozonization and other less well known methods of sewage purification, all claim a certain amount of attention from experts, but most of these processes have not yet passed far beyond the laboratory stage and do not seem worthy of special description in this place.

17.—SUMMARY.

In considering in detail methods of sewage disposal as applied to any specific case, it is necessary to have available a very large number of facts pertaining to that case, and in this instance many subjects of local bearing have not been available to the Board of Experts. The essentials of the problem which have been accessible have led to the formation of certain opinions which were expressed in part in the Preliminary Report. Further study has confirmed these statements in most particulars.

In discussing the various methods available for the treatment of the sewage of Chicago, the first consideration is the nature of the stream into which the effluent is to be discharged. Consideration of this phase of the question leads the Board of Experts to say at once that it has not yet become necessary to produce so well purified an effluent as is obtainable by broad irrigation or intermittent sand filtration or other bacteria beds; indeed, it is doubtful whether the highest class of effluent will be needed for a very long time. But the Board is clearly of opinion that the possibility that the sewage may some day require thorough purification should be kept in mind in the designs of any works which are put down.

It is the opinion of the Board that some parts of the waterways should be freed entirely of the dry weather flow of sewage, and that storm water sewage should not be allowed to flow from the ordinary sewers of the city into them. As a general proposition, storm water over-

flows should not come into operation until twice the dry weather flow has passed forward to the treatment works. If this view is accepted, the crucial question will resolve itself into the condition of the Drainage Channel above Lockport and the condition of the Desplaines and Illinois Rivers.

The Board of Experts believe that if the standard of purity for the outlet of the Drainage Canal were fixed at an amount of dissolved oxygen equivalent to between 60 and 70 per cent of saturation, a good tank effluent, perhaps after subjection to aeration, would be found to be sufficient for the treatment of most of Chicago's sewage for the present, provided the trade wastes were properly dealt with. The increase of the population in the Sanitary District would be the main factor which would call for a change in this respect; but it would be a gradual change and dependent upon the amount of oxidizable matter at the time of discharge.

As the demand upon the oxygen in the water of the channel increases, it will be necessary to construct bacteria beds, or make other arrangements for oxidizing the sewage. The method to be adopted will depend upon the amount of work to be accomplished. It may be a question whether it is better to produce a small quantity, comparatively, of highly purified effluent, or a larger quantity of effluent not so fully oxidized. Upon the answer to this question will largely depend the kind of oxidizing treatment to be employed.

An immediate question to be determined relates to the disposal of the screenings and sludge. If there is 2½ per cent of nitrogen in the sludge, it may be worth attempting to utilize it as a base for a fertilizer. If, however, it is found not to be so rich in nitrogen, the sludge might be septicised, air-dried and deposited upon a spoil tip, where it may some day be found to possess a value in excess of the cost of conveying it to the site where it would be used. It would not be surprising if burning was found to be the best way to get rid of it.

Part VIII

POLICIES AND METHODS

It must be evident from the foregoing that Chicago has pursued definite policies in the protection of her water supply and in the disposal of her sewage and is in various ways committed to them. The most important of these policies are: 1, The protection of the drinking water by diverting the sewage from the lake; 2, The use of the city's waterways for the reception of the crude sewage; and 3, The discharge of the sewage with a certain proportion of diluting water to the Illinois Valley, there to be disposed of by the natural self-purifying agencies in the water.

In other parts of this report an effort has been made to show how far these policies have accomplished the results intended, and this effort will now be continued with the object of indicating, so far as is practicable, to what extent they should be modified or abandoned. Certain more or less definite projects have been proposed by the engineers of the Sanitary District to assist in accomplishing a sanitary disposal of the sewage, and these may profitably be considered at the same time.

1.—PROTECTING THE DRINKING WATER BY DIVERTING THE SEWAGE FROM THE LAKE.

For about twenty-five years, Chicago's policy has been to divert her sewage from Lake Michigan and send it to the Illinois Valley with the double object of protecting the city's water supply and preventing the Chicago River from becoming excessively foul. It has been recognized that for this procedure to be effective, all the city's sewers must be prevented from discharging into the lake, and this has now been accomplished.

It has been assumed that if all of Chicago's sewage was kept out of the lake, the water would be pure enough for drinking. This is a mistake. Chicago's sewage is not the only source of pollution of Lake Michigan.

One of the difficulties with the policy of protection which has been followed lies in the fact that the control which should be exercised over sewage should extend over a very much larger territory than it is practicable to include in a single jurisdiction. It was discovered that the area comprised in the Sanitary District was not nearly large enough in the beginning, and as a result of this discovery, the territory was more than doubled. It is not large enough now, if the city is to depend upon the protection of the lake as the only means of securing pure water. Sewage is being produced to the north and to the south which cannot be taken to the Chicago Drainage Channel and must, apparently, go to the lake.

There would have to be a single Sanitary jurisdiction exercised over the whole area bordering the southern end of Lake Michigan, including parts of Wisconsin, Indiana, Illinois and Michigan, if the best results were to be accomplished. No such easy means of outlet through the back lots is available as was the Chicago Main Drainage Channel. It is impossible to build another canal like it, for it is inconceivable that the United States and Canadian Governments would allow more flushing water to be taken from the lakes than is actually needed for the disposal of the sewage of the Sanitary District.

Since all the sewage which is produced at the southern end of Lake Michigan cannot be diverted, the balance must be purified. If it is to be discharged into the lake it should first be rendered incapable of doing harm. It is a difficult undertaking to purify sewage to the point where it cannot produce nuisance or disease. Such complete treatment is seldom attempted. The usual object is to remove from it only those properties which are capable of putrefying and causing nuisance in the streams. Com-

plete purification usually means sterilization by chemicals as a final process.

It is apparently impossible to bring about such complete cooperation between the states and cities bordering Lake Michigan as will wholly remove the danger of pollution from Chicago's water supply. Four years ago the Lake Michigan Water Commission and certain prominent Chicago officials pointed out the dangers connected with the use of the lake both as a receptacle of sewage and a source of water supply, and methods of guarding against them, yet there has been little progress made in bringing the many interests together in that close agreement which is essential to successful protection.

2.—THE DANGER OF CHANCE POLLUTION.

And even if it were possible to divert all the sewage from the lake and purify it beyond the possibility of danger, there are other sources of pollution which would have to be eliminated before the water supply could be considered safe.

Lake Michigan is a great highway of commerce and vessels of many kinds are passing in and out of Chicago's harbor and the Calumet continually. It has been shown by Health Commissioner Young of Chicago that it is possible materially to reduce the risks of pollution from large pleasure craft and some other types of boats, but the complete elimination of this danger is scarcely practicable.

The part placed by seemingly healthy carriers of infection in spreading typhoid and other diseases should be remembered in this connection. A single boatman, while sailing by an intake, might unconsciously cast millions of typhoid germs overboard which would get into the public water supply.

The pumping out of water taken in as ballast at some filthy harbor can doubtless be done away with as a practice among vessels approaching Chicago, as can the improper dumping of dredgings, but whether the rules which may be made to prohibit these practices can be so rigidly enforced as utterly to prevent infringement is doubtful.

3.—THE QUESTION OF CLEARNESS.

It should be recognized that no plan of diverting the sewage from the lake, or otherwise protecting the water from pollution, is capable of excluding the solid matter which, at times of storm, makes the water turbid. Clearness can be had only by purifying the water, presumably by filtration.

The degree of clearness proper for a water supply is a matter of public opinion. Various Southern and Western cities seem satisfied with water which, at some seasons of the year, is so muddy as to look wholly unfit for drinking, while the Eastern cities of the United States and the cities of Northern Europe are not content with less than the cleanest and brightest water which is obtainable.

In Chicago there seems to be no general feeling of discontent that the city drinking water is less bright and attractive than it should be, although it has been noted that there are many household filters and that nearly all who can afford to do so, drink bottled waters. Such a feeling is bound to arise in course of time.

When the water supply becomes noticeably turbid, and this happens often, the turbidity is commonly attributed to solid matter which is stirred up from the lake bottom by the action of waves. But it would appear that this could give but a poor assurance of its harmlessness, for the color and consistency of the deposit plainly suggest that some of the solid matter originally came from the city.

It is impossible to see how the solids which make the water turbid could be avoided by changing the position of the intakes. How far it would be necessary to extend them in order to obtain water which would always be pure and clear cannot be stated. Waves stir up the bottom in depths up to 50 feet and the turbid water so produced may travel far. In this connection it is necessary to remember that there are sometimes vertical, as well as horizontal, currents. The Chicago intakes are about as far from shore as it is desirable to build them in view of their cost

and the quality of water obtainable. Lake Michigan is so shallow that it would apparently be necessary to go from 10 to 15 miles in order to get water from a depth of 50 feet.

It would be wise policy for the city to provide for the coming filters without loss of time. Hyposulphite treatment is excellent as a temporary and emergency measure, but it is not a substitute for filtration in cases of this kind. It sterilizes, but it does not clarify.

The filtration plants should be located on the water front in connection with the intakes. So far as the protection of the lake is concerned, the object should be to keep out all gross pollution, and maintain the water in such a state as will permit the filtration works to produce a satisfactory effluent at the lowest cost.

4.—THE PROPER DEGREE OF PURITY FOR THE DRINKING WATER.

If Chicago was to take her drinking water unpurified from Lake Michigan, the water should be kept as pure as that of a mountain lake. This is a high standard, but not too high as gauged by many of the water supplies of the world's greatest cities. The drinking water of London and Berlin are stored and filtered and are of great purity; that of Paris is obtained from distant springs; in order to protect New York's water from pollution, thousands of acres of land have been purchased along the margins of the collecting streams and plans have been made to filter it; Philadelphia, Cincinnati, New Orleans, Pittsburgh and many other large American cities filter their water.

In framing a standard for the purity of Chicago's drinking water, regard should be had for the progressive development which is taking place in public opinion with regard to sanitary matters. In 1880, according to Professor Whipple,* the quality of American water supplies

> "was low, judged by modern requirements. Clearness and freedom from color, taste and odor were the ruling standards and even these were very often not complied with. Water

*The Present Status of Water Purification in the United States, George C. Whipple.

analysis was confined chiefly to the mineral constituents. The germ theory of the transmission of disease through the agency of sewage polluted water had not arisen."

More than thirty years later, grossly polluted supplies were still in use, and in many cases were distributed without filtration or treatment of any kind. Water-borne diseases were rife, and were put up with as a matter of course.

During the last thirty years, the education of the public with respect to water supplies has proceeded apace. The casual relation of water to disease has been clearly established, the public opinion rightly demands that water, the prime necessity of life, shall not be allowed to serve as a vehicle of disease and death. The spread of this enlightened public opinion is reflected in the increasing use of filters as a safeguard against pollution, and its soundness is placed beyond question by the marked drop in the prevalence of water-borne diseases wherever filters have been installed. In 1860, less than a quarter of one per cent of the urban population of the United States were supplied with filtered water. In 1910, over 28 per cent were so supplied, and the percentage is still increasing. There can be no doubt that before long the use of surface water without filtration will cease in all but a few undeveloped and backward communities. Even in the case of the purer supplies, there is an increasing tendency to place the water beyond the risk of chance pollution.

The value which a great city attaches to a wholesome water and its determination to place its supply above suspicion, are well exemplified by the works completed in 1904 for Birmingham, England, at a cost of $23,000,000. The water is collected from 71 square miles of elevated moorland in Mid-Wales, some 80 miles from the city, and stored in three reservoirs of a united capacity of 11,145,000,000 imperial gallons. Notwithstanding its purity, it is subjected to two filtrations: the first through three acres of coarse sand and shingle at the head of the aqueduct, and the second through fourteen acres of fine sand filters at the service reservoirs near the city.

Up to the present, Chicago's policy has been to keep the lake water as pure as practicable without having any definite standard by which to judge the success and failure of its efforts, except the death rate. Probably no standard, however scientifically devised and suited to the peculiar situation, would have been of much use, since little could be done to improve the bacterial condition and turbidity, if the quality was found below par. If filtration works are built, it will be desirable to establish standards of clearness and of bacterial purity, and it will be the duty of those who are in charge of the works to so operate them that the requirements of the standard are always complied with. The chances of accidental pollution will then be eliminated and the appearance of the water will not be affected by storms.

5.—NECESSITY FOR PURIFYING THE WATER.

Chicago is fortunate in possessing in Lake Michigan a source which is unlimited as regards quantity, and in its pristine state, of an exceptionally high degree of purity. No other source has, or need be, thought of, so long as this water can be used.

The quality of the water has been improved by the more and more complete diversion of the sewage from the lake, but further improvement is demanded. The present typhoid mortality is less than that of many other American cities, but it does not compare favorably with 2 per 100,000 in Edinburgh or 3 per 100,000 in London.

As the population grows, it will be both more difficult and more important than the drinking water shall be safe. If we accept the conclusion of Dr. W. A. Evans, formerly Health Commissioner of Chicago, that only a small part of Chicago's typhoid fever is water-born, and in view of the vigorous health administration now in force, a typhoid rate of 10.5 per 100,000 from other causes seems hardly probable—it should not be taken for granted that the mortality will be maintained at the comparatively low figure at which it now stands. Epidemics of typhoid

fever are often of an explosive nature, and occur without warning in communities which have enjoyed for many years a comparative immunity from the disease. The epidemics at Worthing, Maidstone and Lincoln, in England, and Butler, Ithaca, and Grand Forks, in America, are well known instances of the results of a chance pollution of supplies which for many years had been regarded as safe.

The measures which have hitherto been adopted for the protection of Chicago's water supply amount merely to the stoppage of certain well defined avenues of pollution—excellent work, so far as it goes, but not sufficient. In order to safeguard the water supply effectually, the line of defense should be continuous. It must intercept not merely two or three of the more important sources of pollution, but all. This can only be done with absolute certainty by applying some form of treatment to the whole of the water supplied.

Sterilization by means of chemicals, and filtration, rapid or slow, are well tried methods of purification, either of which can be relied on to yield a water which will not communicate disease. But the desirability of eliminating the turbid appearance of the water after storms reduces the problem to one of filtration. The annual cost of filtration, as shown in the report of the Chief Engineer of the Sanitary District in 1911, about 60 cents per head of population, would be a very moderate premium to pay against the risk of infection with typhoid or any other disease through the medium of the city drinking water supply. Against this cost should be set the saving of the greater part of the money spent on bottled water, estimated at between $200,000 and $300,000 per annum, and the filtration of private supplies.

6.—THE PRESENT WASTE OF WATER AND ITS PREVENTION.

The consumption of water in Chicago, which now amounts to 213 gallons per head per day, is characterized by the Department of Public Works as "wasteful and extravagant." It is nearly five times as much as is consumed

in London for all purposes, and far exceeds the consumption in the majority of American cities. The annual cost of pumping and distributing this water is over $3,600,000, a large part of which might be saved, if the consumption were brought within reasonable bounds.

It would not be expedient, neither is it desirable, to place any restriction on the legitimate use of the water, but, short of this, much may be done to check the waste. As an indication of what may be accomplished in this direction, attention may be called to the vigorous campaign against the waste of water which was carried on in New York City in 1912, with the result that the average daily consumption for the whole year was brought down to 100 gallons per head. The expense incurred in the prevention of waste was about $167,000, and the aggregate value of the water saved, at the meter rate of $133 per million gallons, was nearly $6,500,000. Other large cities, such as Cleveland, Minneapolis, Pittsburgh, Cincinnati, Philadelphia and Rochester, are keeping down the cost of their water supplies without any hardship to consumers, by the introduction of water meters.

It must be remembered that an excessive consumption of water affects not only the cost of the water supply, but the cost of sewage disposal. In the latter case, larger sewers, more pumping, and larger treatment works are required than would otherwise be necessary. In view of these considerations and of the large amount of money which is spent every year in pumping the water, it seems reasonable to suppose that the saving in preventing waste would go far towards paying for the filtering of the lessened daily consumption, and that the whole of the water supplied to the city may be rendered safe and bright, and placed above suspicion at a cost not appreciably exceeding that of the present unsatisfactory supply.

It should not be overlooked that a wholesome and attractive water will enhance the value of every dollar's worth of real estate within the city. Apart from monetary considerations, it is unthinkable that Chicago will long

continue to put up with a supply which would not be tolerated by any city in Western Europe.

7.—THE POLICY OF DISCHARGING THE CRUDE SEWAGE INTO THE WATERCOURSES.

It has been Chicago's policy to discharge her crude sewage into the Chicago River and its branches and rely upon the flow of water from Lake Michigan to flush this dangerous and offensive material away. This is the very opposite of the policy which most other modern cities have adopted, and suggests the time, now many years past, when it was not known that sewage could be got rid of in any other manner.

Sewage disposal is essentially a modern accomplishment. Within the recollection of many now living, sewers were practically unknown. In the foremost cities of Europe and America, household slops were thrown upon the ground to soak into it or run off by gutters or other surface channels. Occasionally, where highway drains existed, they were used for slop water also. The resulting pollution of the water courses was much less objectionable than it is today, for the reason that water closets had not yet been invented, and there were, consequently, no such gross offenses to the eye as are now occasioned by the discharge of a modern sewer.

With the introduction of public water supplies and the increasing use of water closets, the need for complete drainage systems to carry the sewer to suitable points for disposal became apparent. The earliest sewers discharged their burden into the nearest rivers which were regarded as its natural and proper destination. In the manufacturing districts of England, where the cities are large and close together, the rivers rapidly became very foul, and by the middle of the last century, the condition of many of them was so bad that an urgent demand arose for its amelioration.

For the past sixty years, a more or less complete treatment of sewage has been recognized as the duty of every

urban authority not in the fortunate position of possessing a sea outfall, and of late years even many of the towns so favored have laid down purification works. Section 17 of the English Public Health Act of 1875 provides that

> "Nothing in this Act shall authorize any local authority to make or use any sewer, drain or outfall for the purpose of conveying sewage or filthy water into any natural stream or water course, or into any canal, pond or lake, until such sewage or filthy water is freed from all excrementitious or other foul or noxious matter, such as would affect or deteriorate the purity or quality of the water in such stream or water course, or in such canal, pond or lake."

Nothing is said about the position of the outfall, the relative volumes of the sewage and of the stream, the uses to which the stream is put, or other circumstances which ought to be taken into consideration in deciding on the amount of the purification which should be undertaken. This is the legal position today, no other legislation on the subject having taken place.

The history of sewage disposal in Great Britain is being repeated in some of its features on the continent of Europe and in the United States at the present time. No sewage whatever is allowed to flow into the Seine at Paris, or into the Spree at Berlin, or into the Thames at London, except at times of storm.

Throughout Germany it is the rule to carry the sewage in closed conduits to a central point, usually beyond the city limits, where it is screened or settled before the liquid portion is discharged into the turbid rivers.

This custom is growing in America, and Boston and many towns in its vicinity have united in a system of main drainage which carries the sewage to sea. Providence, Baltimore, Worcester, Atlanta, Columbus, Washington, and other cities carry their sewage to central points at a considerable distance from the built-up portions of those cities and there treat it before discharge. In no case is crude sewage discharged in such quantity into such small water courses as is done at Chicago.

The use of the Chicago River and its tributaries as

sewers raises questions of decency and self-respect, as well as problems of health. That same delicacy of feeling which relegates the sanitary offices of a home to the background will sooner or later revolt against the conversion of the waterways, especially those in the built-up portions of the city, into common sewers. This feeling is a sound one. It does not depend upon aesthetic considerations merely, but rests ultimately upon the instinct of self-preservation. It is never wise to assume that an offensive condition is harmless. Clean bodies, homes and cities make for safety; dirt, on the other hand, very often means danger.

It is by no means certain that the gross pollution to which the Chicago River and its tributaries are subject is not responsible in part for the existence in Chicago of a typhoid death rate three times that of London. There are more possible avenues of infection than one. Typhoid is not only a water-borne disease—it is also a fly-borne disease. The slimy deposits which form along the water line on the banks of the river and the abutments of the bridges furnish at once a breeding ground for flies and a source of the virus which they convey.

And how is it possible for a municipality to insist upon a clean and orderly management of filth on the part of householders, if it is itself careless and unskillful in the maintenance of the public places which are committed to its charge?

8.—CONDITIONS WHICH PROPERLY CONSTITUTE A NUISANCE.

In considering the sanitary conditions of the Chicago River and its outlet it is necessary that a clear understanding be arrived at as to what constitutes a nuisance. The word "nuisance" represents a conception which does not admit of precise definition. The courts have frequently been called upon to deal with it, and sanitarians are compelled to face it in innumerable forms.

Generally, a nuisance may be considered as a condi-

tion or set of conditions working harm to one or more persons through an assault or offense to the sense of decency, propriety or comfort. The effect is positive, not slight or partial. An odor or a sight which seriously disturbs the peace of mind which is necessary to the ordinary vocations of life may constitute a nuisance.

Obviously what is a nuisance to some may not properly be called a nuisance by others, there being marked differences in susceptibility to the disturbing conditions among persons of different sensitiveness. In determining whether a nuisance does or does not exist, a reasonable and liberal interpretation of the facts should be arrived at and the susceptibility of the average person who is affected must be accepted as the gauge.

It is worthy of remark that a nuisance cannot exist without reference to those persons who may be affected by it. The putrefaction of sewage may proceed to the point where the most foul-smelling and other objectionable consequences are produced, but if there is nobody in the vicinity the conditions cannot be said to constitute a nuisance. Conversely, a very small amount of putrefying sewage in the midst of a crowded section may be so objectionable as to constitute a nuisance, in the fullest sense of the word.

In the light of foregoing remarks, it must be obvious that the putrefaction of sewage should not be permitted in the closely built-up sections of cities, but may be allowed to proceed in rural districts remote from habitations or places of work and not passed by vessels or vehicles of transportation by land.

Applying the conception of nuisance here described to the condition of the waterways of Chicago, it may be said that nuisance exists in various places in the contributing arms of the Chicago River and not to a considerable extent, so far as the personal observations of the Board of Experts have extended, in the main channel from the lake to the Drainage Canal. Practically the entire watershed of the Chicago River is populated or soon will be built up, and it seems only a question of time when a de-

cided nuisance will exist. The Drainage Channel flows through the open country for many miles, and its condition, although observed to be foul by those who have had occasion to visit it, does not constitute a nuisance for the reason that none are compelled to reside or work within the sphere of its offensiveness. On the other hand, nuisance undoubtedly exists along the Desplaines and Illinois Rivers.

Some modification of the ordinary acceptance of the term should be made in considering its application to the Chicago conditions. The condition of the waterways is so much better in most places than formerly that the public is generous in its criticism. Complaint is not likely to be vigorous where a decided change for the better is seen to have been made. In course of time it may reasonably be expected that the sanitary ideals of those who are now lenient may become more exacting, so that it will not be safe to assume that Chicago's waterways can properly be allowed to be more polluted than the waterways of any other city where the education and intelligence of the public are at a high level.

There is another consideration which in some degree mitigates the exceedingly foul condition of some of the city's open waterways. Odors of a peculiarly offensive and pervading character exist from certain industrial establishments in close proximity to points of excessive sewage pollution. The sewage pollution adds to, but does not create, the original offense. From the standpoint of some it is far less objectionable to maintain the sewage nuisance in the presence of the trade offense than it would be to permit it in the best residence or business districts.

Excuse upon this ground is fallacious. The existence of one nuisance cannot condone another. Nor is it reasonable, where many persons are affected, to aggravate one offensive condition of the atmosphere by the addition of another. The aerial nuisance may, or may not be, prevented. In so far as it relates to the pollution of the waterways by sewage which, for other reasons can, and should be, disposed of in a sanitary manner, nothing short

of radical improvement should be regarded as satisfactory. A municipality cannot equitably insist upon the prevention of an aerial nuisance from a manufacturing establishment if it maintains an aerial nuisance from its sewage.

It makes little difference whether the pollution of the open water courses is due to sewage or trade wastes. If the wastes are recognized to be a public charge, it is incumbent upon the city to dispose of it. If responsibility for the wastes devolves upon the manufacturing establishments, it is but reasonable to require that the establishments shall dispose of the wastes without inconvenience to the public welfare, or pay the municipality for disposing of them.

9.—INEFFECTIVENESS OF DREDGING AND FLUSHING IN KEEPING THE WATERWAYS CLEAN.

A great deal of dredging has been done in the Chicago River and its tributaries, and there is little doubt that more will have to be done to relieve some of the arms of their excessive accumulations. But it would not be either a prudent or permissible policy deliberately to allow sewage sludge to form on the bottom of the waterways with the intention of removing it by dredging.

However useful dredging operations may be in deepening rivers to improve them for navigation, they are quite unsuitable as a main reliance for keeping waterways, like the Chicago River and its tributaries, in a sanitary condition. The unsuitability of dredging is fundamental and rests upon the fact that it is a remedy and not a means of prevention. Dredging will not keep clean waterways clean. In sanitary work it is chiefly useful in removing accumulations which have made the rivers foul. It is most serviceable in those cases where, for some reason, effective measures cannot be employed for the exclusion of the settling solids.

Sewage deposits, such as it is practicable for dredges to remove, are among the most objectionable consequences of discharging crude sewage into water courses. They

readily ferment and give off offensive gases, often in large quantities, and their characteristically black, muddy consistency imparts to the water above them an appearance of foulness which it is the very object of scientific sewage disposal to avoid. Prof. Adeney has shown in his researches for the Royal Commission on Sewage Disposal of England, and for the Metropolitan Sewerage Commission of New York, that sewage deposits play a most important part in exhausting the oxygen from the overlying water, a conclusion that is supported by the results of numerous investigations of over-polluted rivers in all countries.

Flushing has always been depended on as the principal means of keeping Chicago's waterways clean, notwithstanding the fact that it has never proved entirely satisfactory. The city has been disappointed in the effects of flushing and it is bound to continue to be disappointed so long as it believes that this procedure will keep the river and its branches free from accumulations of sewage.

The leading difficulty with flushing lies in the immense amount of water which is required for it and the necessity of applying the water in such a way as to cause a circulation through every part of the system of waterways. The water will not of itself seek out the places which need it most; its tendency is to take the path of least resistance and flow away by the easiest and most direct course, leaving undisturbed accumulations which should be scoured out. It is possible without works of prohibitive cost to provide all parts of the waterways, including the corners and other naturally quiet places with self-cleansing velocities.

Sewers are built to be self-cleansing at velocities which range from 2 to 4 feet per second, from which it will be seen that solid matters which require this velocity to keep them moving will deposit if discharged into a more slowly flowing stream. Four feet per second is equal to 2.7 miles per hour. Nothing like this can be maintained at Chicago in the main channel because of the interference which the current would cause to navigation.

When the Drainage Canal was opened, the permit from the United States Government under which it was to operate was for a "flowage capacity of 300,000 cubic feet per minute, with a velocity of 1.25 miles per hour." But the capacity of the river had been overestimated, and the velocities which were necessary in order that the desired volume of water should be passed, were considerably in excess of the expected rate. Protests were made by various commercial and navigation interests that currents were produced of nearly 3 miles per hour, and in consequence of these protests, the rate of discharge was reduced to 250,000 cubic feet per minute. This allowance is still in force, subject to further change in the discretion of the Secretary of War.

Currents of 2 miles per hour in the main stream, where vessels ply mean much lower rates close to the shores, in slips and through the less frequented places. There is no doubt that extensive deposits would take place in the channel and South Fork were it not for the movements of boats which continually stir up the bottom.

To maintain self-cleansing velocities throughout the waterways without excessive waste of diluting water, undue interference with navigation and other interests would require a nice proportioning of the cross sections of the river and its branches and a carefully arranged supply of water at many points. No attempt has been made at such proportioning or supply and none is practicable.

An objection to flushing as practiced at Chicago is that it does not carry the sewage to a point where any of the recognized methods of sewage disposal can be applied to it. The sewage is not rendered any more amenable to treatment, except such treatment as nature gives it in the rivers into which the sewage is discharged. On the contrary, the dilution so increases the bulk that no method of sewage purification can be applied to it.

The employment of the waterways for the crude sewage has required the use of an extensive system of canals which add nothing to the attractiveness of the city and, in the aggregate, probably causes more inconvenience to

transportation than benefit to it. The North Shore Channel and the canals called arms, in the neighborhood of the stockyards, appear to be of little or no use to commerce.

If Chicago needs canals for commerce, canals should be built and maintained frankly for that purpose. But in this event they should be kept free from sewage, following the custom of Hamburg and many cities. It is a mistake to use highways for crude sewage, be they highways of land or water. If the city needs sewers it should by all means have sewers; it should not seek to get along by using the waterways for that purpose. Surely Chicago is not so backward or so niggardly as to refuse to adopt proper means of carrying the sewage away.

The policy of constructing the Drainage Canal and reversing the flow of the Chicago River is unquestionably sound when considered from the sanitary standpoint, and nothing in this report should be understood as expressing an opinion to the contrary. It has the merit of standing as the first great step toward a complete and permanent plan of sewage disposal. For the proper operation of the Drainage Canal a sufficient supply of flushing water from Lake Michigan is indispensable. It is reasonable to suppose that a certain amount of dredging will always be necessary. It is upon what the Board of Experts considers to be a mistaken policy in the use of the Drainage Canal and other waterways that criticism is here based.

10.—STANDARDS OF CLEANNESS SUGGESTED FOR THE WATERWAYS.

At the present time there is no single guage which can be applied to the Chicago River and the Desplaines and Illinois Rivers by which to describe their condition with mathematical accuracy. It is impossible to analyze the water-and-sewage mixture and say that it does or does not comply with any specified requirements, for there is no universally accepted standard which applies to it. The nearest approach to such a criterion lies in the amount of dissolved oxygen present; but the oxygen cannot give an idea of the color, suspended matter, or odor, particularly

if the pollution is recent. Nevertheless, a consideration of all the facts makes it seem perfectly plain that the intentions of the Legislature as to the protection of the Desplaines and Illinois Rivers have not been complied with.

The degree of cleanness which is necessary and sufficient for the water depends upon many considerations, including the location of the place, the number of persons affected, the uses to which the water is put, the season of the year and the protection of fish life.

In England the law requires that the sewage of large towns shall be treated before it is discharged into the streams, the Rivers Pollution Prevention Act of 1876 imposing on the local authority the duty of adopting the best practical and available means to render the sewage harmless before it enters the river. Standards for the effluents of purification works have been proposed by the Royal Commission on Sewage Disposal in their Fourth, Fifth and Eighth Reports, the present position of this authority being that the standard of purity for a sewage effluent should vary with the volume, velocity and quality of the river water. In all cases the object to be accomplished is the avoidance of the conditions which are defined in the Fifth Report of the Royal Commission issued in 1908, Part VI, paragraph 303, p. 217. This paragraph is as follows:

> "The harm caused by allowing unpurified, or imperfectly purified, sewage to flow into rivers and streams may be placed under one or more of the following headings: The de-aeration of the water of the river, and consequent injury to fish; the putrefaction of organic matter in the river to such an extent as to cause nuisance; the production of sewage fungus and other objectionable growths; the deposition of suspended matter, and its accumulation in the river bed or behind weirs; the discharge into the river of substances, in solution or suspension, which are poisonous to fish or to live stock drinking from the stream; the discoloration of the river; and the discharge into the river of micro-organisms of intestinal derivation, some of which are of a kind liable, under certain circumstances, to give rise to disease."

In order to fix upon a standard of cleanness suitable for New York Harbor, the Metropolitan Sewerage Com-

mission of New York had a number of European and American sanitary experts report individually upon this subject, and from the opinions so expressed, formulated a standard or limit of pollution to serve as a guide in the design of the sewage disposal works which were required.

The New York standard specified that garbage, offal, or solid matter recognizable as of sewage origin should not be visible in any of the city's waterways. Marked discoloration or turbidity due to sewage or trade wastes, effervescence, oily sleek odor or deposits should not occur, except, perhaps, in the immediate vicinity of sewer outfalls and then only in such places and to such an extent as were permitted by the authority having jurisdiction over the sanitary condition of the harbor. The discharge of sewage should not materially add to the formation of deposits injurious to navigation. The preservation of fish life, not being a consideration, it was at first recommended that the dissolved oxygen in the water be not allowed to fall below 3.00 cubic centimeters per liter of water. This amount of oxygen would be about 58 per cent of saturation under summer conditions. The oxygen limit was finally eliminated as not necessary, for, if the other conditions were complied with, it was evident that there would then be ample oxygen in the water.*

In September, 1913, a committee of the American Public Health Association reported the results of a study of the ways in which sewage and industrial wastes might prove objectionable when discharged into water courses, the means by which these conditions might be expressed and the permissible limits of pollution which it would be reasonable to impose under various circumstances. It was recognized that some index of pollution should be devised, even though it be somewhat arbitrary, but the committee was unable to propose one.

The opinion was expressed that the standard should rest not only upon analyses, but also on the conditions

*Present Sanitary Condition of New York Harbor and the Degree of Cleanness which is Necessary and Sufficient for the water. Report of the Metropolitan Sewerage Commission of New York, August, 1912, Part II, pp. 69-164. Also Report of April 30, 1914, Part III, The Oxygen Question, p. 15 et seq.

which were revealed by inspection. The aesthetic sense of the community should not be offended by water obviously foul. Where the waterways were used for recreation purposes, and this use was to be encouraged, the water must look clean and there must be no sewage or other waste discharged into it that would injuriously affect the appearance or odor, even in the immediate vicinity of sewer outfalls. The possible injury to cattle from drinking from polluted water courses and the injury to industries should be settled upon economic grounds. With respect to cleanness for cleanness' sake, the position of the committee was very much like that which had been expressed by the Metropolitan Sewerage Commission of New York.*

One of the most important steps to be taken at Chicago is to fix, tentatively, at least, upon standards of cleanness for the open waterways, the Drainage Canal and the Desplaines and Illinois Rivers. Owing to the dif ferent circumstances which surround these waterways in different places, a single standard should not be made for all, but different standards, or modifications of a general standard, should be prepared which will be applicable where needed. The standards should be based upon a thorough knowledge of what it is desirable and practicable to accomplish. At first the requirements should be comparatively lenient, otherwise the cost of complying with them will seem to be prohibitive.

As a tentative list of minimum requirements, it is suggested that, (a) Solids which can readily be recognized as of sewage origin should not occur in any part of the waterways of the Sanitary District; (b) Putrefactive decomposition should not occur in those parts of the Chicago River and its tributaries and outlet which pass through built-up sections of Chicago or any other city or town or village; (c) Conditions necessary for healthy fish life should be maintained from Lake Michigan through

*Report of the Committee on River Cleaning of the American Public Health Association; American Journal of Public Health, Vol. IV, No. 10, Oct., 1914, pp. 934-938.

the South Branch, Drainage Channel, Desplaines and Illinois Rivers and in at least the larger arms and tributaries of these waterways.

11.—HOW THE PROPER DEGREE OF CLEANNESS CAN BE OBTAINED.

There is but one way to insure a proper degree of cleanness for Chicago's waterways and that is to keep out of them the sewage which makes them foul. They must always receive most of the storm water, and unless the entire sewerage system is rebuilt on the separate plan, some domestic sewage will be swept into the stream from the sewers at times of rainfall. But it is entirely feasible to keep out the great bulk of domestic sewage, and this should be done.

The works which will be required for this purpose will be similar in their general character to those which have been built by other cities. Intercepting sewers are needed to collect the sewage before it discharges to the waterways, and to carry it to a place or places, where it can be sufficiently purified to permit of its being discharged into those waterways which may properly receive it.

The exact location of the treatment works and the precise method of treatment can only be determined after careful surveys and other studies have been made of the topography, distribution of population, character of municipal development, and other matters concerned with the region. The design of the sewage disposal works should depend not only upon the sanitary requirements but also upon the particular circumstances and conditions under which they must operate. Probably the interceptors which will be necessary can be built in more than one location and their best position can only be arrived at by a mature consideration of the possibilities of each.

With respect to the location of the disposal works, a large number of possible sites would doubtless have to be considered before a wise choice could be made. In all

probability, there will ultimately be needed one large plant and a number of smaller ones.

The method of treatment which the sewage should receive ought to be nicely adapted to the work to be performed and to the opportunities which the site, the composition of the sewage and the necessary degree of purification permit.

It is extremely doubtful if there would be any need of inventing new methods of collecting or of disposing of the sewage, but in the adaptation of well established principles to the particular conditions to be met with, there would be room for the exercise of much ingenuity and skill.

All work should be so planned as to fit into, and be a part of, a comprehensive system of sewage disposal for the entire Sanitary District. It is not necessary that all parts of the system should be built at once or in the near future.

The system as designed would represent a program of construction, the various parts of which would be constructed as opportunity and necessity required. All local sewerage would be tributary to this system.

The processes of sewage treatment which would ultimately be required might not be the same as those which at the outset would be sufficient. The treatment plants should be so designed as to permit of considerable development along lines which would make for greater and greater efficiency without undue loss of completed work.

The Drainage Channel should be employed to carry off the effluent from practically all the treated sewage of the central part of the city, and if possible, participate in the purifying process. The disposal of the sewage which originates far to the north of Chicago and that of the sewage from the south are separate problems and should be solved separately, as far as practicable. This sewage should not be brought toward the center of population for disposal, but kept away from it.

The Drainage Channel should be reserved chiefly for the disposal of the sewage which originates in the thickly

built-up part of the city. Chicago's main sewage disposal plant should be located to the west of the city.

In recommending that the sewage of Chicago shall be treated, the Board of Experts is fully aware that they are suggesting a proposition which involves a large sum of money. The cost can be determined only after the plans are made. As in the case of all engineering works, the initial and annual expense should be kept down to the lowest figure which is consistent with the results to be attained.

12.—THE POLICY OF DISCHARGING THE SEWAGE INTO THE ILLINOIS VALLEY.

The State law which provided for the creation of the Sanitary District distinctly stated that the sewage must not be allowed to produce a nuisance, and it would appear that the people of the Desplaines and Illinois Valleys have a right to insist that Chicago take care of its sewage and not send it down to poison the waters of that beautiful region. That there has been some compensation afforded in the form of increased water power and fish food and that some justification lies in the fact that the towns along the rivers are themselves polluting the water, is true. But no polluting matters which the people in the valley could pour into the river would render the water so foul as it is today, and no efforts which they could make would restore the river to its original purity. And the benefit of water and of fish are benefits to but few; they are largely offset by the injury done to the low lands by flooding.

Justification for the pollution of the Desplaines and Illinois Valleys is sometimes urged on the ground that a sanitary improvement is a strictly commercial proposition, the justice of which is to be determined by weighing the money gained against the money lost. According to this theory, if it costs a greater sum to abate a nuisance than the loss which the nuisance occasions, it is better not to abate it. This mercenary way of looking at the matter has little of justice about it. Health and money are not interchangeable commodities. And at best the validity of

this argument would depend upon whom the burden fell. If the nuisance produced loss only to those who caused it, the argument might have some force, but when the sewage of a city does injury to a great valley for one hundred miles, the unfairness of this manner of reasoning becomes apparent.

Were it impossible for Chicago to dispose of its sewage in any other way than by sending it down into the country without any attempt at purification, there would be some color of excuse for continuing the present scheme of final disposition. But this is not the fact. No one who is familiar with modern methods of sewage disposal, can question the practicability of removing large quantities of the most offensive solid matters before the sewage is discharged and of rendering innocuous and inert the residual liquid. In fact, sewage can be purified to any extent desired—the limit depends merely upon the cost which can be incurred.

That the inhabitants of the valley have not insisted that some better scheme of disposal should be employed is probably due in part to the fact that no better scheme has been known to them, and in part to the fact that the Desplaines and Illinois Rivers are in better condition than they were when the Illinois and Michigan Canal was carrying the sewage of Chicago to them with less dilution.

The best time for the valley to have objected was when the Drainage and Ship Canal was being projected, and it appears that there was objection made to it at that time. It seems that the protests delayed the passage of the Sanitary District bill through the State Legislature for two years. Material modifications were then made in the Act as originally drawn and it became law. In the bill as finally passed, it was distinctly stated that the flow of water and sewage from the District's channels should be neither offensive nor injurious to any of the people of the State. Section 20 of the District Act is as follows:

> "Any channel or outlet constructed under the provisions of this Act which shall cause the discharge of sewage into or through any river or stream of water beyond or without the

limits of the district constructing the same, shall be of sufficient size and capacity to produce a continuous flow of water of at least two hundred cubic feet per minute for each one hundred thousand 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 shall be neither offensive or injurious to the health of any of the people of this state; and before any sewage shall be discharged into such channel or outlet, all garbage, dead animals and parts thereof, and other solids shall be taken therefrom, and said district shall, at the time any sewage is turned into or through any such channel or channels, turn into said channel or channels not less than twenty thousand feet of water per minute for every one hundred thousand inhabitants of said district, and shall forever thereafter maintain the flow of such quantity of water."

From the foregoing, it appears that the Sanitary District is compelled by law to maintain sanitary conditions in the Desplaines and Illinois Rivers. The law does not relieve the District from responsibility for the sanitary consequences of its acts any more than it relieves it from responsibility for flood damages. It is quite clear that the Legislature intended there should be no nuisance.

13.—SANITARY AUTHORITY FOR THE PRESENT RATIO OF DILUTION.

History shows that the plan of discharging the sewage into the Illinois Valley and relying on the forces of nature to purify it, is the outcome of years of effort to improve the condition of the Chicago River and Lake Michigan and not the result of a carefully worked out theory of sewage purification. It was not founded upon a knowledge of how the forces of nature would act, or how they should be employed in order that the best results might be accomplished.

The scheme as it exists today is the outcome of the accidental circumstance that the Illinois and Michigan Canal had to be fed from the Chicago River. When the outlet first provided was found to be effective in carrying filth away, it was enlarged and then enlarged again.

When no further enlargement was practicable, a new, and greater canal was built.

In all other means of disposing of sewage than discharge into water, definite measures are employed to accomplish definite ends. Arrangements are provided whereby greater or less use can be made of the principles of purification upon which the success of the process depends.

The words "method" and "system" imply an orderly arrangement of parts toward a desired end, and in scientific methods of sewage disposal this arrangement proceeds according to rules for the application of the mechanical, biological and chemical principles involved. Few, if any, rules are followed in disposing of sewage by dilution. Practically the only specification is that there shall be at least a certain quantity of diluting water for a given quantity of sewage. Very little is known about the conditions which have to be brought about in order that the sewage materials shall be assimilated without nuisance or injury to health. Strictly speaking, disposal by dilution is less a method than a means of avoiding the employment of a method of sewage disposal.

It is interesting to learn how the State came to specify how little water Chicago might use for the disposal of her sewage by dilution. Under date of May 31, 1906, Gen. O. H. Ernst, Chairman of the American Section of the International Waterways Commission, asked Mr. Lyman E. Cooley upon what sanitary authority rested the Illinois State law that 20,000 cubic feet per second of water must be diverted into the Chicago Drainage Channel for every 100,000 inhabitants, and how much water was really required to dilute the sewage. In a reply dated June 29, 1906, Mr. Cooley reviewed the considerations which determined the ratio of dilution in the Sanitary District Law and told how he justified the same.

Mr. Cooley said that he had "had everything to do in determining the prime essentials of the Sanitary District law above quoted." He had projected the work in its substantial outlines in a report which he had drafted for

a committee of the Citizens' Association in September, 1885. As Chief Assistant to the Water Supply and Drainage Commission in 1886-7, he had charge of the canal solution. He was Consulting Engineer to the State Board of Health in 1887-9 and again in 1891, while its chemical investigation of the stream between Lake Michigan and St. Louis was under way. He was Consulting Engineer to the joint committee of the Legislature that framed the Sanitary District act, and later represented before the General Assembly the several organizations of Chicago which were engaged in promoting this legislation.

The reply to General Ernst does not give any data in support of the State law that the sewage of every 100,000 inhabitants shall be diluted with at least 20,000 cubic feet of water per minute, nor does it state that the amount of diluting water had been accurately determined. The Water and Drainage Board of 1886-7 had recommended a dilution of 24,000 cubic feet per minute, but without presenting any justification for doing so, and not with the idea that their recommendation would be regarded as final. The committee of the Legislature which considered the Hurd bill for the creation of the Sanitary District in 1887 developed much diversity of opinion and could not tell what allowance to provide for. Mr. Cooley says in his letter:

> "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 for Mr. Cooley's investigations, he says, were: A study of the filth-producing industries of Chicago and the condition of the Chicago River, and the Illinois and Michigan Canal; the history and condition of the sewage in the Desplaines and Illinois Rivers for the fifteen years prior to 1887 between Joliet and La Salle; the results of the State Board of Health's chemical investigation over the route from Lake Michigan to St. Louis; the conditions produced by the distilleries at Peoria and

Pekin. There were also reports on the condition of the Seine at and below Paris, reports on the Sewage disposal works at Berlin, three reports by Parliamentary Commissions on river pollution in Great Britain, reports on the pollution of streams in Massachusetts and reports on the pollution of the Passaic River in New Jersey.

> "The general result arrived at," Mr. Cooley says in his letter, "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 fifty per cent on account of the special industries characteristic of Chicago and the quality of her site —flat topography, with impermeable subsoil. These considerations raised the dilution ratio to 20,000 cubic feet per minute as a minimum, and it was so recommended.*

14.—LIMITATIONS OF DISPOSAL BY DILUTION AT CHICAGO.

The efforts which have been made to dispose of Chicago's sewage and the consequences which have followed make it clear to the Board of Experts that radical improvements will have to be carried out in order to make the scheme a sanitary success.

The conditions of the present have been sufficiently described. The outlook for better conditions in the future, when the population becomes greater and the volume of sewage increases, is exceedingly dark.

One of two things will have to be done; either disposal by dilution will have to be given up, or it must be placed upon a more efficient footing. Every consideration favors the latter alternative. It is desirable that the functions and limitations of the present means of disposing of the sewage shall be determined and the fullest use made of the diluting power of the water which is consistent with a due regard to the sanitary amenities. There is nothing wrong with the idea of utilizing the self-purifying power of the water to the limit in getting rid of the

*Report International Waterways Commission, January 4, 1907, Appendix B, Letter from Lyman E. Cooley, Esq., to General O. H. Ernst, Chairman of American Section.

sewage. The whole difficulty with Chicago's scheme of sewage disposal lies in the fact that the proper limit has not been recognized and the necessary works developed accordingly.

It is of prime importance that the functions of water in assimilating sewage shall be understood, and, when understood, applied. One of these functions lies in the oxidizing of the organic matters. A large amount of work has recently been done in connection with the subject in various parts of the world.

It is desirable that the present-day theories as to the demands which sewage makes upon the oxygen be examined, and if found correct, applied; that the supposed manner in which the absorption of oxygen takes place from the atmosphere be tested and the correct principles established under which the natural supply of oxygen in the water can be reinforced. It is possible that recent experiments in Europe and America may be helpful in showing the extent to which artificial aeration may be of much service.

The experience of other cities in making use of the principle of sewage disposal by dilution may or may not be helpful: Mere ratios of dilution mean little. It is rare to find two situations alike. But it may prove suggestive to consider what proportion of sewage to water has been thought permissible in situations not altogether unlike those of Chicago.

The following conclusions with regard to ratios of dilution, standards of purity and methods of treatment reached by the English Royal Commission on Sewage Disposal, are stated in their Eighth Report:

> "Our experience leads us to think that as a general rule, if the dilution, while not falling below 150 volumes, does not exceed 300, the dissolved oxygen absorption test may be omitted, and the standard for suspended solids fixed at 6 parts per 100,000. To comply with this test no treatment beyond chemical precipitation would ordinarily be needed. If the dilution, while not falling below 300 volumes, does not exceed 500, the standard for suspended solids may be further relaxed to 15 parts per 100,000. For this purpose tank treatment

without chemicals would generally suffice if the tanks were properly worked and regularly cleansed. These relaxed standards should be subject to revision at periods to be fixed by the Central Authority, and the periods should be shorter than those prescribed for the general or the more stringent standards.

"With a dilution of over 500 volumes all tests might be dispensed with, and crude sewage discharged, subject to such conditions as the provision of screens or detritus tanks as might appear necessary to the Central Authority."

The ratios referred to are based on ordinary English domestic sewage of, say 25 Imperial gallons (30 U. S. gallons) per head per day, and would not apply without correction to the more dilute sewages of America. The following table in which the proper corrections have been made, will show how the volumes per head contemplated by the Commissioners compare with that which has been adopted in the case of Chicago:

	Gallons per head per day.
Chicago sewage	200
Diluting water, 3.3 cu. ft. per sec. per 1,000 people	2,138
Total	2,338

Recommended by Royal Commission.

Previous treatment.	Dilution.	Gallons per day per head.
Chemical precipitation	150 to 300 volumes	4,500 to 9,000
Sedimentation	300 to 500 volumes	9,000 to 15,000
Screening or detritus tanks	over 500 volumes	over 15,000

The English ratio of dilution for screened sewage is more than seven times the Chicago rate for crude sewage. In order to satisfy the English standard, the sewage of Chicago would have to be subjected to some form of tank treatment or its equivalent, and then passed through oxidizing filters before being discharged into the Drainage Channel. In no case do the Royal Commissioners contemplate the discharge of unscreened sewage, however great the dilution.

It is, of course, not suggested that the standards which have been proposed for England necessarily apply to the case now under consideration: the special circumstances of the Drainage Channel may quite properly be taken into account. It is not likely, however, that the public opinion of Chicago will permanently be satisfied with a standard of cleanness which is inferior to that which is recommended in England.

In regard to the capacity of the water to assimilate sewage, it is worth while to note that there are seasonal differences in the amount of dissolved oxygen present in the lake water which operate against disposal by dilution. The water holds only about one-half as much oxygen in summer as in winter. And in summer when the oxygen content is least, the demand upon it is greatest, for it is then that the activity of the bacteria of decomposition is at a maximum and the augmentation of the volume of diluting water by the natural flow of the river is at a minimum.

Even if Chicago were content with the condition of the Drainage Channel and the rivers into which it discharges, that condition, poor as it is, will steadily deteriorate, and the time has now arrived when she must face the need of supplementing the process of dilution by some preliminary treatment wherein the demand made by the sewage on the oxidizing power of the diluting water may be reduced.

This does not mean that the Drainage Canal has been useless. Far from it. In the diluting water which is drawn from Lake Michigan, Chicago has an asset of the greatest importance, and the Drainage Channel is a valuable asset for its utilization. Apart from its utility as a waterway, the justification for the Drainage Channel lies in the fact that it constitutes a first step towards providing Chicago with a water supply which shall be not only safe but attractive, and towards converting the Chicago River into a stream of appropriate cleanness and purity. There was no need to cut a $64,000,000 canal merely for the sake of removing the danger to the water supply. It

would have been cheaper, far cheaper, to go on turning the sewage into the lake, and to rely on filtration for the protection of the water supply.

Particular attention to the conditions favorable, and unfavorable, to the disposal of sewage through dilution has been paid by the Massachusetts State Board of Health. No set of men have had so broad an opportunity to study this question as intelligently or over so long a period of time. In a special report issued by the Board in 1890, a table was given showing the chemical ingredients added to streams by domestic sewage for various ratios of population to quantities of water flowing.* It was stated that objectionable conditions might exist when the ratio included ratios of diluting water from 2.5 to 7.0 cubic feet per second per 1,000 persons contributing the sewage. The Board said (p. 791):

> "With smaller volumes of water the pollution is so great as to be inadmissible. With lower volumes, the pollution is so small as to be clearly admissible from the standpoint of the offensiveness of the water."

The information furnished by subsequent investigations considerably narrowed the debatable ground and it was stated by Mr. X. H. Goodnough, Chief Engineer of the Massachusetts State Board of Health, in a report published in 1903,† that

> "when the rate of dilution is less than 3.5 cubic feet per second, objectionable conditions are likely to result from the discharge of sewage into a stream; while, in cases where the dilution exceeds 6.0 cubic feet per second per 1,000 persons, objectionable conditions have not been produced. This conclusion, as already indicated, relates only to the effect produced upon a stream or body of water after the sewage has become mingled with it, and it is assumed that the water of the stream or pond receiving sewage is unaffected by other pollution."

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*Examinations by the State Board of Health of the Water Supplies and Inland Waters of Massachusetts 1887-90; Part I of Report on Water Supply and Sewerage, pp. 785-802, dated December 18, 1902.

†Report of the Committee on the Charles River Dam (Boston, Mass.), Appendix No. 5, p. 307-8.

In accordance with the provisions of a special Act of the Legislature passed in 1901, examinations were made of the outlets and sources and the effect of sewage disposal throughout Massachusetts, and at the end of a report dated August 20, 1903,* is given a summary of the ratios of dilution which were found to be necessary for inoffensive conditions. It is stated that:

> "The results of the investigation 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 pollution of a stream in dry weather. Under favorable circumstances, 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 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."

In the opinion of Messrs. Hering and Fuller as expressed in their 1906 report to the International Waterways Commission,† a dilution of 3.3 cubic feet per second per 1,000 of population would prevent nuisance in the proposed Calumet Canal at Chicago, if the trade wastes were eliminated.

15.—THE INDUSTRIAL WASTES REPORT OF 1914.

For many years the sanitary disposal of Chicago's sewage has been complicated by the fact that enormous quantities of putrifiable wastes were produced by industrial establishments. The most important of these have been concerned in the slaughter and packing of cattle, hogs and sheep, and in the many industries connected therewith. When considering the allowance of diluting water which would be necessary in order to render Chicago's sewage unobjectionable, Mr. Cooley says that in 1889 he estimated that the wastes coming from the stockyards and rendering establishments alone was equivalent

*Thirty-fourth Annual Report of the State Board of Health of Massachusetts, 1903, p. 452.

†Document No. 293, United States War Department, 1907, p. 45.

to the sewage of 700,000 people, and to the ratio of dilution which he recommended for the Drainage and Ship Canal he added 50 per cent. on account of the special characteristics of Chicago.*

A report upon the treatment of the wastes from the Stockyards and Packingtown district was issued by the Sanitary District in January, 1915. Its 346 pages are devoted to the conditions which exist in the square mile of territory within the city limits of Chicago where the famous slaughtering and packing industries are located. The drainage from this territory now flows into the east and west arms of the South Fork of the South Branch of the Chicago River, known as "Bubbly Creek".

In this territory none of the streets has been dedicated; sewers have been built in every conceivable direction without plan. No limit is placed upon the quantity or composition of the liquid and semi-liquid wastes which may be thrown into the sewers.

The industries include the following: The handling and storage of live stock of all kinds; slaughtering and packing; butterine works; rendering establishments; soap factories; glue factories; casing works; sausage making; garbage rendering; canning of fruits, vegetables and meats; pickle manufacturing; brewing; fertilizer works.

Within recent years there has been some restriction in the wastes from the larger establishments, due to efforts made to utilize the by-products, but the small establishments still discharge blood, offal, tankage and other objectionable material to the sewers. The amount of solid matter emptied through the sewers into Bubbly Creek is considerable. Dredging was carried on in 1913 at a cost of $34,534.05, of which a committee of the packers paid $26,864.38.

The sewage is very strong both in suspended and dissolved matter and is much warmer than the domestic sewage of the city. Biological tests indicate that the oxy-

*Report of the International Waterways Commission, January 4, 1907, Appendix B; Letter of Lyman E. Cooley to Gen. O. H. Ernst, Chairman, American Section, June 29, 1906.

gen requirement is from six to ten times that of ordinary sewage. Practical test has shown that all the methods of sewage treatment which are applicable to city sewage, either domestic or combined, can be used to purify the sewage. The volume in 1911 was computed to be 31.7 cubic feet per second by day and 12.2 cubic feet per second by night.

In order to determine the best means of disposing of the wastes of the stockyards district, the Sanitary District established an experimental testing station in 1912 at the stockyards with funds largely subscribed by the industrial establishments. The report now made public gives the results of these tests.

The report recommends that the larger part of "Bubbly Creek" be filled in and that there be built a "community" sewage disposal plant to purify the wastes sufficiently to permit the effluent to be discharged into the Sanitary and Ship Canal. The method of treatment would employ fine screens at each individual house or group of houses belonging to a firm and grease skimming. The sewage, thus relieved of its coarser ingredients, would then be passed through a sedimentation plant for the whole region and finally discharged into the Drainage Canal. The sedimentation plant would be located at the west end of the west arm of the South Fork. The sewage would be carried to this point in an intercepting sewer to be built for the purpose.

Ultimately, biological treatment, presumably in sprinkling filters, would be necessary, and for this purpose the sewage from the settling basin plant would be carried westward to some point where land of suitable area and price could be obtained. The cost of the first stage would be $985,000 and of the completed project $3,600,000, exclusive of land, legal and engineering expenses. The volume of sewage to be provided for is not given, but the report states that to carry it with an allowance of twice the dry weather flow, a sewer would be needed approximately 7.5 feet in diameter.

The report gives no details of the proposed works,

and does not deal with the larger problem of disposing of the city's sewage. The project seems good, as far as it goes, and is in line with what the experts of the Real Estate Board think should be done.

16.—THE CHIEF ENGINEER'S 1911 REPORT ON THE INTRODUCTION OF IMPROVED METHODS OF DISPOSAL.

The most important result of the investigations which have been carried out by the Sanitary District's sanitary investigating force is the report of George M. Wisner, Chief Engineer of the District, which was submitted October 21, 1911. This report faces squarely the fact that the population of Chicago is approaching the limit of 3,000,000 for whose sewage the Sanitary and Ship Canal was designed, and states that after this population is reached the canal will not be large enough to carry enough water to dilute the sewage to the legal amount. A population of 3,000,000 is expected by about 1922 and one of 4,000,000 before 1940. Some way of lightening the burden of pollution which will be put upon the waters will then have to be undertaken, and Mr. Wisner suggests the way which appears to him most suitable. The report claims to be but a skeleton upon which to start detailed studies and the author requests authority to proceed with them.

The Report shows clearly that however others may regard the sufficiency of the present means of disposal, the technical force of the District has no mistaken idea that the condition of the Chicago River and the Drainage Canal is satisfactory, nor that there should be any delay in making plans for the better handling of the sewage.

Mr. Wisner has proposed that practically all of the sewage produced in the Sanitary District should be treated by settling basins or sprinkling filters, or both. The settling tanks would be expected to remove about 25 per cent. of the organic matters and the settling and sprinkling filters would produce an effluent which would add nothing to the organic pollution of the water. Some

of the works would be built at once, but most of them would not come into use for some years.

17.—THE WORKS PROPOSED BY THE CHIEF ENGINEER.

At the 39th Street Pumping Station settling tanks would be constructed and changes made in the pumps and other arrangements to provide for the sewage of 518,000 persons, which is the number which would be expected by 1930. After treatment the sewage would be discharged, as now, into the east arm of the South Fork of the South Branch.

At the Lawrence Avenue pumping station there would be settling tanks for the sewage of a population of 218,200.

On the North Branch there would be eight plants for settling the sewage of a total population of 606,410. The area of land required for the plants would range between about one and nine and one-half acres each. They would be located on the west bank of Lawrence Avenue, Montrose Avenue, Irving Park Boulevard, Addison Avenue, Belmont Avenue, Diversey Boulevard, Fullerton Avenue and Armitage Avenue. The effluent would discharge into the North Branch.

Works at 22nd Street near Ashland Avenue would settle the sewage of a population of 475,000 in 1930.

Five settling plants for the West Side would be located where the following streets meet the Drainage Channel: Oak Park Avenue, Fifty-Sixth Avenue, Fifty-second Avenue, Fifty-fifth Avenue, and Fortieth Avenue.

In the stockyards district, settling basins would be built for a population of 324,090 which, it is estimated, should be provided for by 1930. There would be two plants: one at the forks of the arms and the other at Robey Street, near the west end of the west arm.

In the Calumet, a settling plant would deal with the sewage of about 300,000 people by 1930. The works would be located at a sharp bend in the river somewhat to the

east of the head of the Calumet-Sag Channel. Their object would be to remove as much of the solids as possible before the sewage was discharged into the canal.

In course of time, sprinkling filter plants would be built to complete the treatment begun by three of the settling basin plants originally constructed, viz.: the Calumet, West Side and North Branch plants.

The total population for which provision was made in the estimates for sprinkling filters was 1,421,310. The Calumet plant would be near the Calumet-Sag Channel, the West Side plant would be near the Ogden Dam and the North Side works would be near Lawrence Avenue. Intercepting sewers, in some cases of considerable length, would be necessary in order to bring the sewage to the works.

Mr. Wisner recommends that the construction of the intercepting sewers, pumping stations and settling basins be started in the Calumet region so as to be ready when the Canal is completed. Later, about 1930, the construction of the sprinkling filters should be begun in the Calumet region and be completed before 1935. The settling basin plant for the stockyards district should be ready for use in 1915. The West Side sewers should be extended from the Ogden Ditch to the Drainage Channel and settling basins installed so as to be ready for service by 1925. Construction on the settling tanks along the North Branch should be under way in 1922 and be wholly in operation by 1930. By 1930, also, the settling tanks at the Thirty-ninth Street Pumping Station should be in operation, if required. The West 22nd Street project would not be needed until 1930. No date was set for the construction of the Lawrence Avenue works.

The works call for a total expenditure of about $10,000,000 distributed over a period of twenty years. The annual cost, including interest and depreciation, is estimated at about $80,000 in 1915; $213,000 in 1920; $386,000 in 1925 and $710,000 in 1930.

18.—COMMENTS ON THE CHIEF ENGINEER'S REPORT.

Mr. Wisner's report, in spite of the necessary haste with which it was written, represents a great deal more study than he claims for it and evinces a close knowledge of the local conditions.

Mr. Wisner's report bears testimony to the fact that it is desirable and feasible greatly to improve the conditions and without too much expense. It is necessary for the Board of Experts to point out some of the fundamental difficulties which they find in the schemes. First, in considering what steps it will be necessary to take in order to improve the conditions, the very common mistake is made of regarding the problem too generally. It is assumed that the discharge of a definite volume of sewage into a definite volume of water will produce certain definite effects. The Chicago sewage problem is not of this simple character. As more fully stated elsewhere, the effects produced depend upon many circumstances, none of which is under control. The sewage of Chicago is not, and never has been, disposed of by simple dilution, as that term is commonly understood. Great as has been the load of filth which has been sent to the Illinois Valley through the Drainage Canal, the Canal has not carried it all. A great deal has been deposited in the river and its stagnant tributaries, a great deal has been dredged and deposited in the lake, a great deal has fermented and been driven off to the atmosphere in the form of gas and enormous quantities have been oxidized in the Chicago River by the oxygen which was brought in by the fresh lake water and that which was absorbed from the air. The waterways into which the sewage is directly discharged act in an important manner in digesting the sewage. Just how useful they are cannot be stated, but that they perform a distinct service cannot be doubted by anyone who is familiar with the conditions.

What Mr. Wisner's projects would do for the waterways it is impossible to say. The settling basins would certainly reduce that part of the burden of pollution which

is now disposed of partly by deposition and fermentation. The sprinkling filters would lighten the burden both as to suspended and dissolved matter. According to these plans the sewage of about four million persons would be settled and that of about one and one-half million treated by sprinkling filters by 1930. The treated sewage of about two million persons would be discharged into the open waterways of the city, not to mention the settled sewage of the loop district, which would be discharged into the South Branch. Partial treatment rather than diversion is the leading feature of Mr. Wisner's recommendations. His plants would, to a considerable extent, be located in the built-up portions of the city.

To treat the sewage by oxidation methods in the crowded part of the city and discharge the effluent into the watercourses which run through the most thickly built-up sections is contrary to the customs of large cities whose sewage is disposed of in a sanitary manner. London, Paris and Berlin, not to mention many other European cities, intercept their sewage by sewers which run along the waterfront and carry the sewage to a point or points outside of the municipal limits for disposal. There are two reasons for this course. The avoidance of offensive conditions connected with the works and the discharge of the effluent where it will do the least amount of harm.

It is doubtful whether the extensive system of settling basins as proposed for the west shore of the North Branch and the Loop District would be sufficiently free from objectionable gases. The opinion of the Metropolitan Sewerage Commission of New York, which gave careful thought to this question of nuisance, and considered every type of settling tank available in 1914, was that settling basins should not be constructed in the closely built-up portions of cities. After pointing out that dangers of explosion existed in covered underground settling tanks, the Commission expressed itself as follows:*

*Main Drainage and Sewage Disposal Works Proposed for New York City; Report of the Metropolitan Sewerage Commission of New York, April, 1914, p. 169.

"The Commission does not share the opinion that the location of settling basins in the built-up parts of the city would be free from public objection. Granting that they would not produce offensive odors, it seems certain that property holders in the vicinity would make vigorous protest against the construction of such works in the belief, mistaken though it might be, that the health and comfort of the neighborhood were seriously threatened. The object of the works would avowedly be to extract as much as possible of the offensive and dangerous materials from the sewage, and before they were disposed of they would have to be stored, transported to the water front, loaded upon vessels and shipped to sea."

In the opinion of the Board of Experts, Chicago's waterways require more protection than can be afforded by passing the sewage through settling basins. They hold the opinion that the only way to secure the needed protection is to divert a large part of the sewage by means of intercepting sewers to some point or points where the sewage can be suitably treated and that it should then be discharged directly into the Drainage Canal. Exact figures are not available to show what it would cost to accomplish this object, but it may be taken for granted that no such extravagant expense would be involved as that indicated by those who wish it to appear that any other scheme of sewage disposal would be prohibitive for reasons of expense.

Before a final opinion is formed in favor of, or opposed to, Mr. Wisner's plans, careful and detailed consideration should be given to them, and this the Chief Engineer has recommended himself.

Part IX

CONCLUSIONS AND RECOMMENDATIONS

The main conclusions which the Board of Experts have reached after their study is that reliance should no longer be placed upon the discharge of the crude sewage of Chicago and its neighboring municipalities into the open channels and waterways leading to the Illinois Valley as a sufficient means of getting rid of this sewage and protecting the drinking water which is obtained from Lake Michigan.

However perfect this scheme may once have appeared from a theoretical standpoint, in practice it has proved to be inadequate both as a means of obtaining pure water and as a means of getting rid of the sewage. It has never produced completely satisfactory conditions at Chicago and it never can do so. It has produced insanitary conditions for many miles down the Drainage Channel and the Desplaines and Illinois Rivers.

1.—THE WATER SUPPLY.

The idea of excluding all the sewage from the lake calls for the placing of a larger territory under central sanitary control than is practicable. The region whose drainage pollutes the lake lies in four states. There is occasional contamination to be feared from vessels in spite of any precautions which can be taken. In short, the sources of pollution which now exist are too numerous, too various and under too many governmental jurisdictions to be centralized. They should be centralized to be controlled. The increase in population which will occur in the future around the southern end of

Lake Michigan will make the possibility of proper control still more remote.

Pollution due to large and local passenger vessels can be, and has been, practically eliminated, but so long as Chicago remains a busy port and Lake Michigan a great highway of commerce, it will be impracticable wholly to prevent the discharge of dangerous wastes from the shipping. The dumping of foul dredgings and the discharge of water ballast taken aboard in sewage contaminated harbors are evils which it is feasible to control almost entirely.

Some polluting matter is undoubtedly swept into the lake from the vast population upon the shores, and although this pollution is more objectionable because it is visible than because of the harmful properties which it may contain, it is unwise to neglect the significance which may properly attach to it.

In considering the suitability of Lake Michigan at Chicago as a source of drinking water, it is not to be forgotten that the lake is devoid of regular currents which are capable of carrying polluting material away. The irregular currents which are set up by the wind are as likely to stir up the water in the vicinity of the intakes and carry shore pollution to them as to cause a cleansing and refreshing action by the inflow of pure water from distant points. Strong on-shore winds make the water at Chicago turbid and cause undertows which extend far out into the lake. In the case of some of the intakes, a marked increase in the colon findings always follows severe storms. Numerous investigators have expressed the opinion that the water supply was occasionally polluted.

The vital statistics can be quoted either to show that the water supply is, or is not, dangerous to health. In comparison with some cities, the typhoid rate is high, with others low. There has been a decided decline in the prevalence of typhoid in Chicago, but this is not remarkable when compared with the decline in other cities and the whole country.

The water supply is, and long has been occasionally polluted, according to detailed official analyses which have been examined by the Board of Experts. The United States Public Health Service classes Chicago with cities whose water supplies are subject to intermittent pollution with great dilution of the polluting material. In the opinion of Dr. Young, head of the City Health Department, water-borne typhoid cannot be considered as having been entirely eliminated. It is the opinion of the Board of Experts that the water supply is not safe.

2.—THE OPEN SEWERS.

Chicago's policy of using its river, and constructing canals, some of them running through the business and residence sections of the city, as open sewers, is not in accordance with good sanitary practice and should be given up. Limits of pollution should be established for these waterways based on what is proper under the conditions and the necessary works should be built.

For cities to utilize the self-purifying capacity of water for the ultimate disposal of their sewage is quite justified under proper circumstances, but to cast the entire burden of Chicago's filth upon the Chicago River and its artificial outlet is to impose conditions upon these waterways which are alike unsanitary, unfair and unnecessary. It violates the first law of public health work, which is that dangerous and offensive wastes shall be promptly removed from their points of origin and kept under control until they are rendered harmless and inert.

Aside from Chicago's right to appropriate the largest river in the State for the purposes of sewage disposal, a proceeding the justice of which is here questioned, the result in the city of Chicago is not satisfactory. The scheme as it exists today, after fifteen years have been devoted to its perfection, leaves very much to be desired.

There is not an arm or branch of the Chicago River which looks clean when viewed in the light of what the best sanitated cities have accomplished. Conditions exist

in parts of the North Branch, South Branch and West Fork which are insanitary in the extreme. Only by comparing the state of the waterways today with their condition in the days when Chicago was regarded as the most insanitary city to be found, can the existing conditions be made to appear satisfactory.

It is a mistake to suppose that the interests of sanitation and of navigation were equally served by constructing the Drainage Channel. This attempt has failed. The two interests are opposed in many ways and in seeking to help the one, the other has been hindered. When the deep waterway from the lakes to the Gulf is sufficiently completed to be extensively used by commerce, the Drainage Channel and the Chicago River will be less suitable than they are today for sewage.

It is time that Chicago separated its sewage and navigation problems. The disposal of the sewage is one thing, and the encouragement of navigation quite another.

3.—THE LAW.

It is impossible to suppose that the Legislature which passed the organic law providing for the construction of the Sanitary and Ship Canal contemplated the existence of the conditions of pollution which exist in the waterways of Chicago and their outlet, and this feature of the law has not been changed by any subsequent amendment. The law is often misquoted and misinterpreted. It is desirable to repeat here a few of its principal provisions.

The object in passing the law was to promote the public health and this was to be done by providing means whereby the sewage could be kept out of the lake. Section 1 of the law states:

> "That whenever any area of contiguous territory within the limits of a single county shall contain two or more incorporated cities, towns or villages, and shall be so situated that the maintenance of a common outlet for the drainage thereof will conduce to the preservation of the public health, the same may be incorporated as a sanitary district under this act, in the manner following: * * *"

The law insists upon a sanitary condition of the outlet. Section 7 says:

> "The Board of Trustees of any sanitary district organized under this act shall have power to provide for the drainage of such district by laying out, establishing, constructing and maintaining one or more main channels, drains, ditches and outlets for carrying off and disposing of the drainage (including the sewage) of such district, together with such adjuncts and additions thereto as may be necessary or proper to cause such channels or outlets to accomplish the end for which they are designed in a satisfactory manner; * * *"

The General Assembly did not regard the ratio of dilution which would be necessary as positively determined, but specified the minimum which should be provided. The end to be accomplished was such a disposal of the sewage as would be neither offensive or injurious to the health of any of the people of the State. Section 20 says:

> "Any channel or outlet constructed under the provisions of this act which shall cause the discharge of sewage into or through any river or stream of water beyond or without the limits of the district constructing the same, shall be of sufficient size and capacity to produce a continuous flow of water of at least two hundred cubic feet per minute for each one thousand 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 shall be neither offensive or injurious to the health of any of the people of this state; and before any sewage shall be discharged into such channel or outlet, all garbage, dead animals, and parts thereof, and other solids shall be taken therefrom, and said district shall, at the time any sewage is turned into or through any such channel or channels, turn into said channel or channels not less than twenty thousand cubic feet of water per minute for every one hundred thousand inhabitants of said district, and shall thereafter maintain the flow of such quantity of water."

The only provision which can be construed into a reference to the elimination of trade wastes lies in that part of the foregoing section which states that "garbage, dead animals and parts thereof and other solids," shall be re-

moved from the sewage before it is discharged into the outlet channel.

Apparently the law neither requires the Sanitary District to dispose of crude sewage, nor forbids it to build sewage disposal works. In other words, it appears that the District may build such works as it needs and is not compelled to depend solely upon dilution as the means of getting rid of the sewage. It is explicitly admonished that any outlet constructed under the provisions of the act shall be kept in such condition as not to be offensive or injurious to any of the people of the state.

4.—SEWAGE WORKS.

The Board of Experts of the Chicago Real Estate Board recommends that a policy of prevention be adopted in place of the policy of cure which has thus far been followed in attempting to make the Chicago River clean. Instead of discharging sewage into the river in unlimited quantities and without restriction as to the composition, limits should be placed upon the quality and amount of domestic sewage and trade wastes which it may receive. Restriction should be placed not only upon industrial drainage, but upon domestic sewage as well. Only that part of the drainage which the water can absorb and carry away without producing offensive conditions anywhere should be emptied into the waterways. The remainder should be collected and disposed of in such ways as the experience of Chicago and other cities shows to be desirable and the opportunities of the situation permit. Intercepting sewers, screens and settling basins will have to be employed extensively and it is probable that more efficient methods of purification will be required to a considerable extent.

5.—TRADE WASTES.

A large part of the difficulty met with in disposing of Chicago's sewage has been caused by trade wastes which have too freely been admitted to the sewers and open

waterways. It is not reasonable that excessive burdens of cost and inconvenience should be placed upon the public by manufacturing establishments in this manner, and it is suggested that a definite and equitable policy be adopted with respect to this subject. As a step toward the formulation of such a policy, it is recommended that trade wastes should be dealt with at private expense when, by reason of their volume, nature or strength, they add unduly to the cost of treating the sewage.

6.—WATER FILTRATION.

No plan or method of dealing with the sewage will afford the complete protection to the water supply which is desirable, and the city must face the fact that the water supply should be purified. Purification in this case means filtration. The object should be not only to produce a drinking water which is bacterially pure, but one whose brightness and attractiveness are not impaired, as now, at times of storm. Filtration works can, and should, be constructed at once for a part of the water supply and extended later to cover the entire supply as necessity and opportunity present.

7.—LAKE PROTECTION.

The adoption of a policy of cleaner waterways and a cleaner water supply do not run counter to the plan which the city has followed of diverting all the sewage from the lake and keeping the lake water as pure as possible for drainage purposes. The filtration works are necessary to supplement the sewage works and are required for the reason that the Sanitary and Ship Canal alone is not capable of accomplishing the results required. It will always be desirable to keep as much sewage as practicable out of the lake and to dispose of the sewage with as little offence as is consistent with a due regard to economy.

It may be expected that the standards by which the success of the sewage disposal works and water purification plants is to be tested in the future will be considerably

in advance of those of today. In the recommendations here made that the water and sewage be treated, due allowance is made for the development of the works as an ultimate to secure a higher efficiency than is at first needed.

8.—PROGRESSION PLAN.

The works here recommended can and should be built in accordance with a progressive plan. It is not intended that the whole, or any very large part of the structures which may be needed fifty years from now shall be put into the ground at once. But the outlook should be sufficiently broad and the plan sufficiently comprehensive so that whatever building is done shall be toward a result which is clearly foreseen.

The next step which should be taken toward a sanitary disposal of Chicago's sewage is the preparation of a definite General Plan and Policy of sewage disposal which will show what works are required, where they should be located, when they should be built, and what they should cost. To do this work properly will require an intimate knowledge of the ground.

Respectfully submitted,

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